REPORT

results

of

WORLD BLOCK LANDSCAPE BLOCK

and

MIRAGRID 5XT GEOGRID

&

MIRAGRID 8XT GEOGRID

&

MIRAGRID 10XT GEOGRID CONNECTION CAPACITY TESTING

submitted to

WORLD BLOCK

CONFIDENTIAL

MIRAGRID 5XT GEOGRID

INTRODUCTION

This report gives the results of a connection testing program carried out to evaluate the mechanical/ frictional performance of the connection between World Block Landscape Block modular concrete units and Miragrid 5XT geogrid.

The test program was initiated in response to a verbal authorization to proceed from Mr. Rod Johnson of World Block received 25 September 2007.

The tests were carried out at the laboratories of Bathurst, Clarabut Geotechnical Testing, Inc. in Kingston, Ontario, under the supervision of Mr. Peter Clarabut.

OBJECTIVES OF TEST PROGRAM

The facing-geogrid connection between World Block Landscape Block units and Miragrid 5XT was investigated using a large-scale connection test apparatus.

The principal objective of the testing was to evaluate the mechanical/frictional performance of these connections. A second objective was to make preliminary recommendations for the selection of long-term tensile connection capacities to be used in the design and analysis of geogrid-reinforced soil wall systems that employ World Block Landscape Block modular concrete units in combination with Miragrid 5XT geogrid.

MATERIALS

World Block Landscape Blocks are solid concrete units weighing approximately 2400 pounds per unit. The nominal dimensions of the block are 24 inches wide (toe to heel) by 24 inches high by 48 inches long. Construction alignment and wall batter is achieved by means of two concrete shear keys cast into the top surface of the units. The installation arrangement is illustrated in Figure 1. A photograph of the World Block Landscape Block units is shown in Figure 2. The blocks used in this series of tests were supplied by World Block and were received at our laboratory on 28 September 2007 and designated as BIC 07-036.

Miragrid 5XT is a coated bi-directional grid composed of 100% polyester multifilament yarn with a tensile strength of 4300 lb/ft in the machine direction (based on ASTM D 6637 method of test and reported in the 2007 Geosynthetics Specifier's Guide, published December 2006). The specimens used in this series of testing were produced at Mirafi's Cornelia facility and cut from roll/lot #031041750/06077-1-2 received at our laboratory on 8 December 2006.

APPARATUS AND GENERAL TEST PROCEDURE

The method of test used in this investigation follows that reported by Bathurst and Simac (1993) and recommended by the NCMA (Simac et al. 1993 and ASTM D 6638). A brief description of the apparatus and test methodology is presented here. The test apparatus used to perform the tests is illustrated in Figure 1. The test apparatus allows tensile loads of up to 35,000 pounds to be applied to the geogrid while it is confined between two block layers. The facing blocks were laterally restrained and surcharged vertically. Strips of grid reinforcement 39 inches wide were attached to a roller clamp and the grid extended over the facing block. The next block was then placed over the grid. Due to the size and weight of these units, two half height - half width bottom course units were manufactured, however the connection interface used was the same as full size units. Two wire-line LVDT(s) were connected to the grid to measure grid displacement at the

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back of the block. Wall heights were simulated by placing one block over the interface and applying an additional surcharge load using the vertically-oriented hydraulic jack shown in Figure 1. A photograph of the World Block Landscape Block units in the connection test apparatus is illustrated in Figure 2. Gum rubber mats were placed over the top block to ensure a uniform distribution of vertical surcharge pressure. The connection force was applied at a constant rate of displacement (i.e. 3/4 inch/minute) using a computer controlled hydraulic actuator. The load and displacements measured by the actuator and the LVDT(s) were recorded continuously during the test by a microcomputer/ data acquisition system. All blocks used in the tests were visually inspected to confirm that they were free of defects. Each test was continued until there was a sustained loss in connection load due to geogrid rupture. Following each test, the blocks were removed and the grid examined to confirm failure modes. A virgin specimen of grid was used for each test.

The only variable in this series of connection tests was the magnitude of surcharge load.

TEST PROGRAM

The surcharge loads used in the test program are given in Table 1. Also tabulated are the failure loads observed for each test.

TEST RESULTS

A summary of tensile loads at peak capacity and after 3/4 inch displacement is given in Figure 3.

The peak connection capacity between World Block Landscape Block units and Miragrid 5XT for walls between 3.0 and 17.0 feet in height ranged between 22 and 34% of the index tensile strength of 4300 lb/ft in the machine direction (based on ASTMD 6637 method of test and reported in the 2007 Geosynthetics Specifier's Guide, published December 2006).

Two repeat tests were performed and the results in Figure 3 illustrate that there is some variability in connection capacity between nominal identical tests. This variability is less than ± 10% of the mean peak load criterion required by the NCMA (e.g. maximum variability is 6.5%) and is likely the result of small differences in the setting up of the blocks and laying out of the geogrid reinforcement. The trends in data for connection loads at 3/4 inch displacement and peak connection loads have been plotted using linear curves. The reduced connection capacity at lower surcharge loads may be due to the combined effect of lower surcharge pressure and more grid slippage.

All tests ended in rupture of one or more geogrid longitudinal members. In all tests there was some localized rupturing of the longitudinal members as well as junction failure after large displacements. There was evidence of slippage of the grid within the concrete block-grid interface in all tests. Grid straining and slippage caused abrasion of longitudinal members as the geogrid was pulled across the concrete surfaces. The amount of slippage was seen to diminish with an increase in wall height.

IMPLICATIONS TO DESIGN PRO LANDSCAPE BLOCK DESIGN AND CONSTRUCTION WITH MIRAGRID 5XT

The long-term design connection capacity in the field must be less than the peak capacity envelope determined in this test series for the same method and quality of construction. The NCMA Segmental Retaining Wall Design Manual (First Edition, 1993) recommends that the design connection capacity at a given surcharge load for a critical wall structure be the lesser of the peak capacity divided by a minimum factor of safety (not less than 1.5) or the

capacity based on a 3/4 inch displacement criterion. The design curve in Figure 4 is controlled by both the ¾ inch displacement and the peak connection capacity criteria.

The design capacity envelope illustrated in Figure 4 should be used with caution. The actual design capacity envelope should be lower if the quality of construction in the field is less than that adopted in this controlled laboratory investigation and/or lower quality concrete is used in the manufacture of the blocks. For example, the interface concrete surfaces should be free of debris before placement of grid and blocks in order to minimize abrasion to the grid and to maximize the frictional resistance that is developed at the concrete block-grid interface.

It is very important that production blocks have uniform dimensions so that there is no stepping at the block joints that can lead to non-uniform frictional resistance at the block-grid interface, pinching of the grid at the block edges and possibly fracture of the concrete units.

SUMMARY OF CONCLUSIONS

A laboratory testing program was carried out to evaluate the mechanical/frictional connection performance of World Block Landscape Block modular facing units in combination with Miragrid 5XT polyester grid. The following conclusions can be drawn:

1. The peak connection capacity between World Block Landscape Block units and Miragrid 5XT for walls between 3.0 and 17.0 feet in height ranged between 22 and 34% of the index tensile strength of 4300 lb/ft in the machine direction (based on ASTM D 6637 method of test and reported in the 2007 Geosynthetics Specifier's Guide, published December 2006).

2. The trends in data for connection loads at 3/4 inch displacement and peak connection loads have been plotted using linear curves. In addition, some variability in connection capacity values was observed between nominal identical tests due to small differences in setting up of the blocks and laying out of the geogrid reinforcement.

3. Care must be taken during the installation of World Block Landscape Block units in order to prevent accumulation of soil and rock debris at the concrete block-grid interface surfaces. This debris may significantly reduce the capacity of the World Block Landscape Block facing unit-grid system.

4. The design envelope in Figure 4 is based on an interpretation of test data as recommended in the NCMA Segmental Retaining Wall Design Manual (First Edition, 1993). The choice of design connection strengths may vary from site to site and quality of construction in the field may require lower design values than those taken from Figure 4.

P. Clarabut R. J. Bathurst, Ph.D., P. Eng.

REFERENCES

ASTMD6638-01. StandardTest Method for Determining Connection Strength between Geosynthetic Reinforcement and Segmental Concrete Units (Modular Concrete Blocks), American Society for Testing and Materials, West Conshohocken, PA 19428-2958 USA.

Bathurst, R.J. and Simac, M.R., 1993. Laboratory Testing of Modular Unit/ Geogrid Facing Connections, ASTM Symposium on Geosynthetic Soil Reinforcement Testing Procedures, San Antonio, 19 January 1993.

Simac, M.R., Bathurst, R.J., Berg, R.R. and Lothspeich, S.E., 1993. NCMA Segmental Retaining Wall Design Manual (First Edition), National Concrete Masonry Association, 2302 Horse Pen Road, Herndon, VA 22071-3406.

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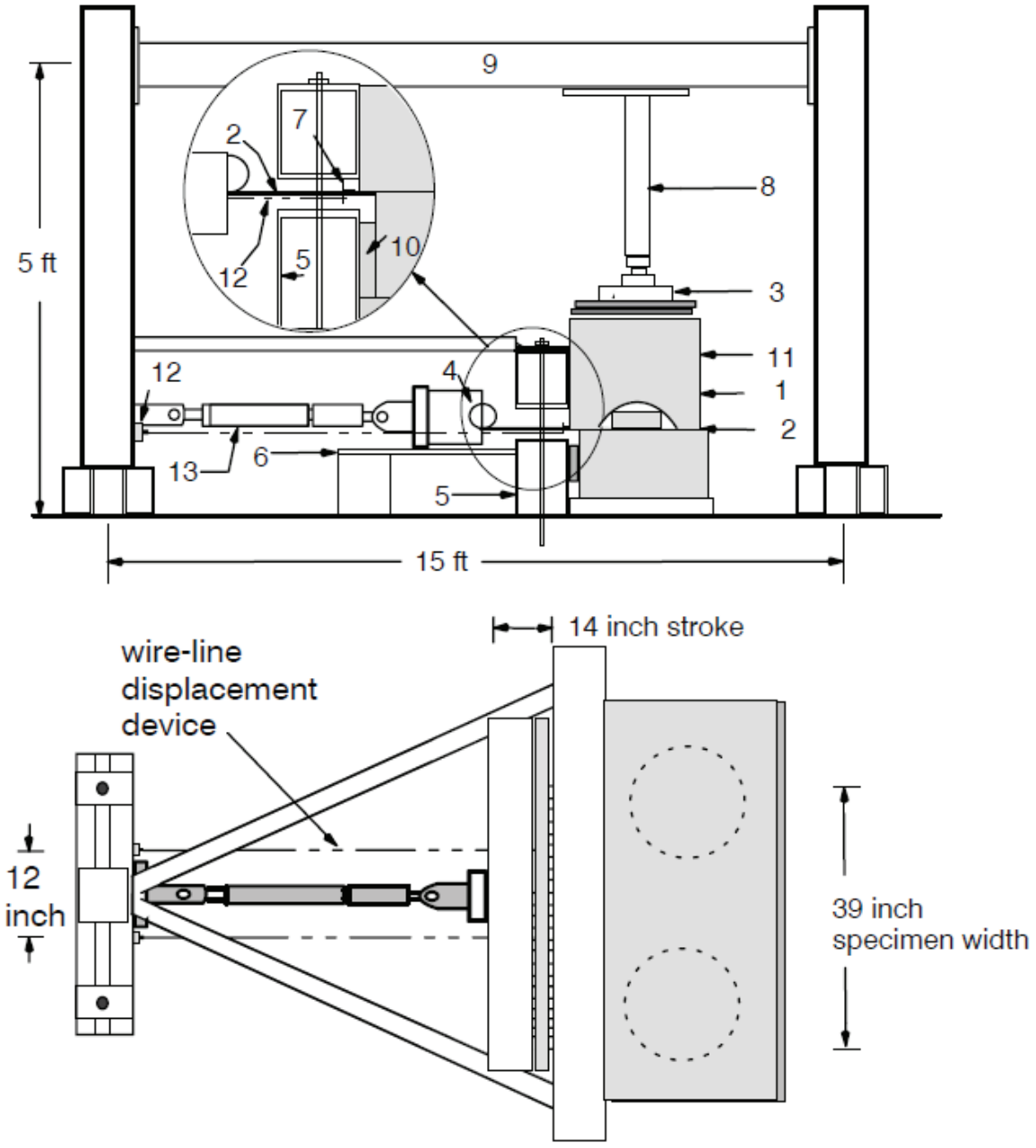
TABLE 1:
Test Program:
World Block Landscape Block modular unit with Miragrid 5XT geogrid connection

Test number	approximate wall height (feet)	approximate number of blocks	normal load (lb/ft)	tensile capacity (lb/ft) at 3/4 inch displacement	peak tensile capacity (lb/ft)
1	8.6	4.3	3158	641	1149
2	3.0	1.5	1087	391	1115
3	5.8	2.9	2119	551	956
4	8.5	4.3	3130	788	1280
5	11.3	5.7	4169	812	1232
6	14.2	7.1	5215	1086	1383
7	8.5	4.3	3144	771	1259
8	17.0	8.5	6240	1264	1465

FIGURE 1:
Schematic of connection test apparatus showing World Block Landscape Block units and Miragrid 5XT geogrid



LEGEND

1	Landscape Block	6	guide rail	11	stiff gum rubber mat
2	Miragrid 5XT	7	LVDT clamp	12	wire-line LVDT
3	loading platen	8	surcharge actuator	13	computer controlled hydraulic actuator
4	roller clamp	9	loading frame		
5	lateral restraining system	10	spacers		

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FIGURE 2:
Photograph of World Block Landscape Block units in the connection test apparatus

FIGURE 3:
Connection capacity versus normal load for World Block Landscape Block tests with Miragrid 5XT geogrid reinforcement

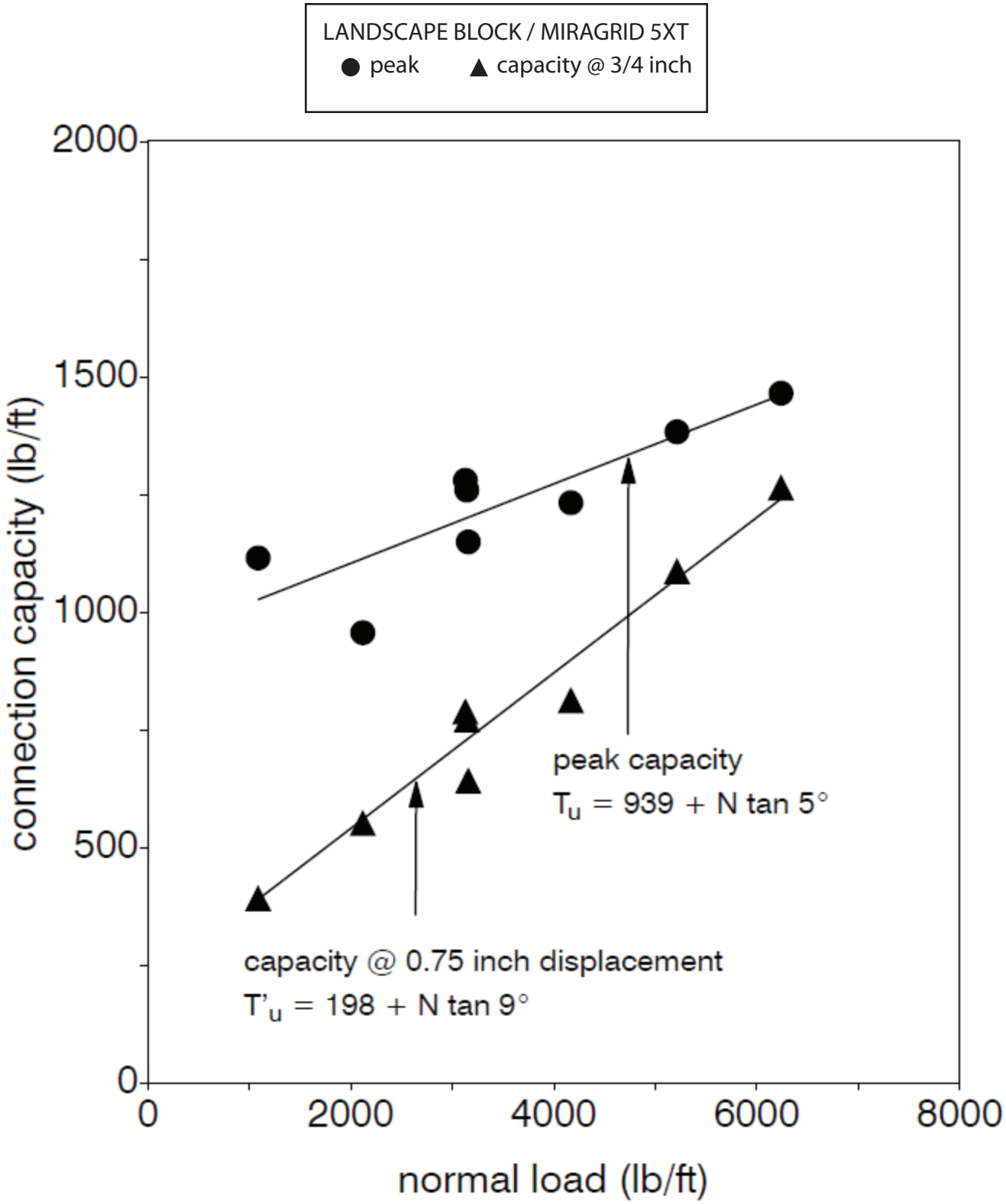

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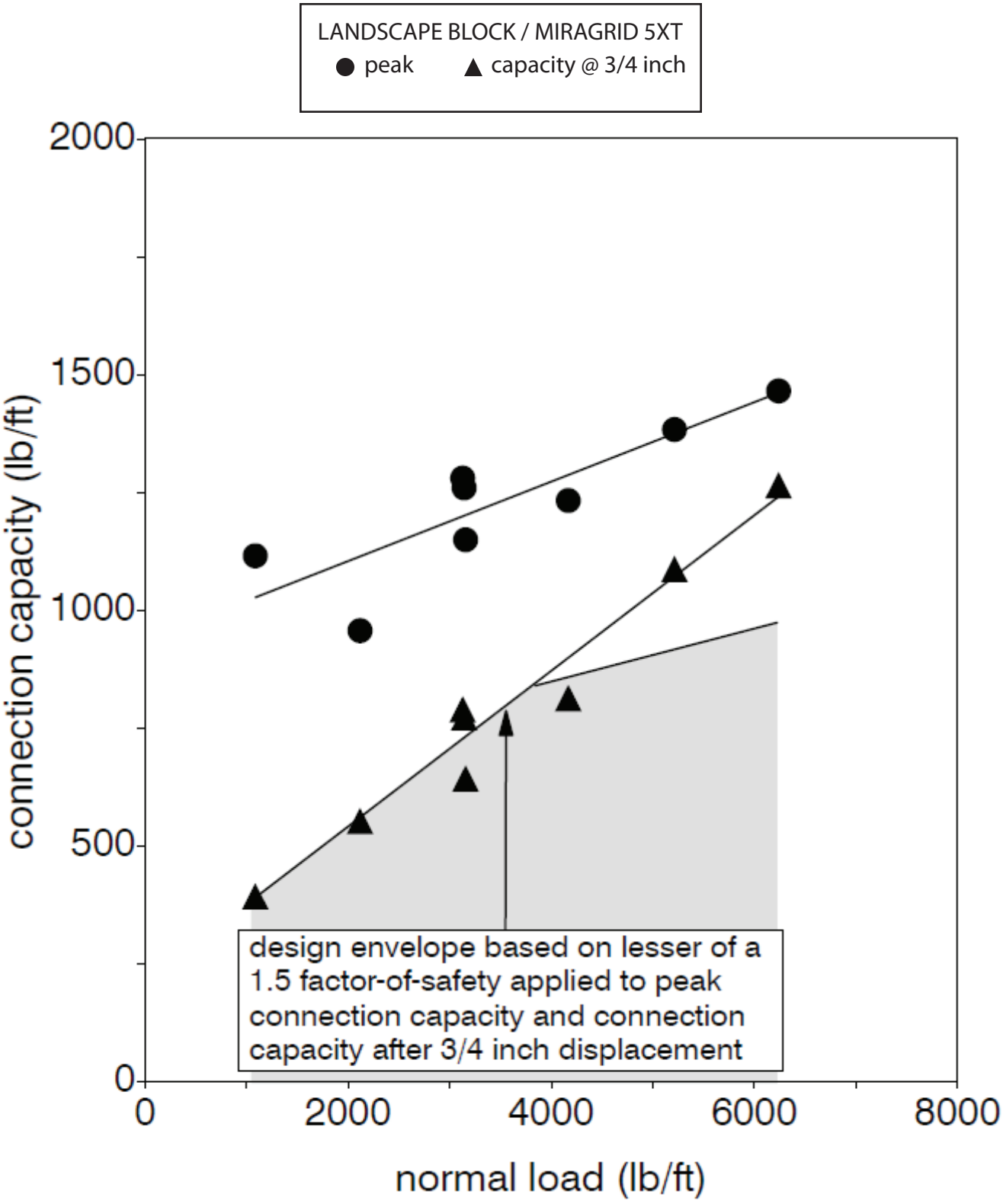
FIGURE 4:
Preliminary design capacity envelope for World Block Landscape Block and Miragrid 5XT



MIRAGRID 8XT GEOGRID

INTRODUCTION

This report gives the results of a connection testing program carried out to evaluate the mechanical/ frictional performance of the connection between World Block Landscape Block modular concrete units and Miragrid 8XT geogrid.

The test program was initiated in response to a verbal authorization to proceed from Mr. Rod Johnson of World Block received 25 September 2007.

The tests were carried out at the laboratories of Bathurst, Clarabut Geotechnical Testing, Inc. in Kingston, Ontario, under the supervision of Mr. Peter Clarabut.

OBJECTIVES OF TEST PROGRAM

The facing-geogrid connection between World Block Landscape Block units and Miragrid 8XT was investigated using a large-scale connection test apparatus.

The principal objective of the testing was to evaluate the mechanical/frictional performance of these connections. A second objective was to make preliminary recommendations for the selection of long-term tensile connection capacities to be used in the design and analysis of geogrid-reinforced soil wall systems that employ World Block Landscape Block modular concrete units in combination with Miragrid 8XT geogrid.

MATERIALS

World Block Landscape Blocks are solid concrete units weighing approximately 2400 pounds per unit. The nominal dimensions of the block are 24 inches wide (toe to heel) by 24 inches high by 48 inches long. Construction alignment and wall batter is achieved by means of two concrete shear keys cast into the top surface of the units. The installation arrangement is illustrated in Figure 1. A photograph of the World Block Landscape Block units is shown in Figure 2. The blocks used in this series of tests were supplied by World Block and were received at our laboratory on 28 September 2007 and designated as BIC 07-036.

Miragrid 8XT is a coated bi-directional grid composed of 100% polyester multifilament yarn with a tensile strength of 7000 lb/ft in the machine direction (based on ASTM D 6637 method of test and reported in the 2007 Geosynthetics Specifier's Guide, published December 2006). The specimens used in this series of testing were produced at Mirafi's Cornelia facility and cut from roll/lot #031035618/05335-1-2 received at our laboratory on 3 January 2006.

APPARATUS AND GENERAL TEST PROCEDURE

The method of test used in this investigation follows that reported by Bathurst and Simac (1993) and recommended by the NCMA (Simac et al. 1993 and ASTM D 6638). A brief description of the apparatus and test methodology is presented here. The test apparatus used to perform the tests is illustrated in Figure 1. The test apparatus allows tensile loads of up to 35,000 pounds to be applied to the geogrid while it is confined between two block layers. The facing blocks were laterally restrained and surcharged vertically. Strips of grid reinforcement 39 inches wide were attached to a roller clamp and the grid extended over the facing block. The next block was then placed over the grid. Due to the size and weight of these units, two half height - half width bottom course units were manufactured, a full size unit was used for the top block, however the connection interface used was the same as full size units. Two wire-line LVDT(s) were connected to the

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grid to measure grid displacement at the back of the block. Wall heights were simulated by placing one block over the interface and applying an additional surcharge load using the vertically-oriented hydraulic jack shown in Figure 1. A photograph of the World Block Landscape Block units in the connection test apparatus is illustrated in Figure 2. Gum rubber mats were placed over the top block to ensure a uniform distribution of vertical surcharge pressure. The connection force was applied at a constant rate of displacement (i.e. 3/4 inch/minute) using a computer controlled hydraulic actuator. The load and displacements measured by the actuator and the LVDT(s) were recorded continuously during the test by a microcomputer/data acquisition system. All blocks used in the tests were visually inspected to confirm that they were free of defects. Each test was continued until there was a sustained loss in connection load due to geogrid rupture. Following each test, the blocks were removed and the grid examined to confirm failure modes. A virgin specimen of grid was used for each test.

The only variable in this series of connection tests was the magnitude of surcharge load.

TEST PROGRAM

The surcharge loads used in the test program are given in Table 1. Also tabulated are the failure loads observed for each test.

TEST RESULTS

A summary of tensile loads at peak capacity and after 3/4 inch displacement is given in Figure 3.

The peak connection capacity between World Block Landscape Block units and Miragrid 8XT for walls between 3.0 and 16.9 feet in height ranged between 20 and 31% of the index tensile strength of 7000 lb/ft in the machine direction (based on ASTMD 6637 method of test and reported in the 2007 Geosynthetics Specifier's Guide, published December 2006).

Two repeat tests were performed and the results in Figure 3 illustrate that there is some variability in connection capacity between nominal identical tests. This variability is less than ± 10% of the mean peak load criterion required by the NCMA (e.g. maximum variability is 5.6%) and is likely the result of small differences in the setting up of the blocks and laying out of the geogrid reinforcement. The trends in data for connection loads at 3/4 inch displacement and peak connection loads have been plotted using linear curves. The reduced connection capacity at lower surcharge loads may be due to the combined effect of lower surcharge pressure and more grid slippage.

All tests ended in rupture of one or more geogrid longitudinal members. In all tests there was some localized rupturing of the longitudinal members as well as junction failure after large displacements. There was evidence of slippage of the grid within the concrete block-grid interface in all tests. Grid straining and slippage caused abrasion of longitudinal members as the geogrid was pulled across the concrete surfaces. The amount of slippage was seen to diminish with an increase in wall height.

IMPLICATIONS TO DESIGN PRO LANDSCAPE BLOCK DESIGN AND CONSTRUCTION WITH MIRAGRID 8XT

The long-term design connection capacity in the field must be less than the peak capacity envelope determined in this test series for the same method and quality of construction. The NCMA Segmental Retaining Wall Design Manual (First Edition, 1993) recommends that the design connection capacity at a given surcharge load for a critical wall structure be the lesser of the peak capacity divided by a minimum factor of safety (not less than 1.5) or the

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SUMMARY OF CONCLUSIONS

A laboratory testing program was carried out to evaluate the mechanical/frictional connection performance of World Block Landscape Block modular facing units in combination with Miragrid 8XT polyester grid. The following conclusions can be drawn:

1. The peak connection capacity between World Block Landscape Block units and Miragrid 8XT for walls between 3.0 and 16.9 feet in height ranged between 20 and 31% of the index tensile strength of 7000 lb/ft in the machine direction (based on ASTM D 6637 method of test and reported in the 2007 Geosynthetics Specifier's Guide, published December 2006).

2. The trends in data for connection loads at 3/4 inch displacement and peak connection loads have been plotted using linear curves. In addition, some variability in connection capacity values was observed between nominal identical tests due to small differences in setting up of the blocks and laying out of the geogrid reinforcement.

3. Care must be taken during the installation of World Block Landscape Block units in order to prevent accumulation of soil and rock debris at the concrete block-grid interface surfaces. This debris may significantly reduce the capacity of the World Block Landscape Block facing unit-grid system.

4. The design envelope in Figure 4 is based on an interpretation of test data as recommended in the NCMA Segmental Retaining Wall Design Manual (First Edition, 1993). The choice of design connection strengths may vary from site to site and quality of construction in the field may require lower design values than those taken from Figure 4.

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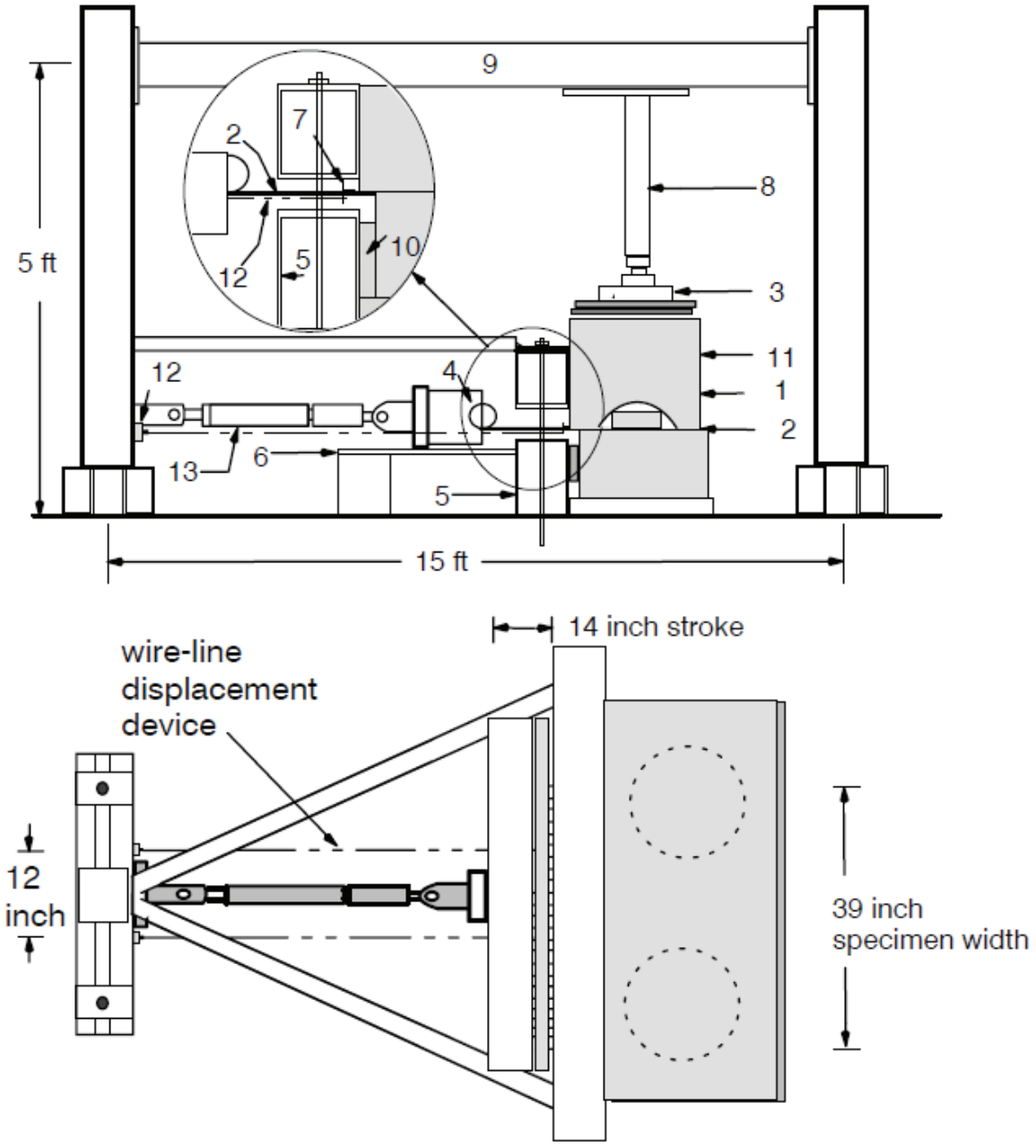
World Block Landscape Block modular unit with Miragrid 8XT geogrid connection

Test number	approximate wall height (feet)	approximate number of blocks	normal load (lb/ft)	tensile capacity (lb/ft) at 3/4 inch displacement	peak tensile capacity (lb/ft)
1	8.6	4.3	3158	885	1768
2	3.0	1.5	1087	659	1410
3	5.8	2.9	2140	828	1672
4	8.5	4.3	3130	978	1631
5	11.3	5.7	4176	1163	1871
6	14.1	7.1	5201	1315	2071
7	8.5	4.3	3144	954	1782
8	16.9	8.5	6233	1320	2181

FIGURE 1:
Schematic of connection test apparatus showing World Block Landscape Block units and Miragrid 8XT geogrid



LEGEND

1	Landscape Block	6	guide rail	11	stiff gum rubber mat
2	Miragrid 8XT	7	LVDT clamp	12	wire-line LVDT
3	loading platen	8	surcharge actuator	13	computer controlled hydraulic actuator
4	roller clamp	9	loading frame		
5	lateral restraining system	10	spacers		

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FIGURE 2:
Photograph of World Block Landscape Block units in the connection test apparatus

FIGURE 3:
Connection capacity versus normal load for World Block Landscape Block tests with Miragrid 8XT geogrid reinforcement

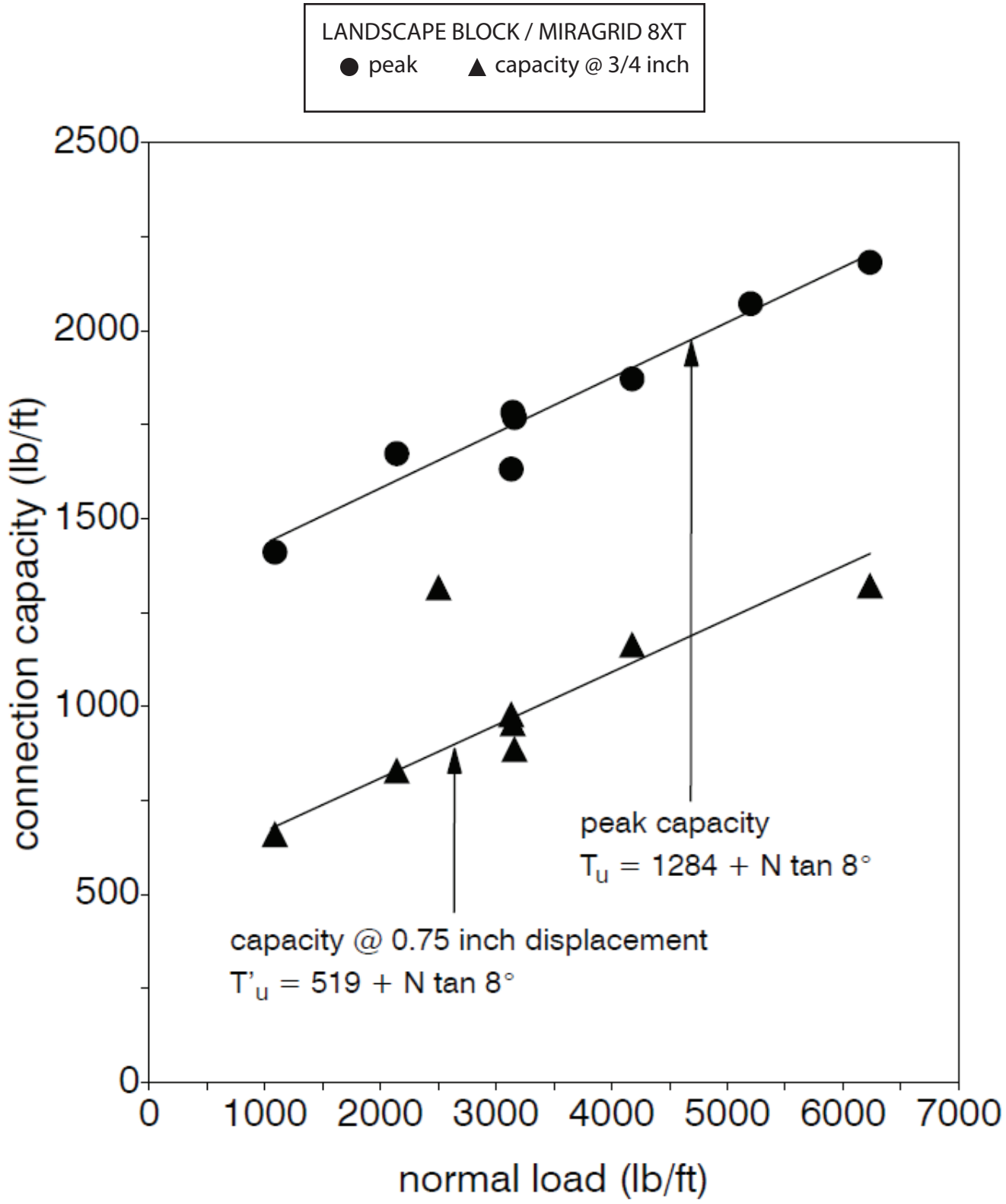

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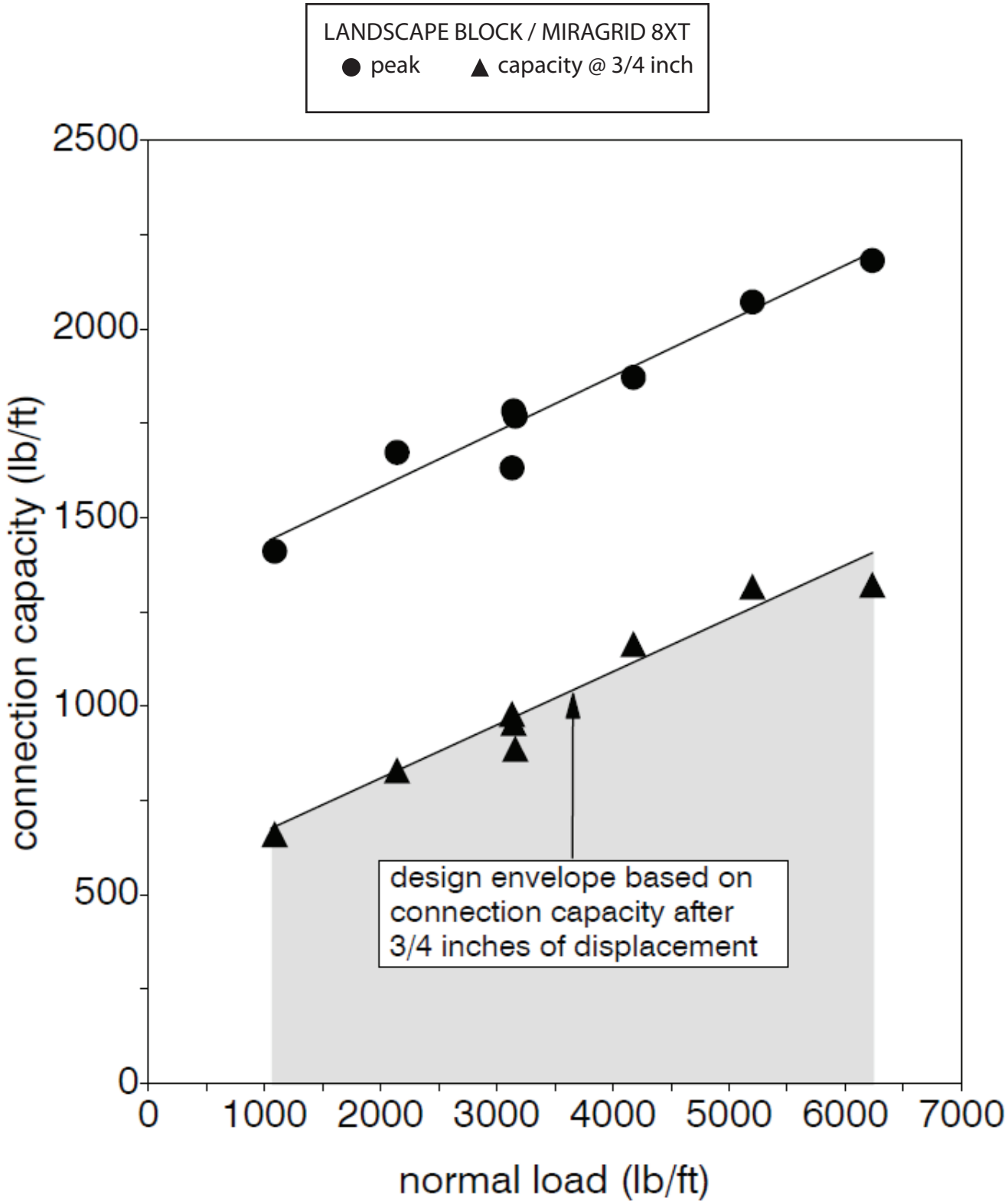
FIGURE 4:
Preliminary design capacity envelope for World Block Landscape Block and Miragrid 8XT



MIRAGRID 10XT GEOGRID

INTRODUCTION

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OBJECTIVES OF TEST PROGRAM

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The principal objective of the testing was to evaluate the mechanical/frictional performance of these connections. A second objective was to make preliminary recommendations for the selection of long-term tensile connection capacities to be used in the design and analysis of geogrid-reinforced soil wall systems that employ World Block Landscape Block modular concrete units in combination with Miragrid 10XT geogrid.

MATERIALS

World Block Landscape Blocks are solid concrete units weighing approximately 2400 pounds per unit. The nominal dimensions of the block are 24 inches wide (toe to heel) by 24 inches high by 48 inches long. Construction alignment and wall batter is achieved by means of two concrete shear keys cast into the top surface of the units. The installation arrangement is illustrated in Figure 1. A photograph of the World Block Landscape Block units is shown in Figure 2. The blocks used in this series of tests were supplied by World Block and were received at our laboratory on 28 September 2007 and designated as BIC 07-036.

Miragrid 10XT is a coated bi-directional grid composed of 100% polyester multifilament yarn with a tensile strength of 9500 lb/ft in the machine direction (based on ASTM D 6637 method of test and reported in the 2007 Geosynthetics Specifier's Guide, published December 2006). The specimens used in this series of testing were produced at Mirafi's Cornelia facility and cut from roll/lot #031035182/05320-1-2 received at our laboratory on 3 January 2006.

APPARATUS AND GENERAL TEST PROCEDURE

The method of test used in this investigation follows that reported by Bathurst and Simac (1993) and recommended by the NCMA (Simac et al. 1993 and ASTM D 6638). A brief description of the apparatus and test methodology is presented here. The test apparatus used to perform the tests is illustrated in Figure 1. The test apparatus allows tensile loads of up to 35,000 pounds to be applied to the geogrid while it is confined between two block layers. The facing blocks were laterally restrained and surcharged vertically. Strips of grid reinforcement 39 inches wide were attached to a roller clamp and the grid extended over the facing block. The next block was then placed over the grid. Due to the size and weight of these units, two half height - half width bottom course units were manufactured, a full size unit was used for the top block, however the connection interface used was the same as full size units. Two wire-line LVDT(s) were connected to the

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TEST PROGRAM

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TEST RESULTS

A summary of tensile loads at peak capacity and after 3/4 inch displacement is given in Figure 3.

The peak connection capacity between World Block Landscape Block units and Miragrid 10XT for walls between 3.0 and 17.0 feet in height ranged between 15 and 25% of the index tensile strength of 9500 lb/ft in the machine direction (based on ASTMD 6637 method of test and reported in the 2007 Geosynthetics Specifier's Guide, published December 2006).

Two repeat tests were performed and the results in Figure 3 illustrate that there is some variability in connection capacity between nominal identical tests. This variability is less than ± 10% of the mean peak load criterion required by the NCMA (e.g. maximum less than 1.0%) and is likely the result of small differences in the setting up of the blocks and laying out of the geogrid reinforcement. The trends in data for connection loads at 3/4 inch displacement and peak connection loads have been plotted using linear curves. The reduced connection capacity at lower surcharge loads may be due to the combined effect of lower surcharge pressure and more grid slippage.

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It is very important that production blocks have uniform dimensions so that there is no stepping at the block joints that can lead to non-uniform frictional resistance at the block-grid interface, pinching of the grid at the block edges and possibly fracture of the concrete units.

SUMMARY OF CONCLUSIONS

A laboratory testing program was carried out to evaluate the mechanical/frictional connection performance of World Block Landscape Block modular facing units in combination with Miragrid 10XT polyester grid. The following conclusions can be drawn:

1. The peak connection capacity between World Block Landscape Block units and Miragrid 10XT for walls between 3.0 and 17.0 feet in height ranged between 15 and 25% of the index tensile strength of 9500 lb/ft in the machine direction (based on ASTM D 6637 method of test and reported in the 2007 Geosynthetics Specifier's Guide, published December 2006).

2. The trends in data for connection loads at 3/4 inch displacement and peak connection loads have been plotted using linear curves. In addition, some variability in connection capacity values was observed between nominal identical tests due to small differences in setting up of the blocks and laying out of the geogrid reinforcement.

3. Care must be taken during the installation of World Block Landscape Block units in order to prevent accumulation of soil and rock debris at the concrete block-grid interface surfaces. This debris may significantly reduce the capacity of the World Block Landscape Block facing unit-grid system.

4. The design envelope in Figure 4 is based on an interpretation of test data as recommended in the NCMA Segmental Retaining Wall Design Manual (First Edition, 1993). The choice of design connection strengths may vary from site to site and quality of construction in the field may require lower design values than those taken from Figure 4.

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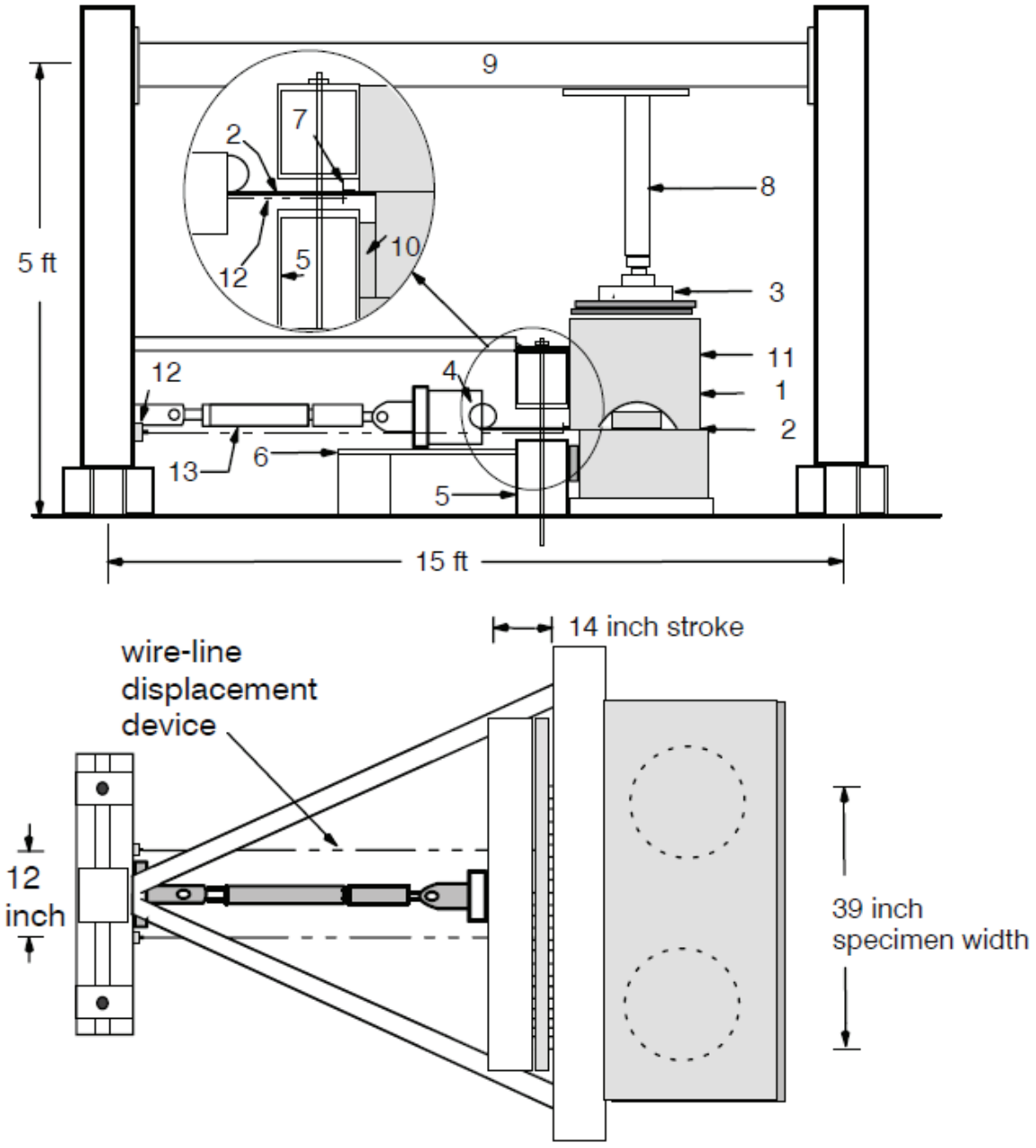
TABLE 1:
Test Program:
World Block Landscape Block modular unit with Miragrid 8XT geogrid connection

Test number	approximate wall height (feet)	approximate number of blocks	normal load (lb/ft)	tensile capacity (lb/ft) at 3/4 inch displacement	peak tensile capacity (lb/ft)
1	8.6	4.3	3165	1181	1961
2	3.0	1.5	1087	700	1397
3	5.7	2.9	2105	874	1830
4	8.6	4.3	3165	1141	1940
5	11.3	5.7	4169	1256	2208
6	14.2	7.1	5229	1343	2174
7	8.7	4.4	3206	1046	1961
8	17.0	8.5	6261	1509	2442

FIGURE 1:
Schematic of connection test apparatus showing World Block Landscape Block units and Miragrid 10XT geogrid



LEGEND

1	Landscape Block	6	guide rail	11	stiff gum rubber mat
2	Miragrid 10XT	7	LVDT clamp	12	wire-line LVDT
3	loading platen	8	surcharge actuator	13	computer controlled hydraulic actuator
4	roller clamp	9	loading frame		
5	lateral restraining system	10	spacers		

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FIGURE 2:
Photograph of World Block Landscape Block units in the connection test apparatus

FIGURE 3:
Connection capacity versus normal load for World Block Landscape Block tests with Miragrid 10XT geogrid reinforcement

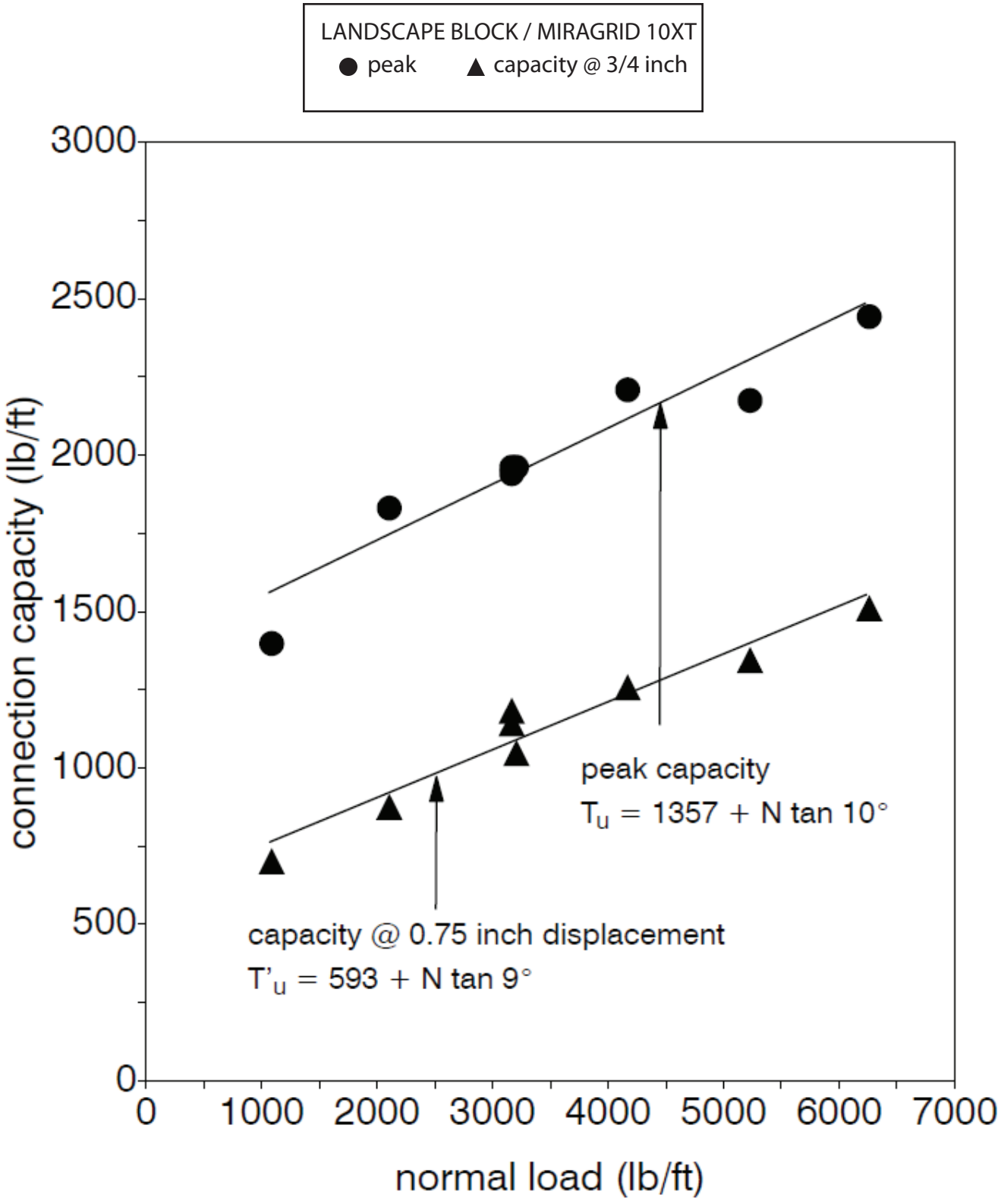

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FIGURE 4:
Preliminary design capacity envelope for World Block Landscape Block and Miragrid 10XT