REPORT

RESULTS

OF

LONDON BOULDER BLOCK WITH MIRAGRID 5XT CONNECTION CAPACITY TESTING

submitted to

CONCRETE PRODUCTS OF NEW LONDON

CONFIDENTIAL

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Introduction

This report gives the results of a connection testing program carried out to evaluate the mechanical/frictional performance of the connection between modified London Boulder® modular concrete block units manufactured by Concrete Products of New London and Miragrid® 5XT geogrid.

The test program was initiated in response to an Email authorization to proceed from Mr. Kelly Morrell of Concrete Products of New London, received 23 April 2004.

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 London Boulder concrete block units and Miragrid 5XT geogrid 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 modified London Boulder blocks in combination with Miragrid 5XT geogrid.

Materials

London Boulder blocks are semi-solid concrete blocks weighing approximately 2200 pounds per unit. The nominal dimensions of the block are 42 inches wide (toe to heel) by 18 inches high by 48 inches long. The blocks used in this investigation were modified by filling the hollow section on the bottom of the block with concrete. Construction alignment is achieved by means of a concrete lip located at the back and bottom of the block. The installation arrangement is illustrated in **Figure 1**. A photograph of the London Boulder block unit is shown in **Figures 2** and **3**. The blocks used in this series of tests were supplied by Concrete Products of New London and were received at our laboratory on 23 January 2004 and designated as BIC 00-156 and BIC 00-157.

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 2003 GFR Specifier's Guide, published December 2002). The Miragrid 5XT used in this connection series was from roll #31004881/03345-1-1 and received at our laboratory on 23 January 2004.

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 geogrid reinforcement 39 inches (1 meter) wide were attached to a roller clamp and the geogrid extended over the lower facing block. The next block was then placed over the geogrid simulating the technique that would be used in the field. Two wire-line LVDT(s) were connected to the geogrid to measure geogrid displacement at the back of the blocks. Wall heights were simulated by placing one block course over the interface and applying an additional surcharge load using the vertically-oriented hydraulic jack shown in **Figure 1**. A gum rubber mat was placed over the top layer of blocks to ensure a uniform distribution of vertical surcharge pressure. The connection force was applied at a constant rate of displacement (i.e. 0.75 inches/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 strength due to geogrid longitudinal member failure. Following each test, the blocks were removed and the geogrid examined to confirm failure modes. A virgin specimen of geogrid 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 4**.

The peak connection strength between London Boulder units and Miragrid 5XT for walls between 2.4 and 14.8 feet in height ranged between 27 and 41% 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 2003 GFR Specifier's Guide, published December 2002).

Two repeat tests were performed and the results in **Figure 4** illustrate that there is minor 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 3.0%) 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 capacities 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 geogrid rupture after large deformation. There was also evidence of slippage of the geogrid within the concrete block-geogrid interface in all tests. Geogrid 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 London Boulder design and construction with Miragrid 5XT geogrid

The long-term design connection strength 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 5** is controlled by the 3/4 inch displacement criterion.

The design capacity envelope illustrated in **Figure 5** 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 geogrid and blocks in order to minimize abrasion to the geogrid and to maximize the frictional resistance that is developed at the concrete block-geogrid 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-geogrid interface, pinching of the geogrid 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 modified London Boulder modular block facing units in combination with Miragrid 5XT geogrid. The following conclusions can be drawn:

1. The peak connection strength between London Boulder units and Miragrid 5XT geogrid for walls between 2.4 and 14.8 feet in height ranged between 27 and 41% 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 2003 GFR Specifier's Guide, published December 2002).
2. The trends in data for connection capacities at 3/4 inch displacement and peak connection loads have been plotted using linear curves.
3. Care must be taken during the installation of London Boulder units in order to prevent accumulation of soil and rock debris at the concrete block-geogrid interface surfaces. This debris may significantly reduce the capacity of the London Boulder facing unit-geogrid system.

4. The design envelope in **Figure 5** 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 5**.

P. Clarabut, C.E.T.

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

REFERENCES

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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.

Table 1

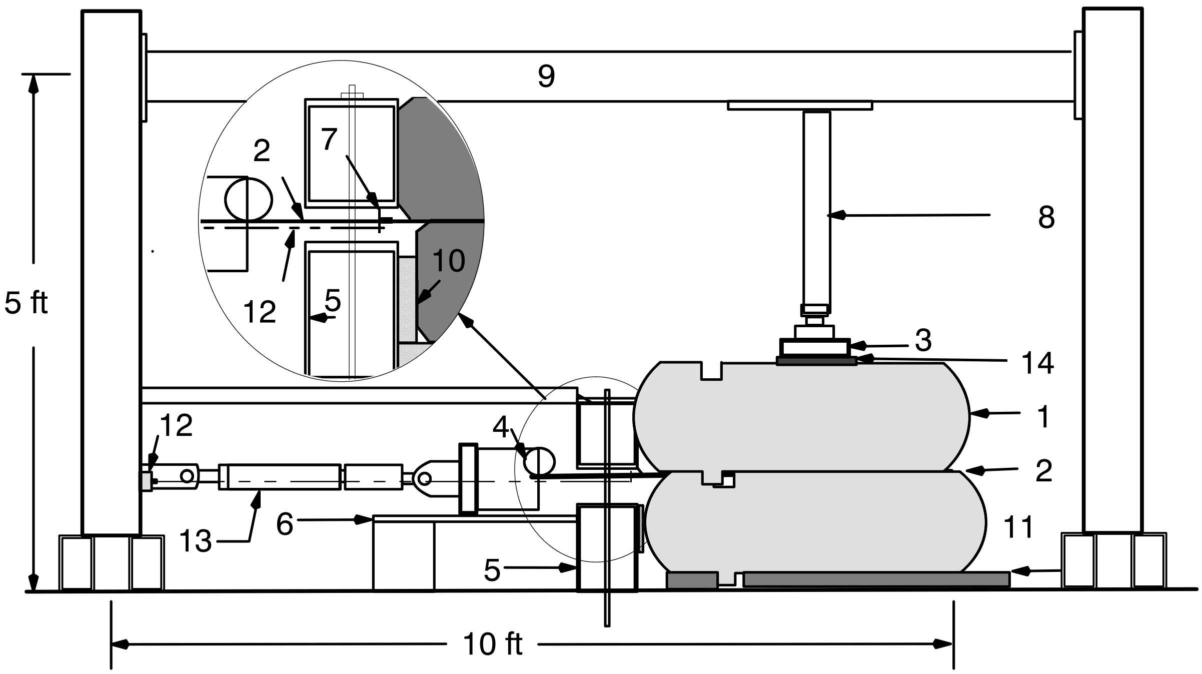
Test Program:

London Boulder modular block unit - Miragrid 5XT geogrid connection (with underside hollow section filled)

Test number	normal load (lb/ft)	approximate wall height (feet)	approximate number of blocks	tensile capacity (lb/ft) at 3/4 inch displacement	peak tensile capacity (lb/ft)
1	827	2.4	1.6	602	1143
2	1682	4.9	3.3	614	1575
3	2503	7.3	4.9	798	1494
4	3330	9.8	6.5	1071	1593
5	4196	12.3	8.2	993	1620
6	5040	14.8	9.8	1148	1746
7	2503	7.3	4.9	710	1440
8	2509	7.3	4.9	812	1521

LEGEND

1	London Boulder	6	guide rail	11	platform
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	14	gum rubber mat



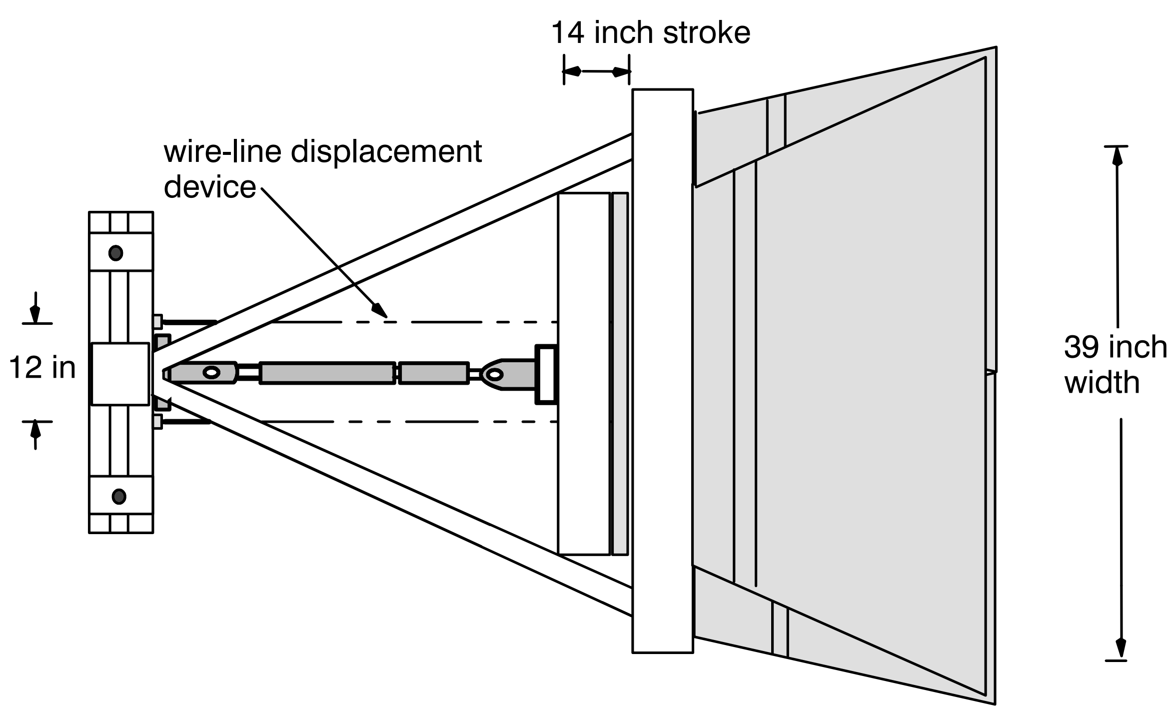


Figure 1: Schematic of connection test apparatus showing London Boulder units and Miragrid 5XT reinforcement

Figure 2: Photograph of the London Boulder block in the connection test apparatus

Figure 3: Photograph of the bottom of the London Boulder block showing the concrete filled section

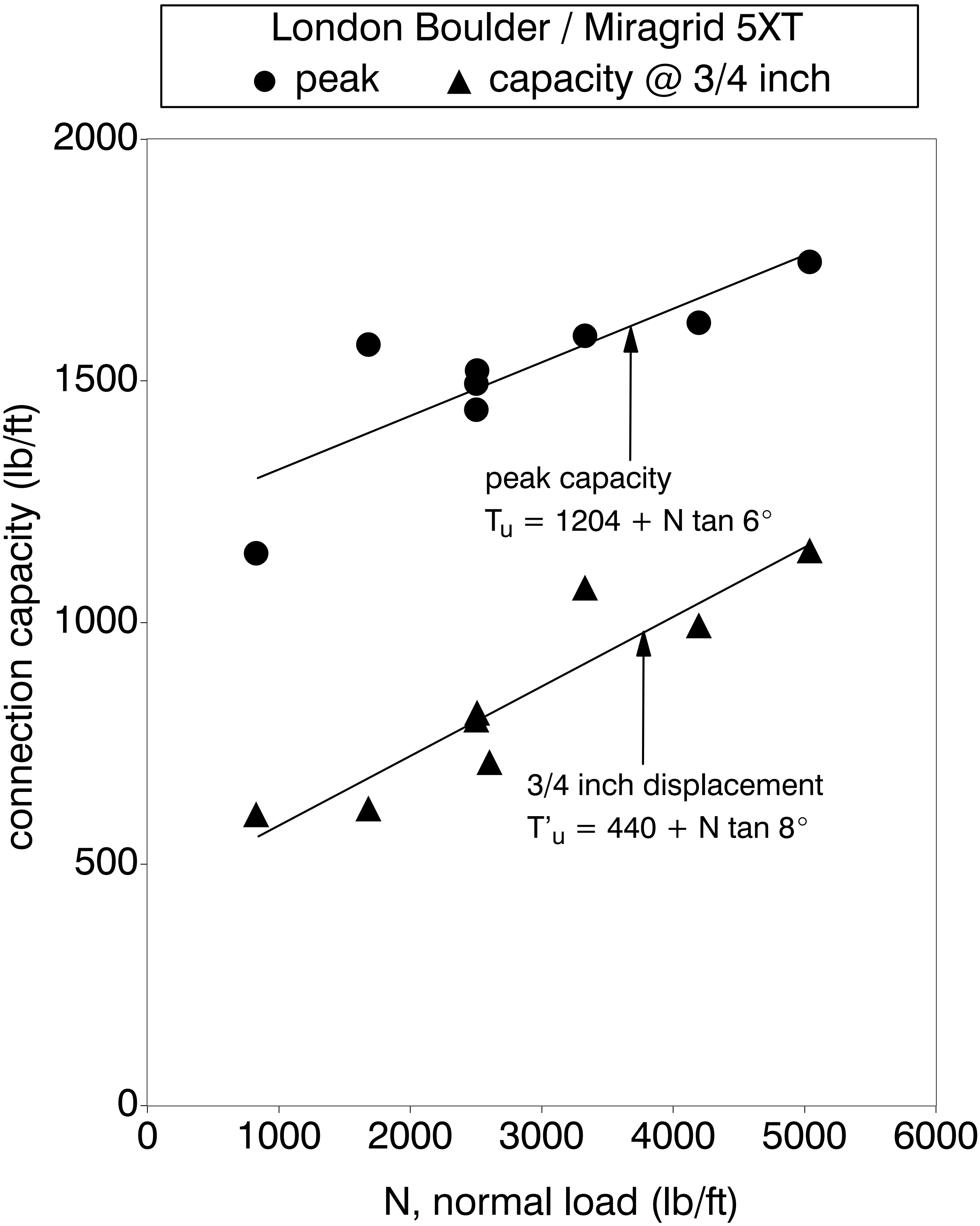


Figure 4: Summary of connection capacities for London Boulder block units (underside hollow section filled with concrete) and Miragrid 5XT geogrid

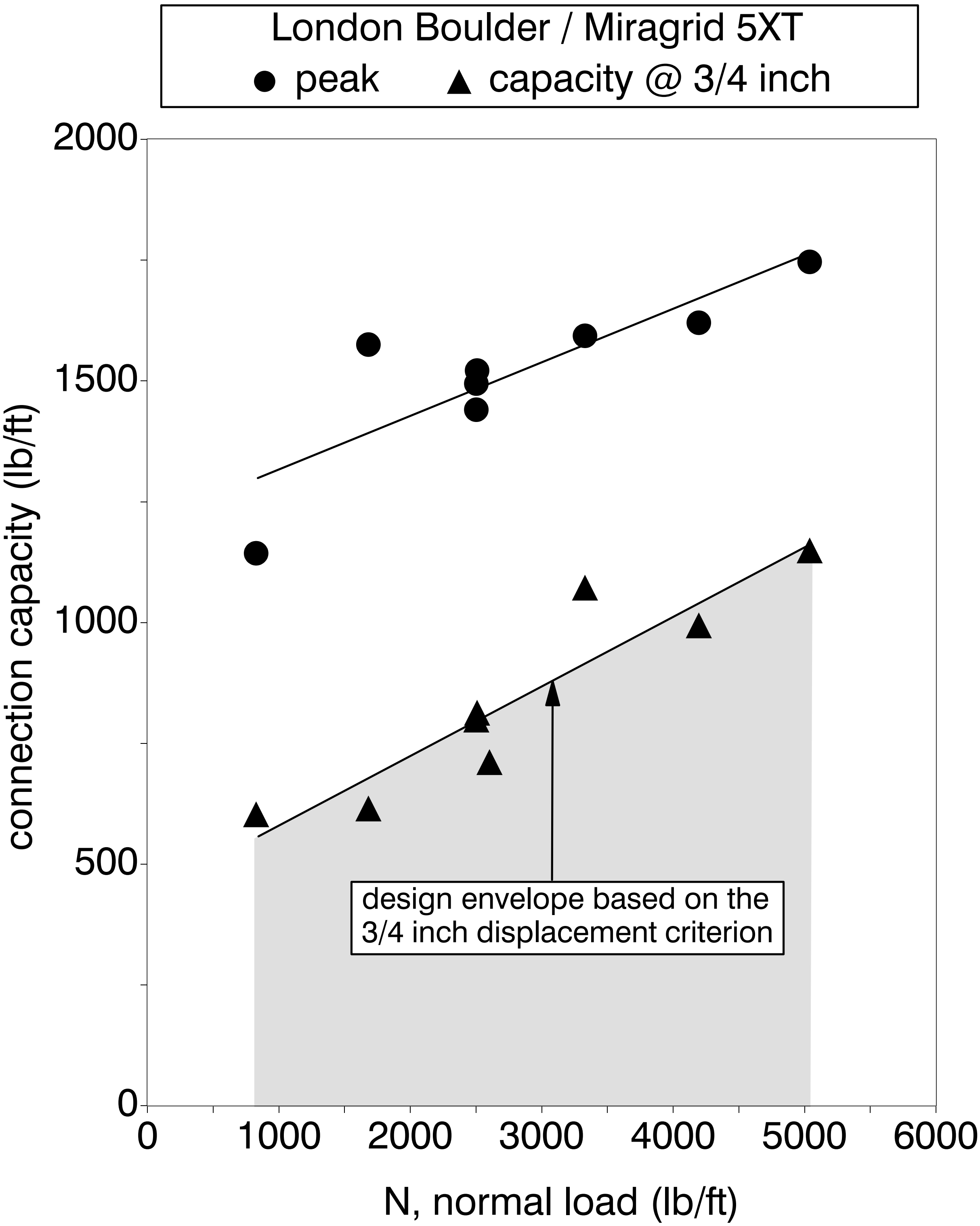


Figure 5: Design envelope for London Boulder blocks with Miragrid 5XT