# REPORT
# RESULTS
# OF
# LONDON BOULDER BLOCK
# (WITHOUT SHEAR LUGS)
# SHEAR CAPACITY TESTING

submitted to

CONCRETE PRODUCTS OF NEW LONDON

CONFIDENTIAL

Distribution:

2 copies Concrete Products of New London
17550 Highway 23 NE
New London, MN USA
56273

2 copies Bathurst, Clarabut Geotechnical Testing, Inc.
1167 Clyde Court, Kingston, Ontario
K7P 2E4 CANADA

**Introduction**

This report gives the results of an interface shear testing program carried out to evaluate the mechanical/frictional performance of London Boulder (with the concrete shear lugs removed) in shear.

The test program was initiated in response to an Email authorization to proceed from Mr. Kelly Morrell of Concrete Products of New London, received 15 January 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 interface shear capacity between London Boulder concrete block units (without shear lugs) placed in a staggered joint (running bond) configuration was investigated using a large-scale test apparatus.

The principal objective of the testing was to evaluate the mechanical/frictional performance of the shear connection between successive layers of London Boulder block units. A second objective was to make recommendations for the selection of interface shear capacities to be used in the design and analysis of retaining wall systems that employ London Boulder blocks.

**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. Construction alignment is achieved by means of a concrete lip located at the back and bottom of the block. However, for this series of tests the shear lugs were removed. The installation arrangement is illustrated in **Figure 1**. 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 BIC-00-156 and BIC-00-157.

**Apparatus and general test procedure**

The SRWU-2 method of test as reported in the NCMA Segmental Retaining Wall Design Manual (1993) and ASTM D 6916 was used in this investigation. A brief description of the apparatus and test methodology is presented here. The apparatus used to perform the tests is illustrated in **Figure 1**. The test apparatus allows horizontal loads of up to 35,000 lbf to be applied across the interface between two block layers. The segmental units were laterally restrained at the bottom and surcharged vertically. A single block was placed over one centrally located running bond (joint) formed by the two underlying units to simulate the staggered construction procedure typically used in the field. Wall heights were simulated by placing a

single block over the interface and applying additional normal load using the air bag arrangement shown in **Figure 1**. The horizontal (shear) force was applied at a constant rate of displacement using a computer-controlled hydraulic actuator. The load and displacements measured by the actuator and displacement transducers were recorded continuously during the test by a microcomputer/data acquisition system. Each test was continued until large shear displacements were achieved. Following each test, the blocks were removed and the units examined to confirm failure modes.

The only variable in this series of interface shear tests was the magnitude of surcharge (i.e. the magnitude of normal load applied to the top segmental unit). The normal loads used in the test program are given in **Table 1**.

**Test results**

Results of interface shear tests are summarized in **Table 1**. Peak interface shear capacities and shear capacity at the displacement criterion (0.36 inch) are plotted against normal load in **Figure 2**. The displacement criterion was calculated to be 0.36 inch based on 2% of the block height. The minimum *peak* shear capacity recorded from the test series was 293 lb/ft.

The test results reveal some scatter in shear capacity for tests carried out at nominal similar normal loads. The three tests carried out at a nominal equivalent normal load of about 2468 lb/ft (Tests 6, 7, and 8) gave peak shear capacity values that ranged from 1328 to 1474 lb/ft with a mean value of 1423 lb/ft. This scatter is less than ± 10% of the mean peak shear criterion required by the NCMA (e.g. maximum variability is 6.7%) and is likely the result of small differences in the setting up of the blocks. In all tests peak shear capacity was observed before 0.36 inches of displacement. The trend in data for peak shear loads has been plotted using a linear curve.

**Implications to interface shear capacity design and construction with London Boulder block units (without shear lugs)**

The interface shear strength in the field may be less than the values 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 shear capacity at a given normal load for a critical wall structure be the lesser of: a) the peak capacity divided by a minimum factor of safety (not less than 1.5) or; b) the capacity based on the 0.36 inch displacement criterion. The *design* interface shear capacity envelope shown in **Figure 3** is controlled by the peak shear load criteria.

The design shear capacity envelope illustrated in **Figure 3** 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. In addition, the interface concrete surfaces should be

free of aggregate particles in order to maximize the frictional resistance that is developed between the concrete surfaces.

**Summary of conclusions**

A laboratory testing program was carried out to evaluate the mechanical/frictional performance of the shear connection between London Boulder segmental concrete units without shear lugs. The following conclusions can be drawn:

1. The minimum *peak* shear capacity recorded from this test series was 293 lb/ft (height above interface equal to 1.0 block units).
2. Variability in shear capacity was observed between nominal identical tests due to small differences in setting up of the blocks and possibly small variations in block dimensions.
3. The design envelope in **Figure 3** is based on interpretation of test data as recommended in the NCMA Segmental Retaining Wall Design Manual (First Edition, 1993). The choice of design interface shear capacity may vary with quality of construction in the field and hence lower design values than those taken from **Figure 3** may be appropriate.

**Concluding remarks**

The test results presented here are applicable to conventional and geosynthetic reinforced-soil segmental retaining wall designs that employ London Boulder units. The inclusion of a layer of geosynthetic reinforcement may reduce the interface shear capacity to values less than those reported in this investigation.

# REFERENCES

ASTM D 6916-03. Standard Test Method for Determining Shear Strength between Segmental Concrete Units (Modular Concrete Blocks), American Society for Testing and Materials, West Conshohocken, PA 19428-2958 USA.

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 (without shear lugs) interface shear testing

| Test number | approximate wall height (feet) | approximate number of blocks | normal load (lb/ft) | shear capacity (lb/ft) at 0.36 inch displacement | peak shear capacity (lb/ft) |
|---|---|---|---|---|---|
| 1 | 1.5 | 1.0 | 512 | 293 | 293 |
| 2 | 4.8 | 3.2 | 1648 | 821 | 821 |
| 3 | 9.7 | 6.5 | 3324 | 1665 | 1665 |
| 4 | 12.2 | 8.2 | 4174 | 2177 | 2177 |
| 5 | 14.7 | 9.8 | 5018 | 2576 | 2576 |
| 6 | 7.1 | 4.8 | 2436 | 1328 | 1328 |
| 7 | 7.2 | 4.8 | 2475 | 1474 | 1474 |
| 8 | 7.3 | 4.9 | 2492 | 1468 | 1468 |

P. Clarabut, C.E.T.

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

1 loading frame
2 horizontal actuator
3 horizontal load cell
4 reaction beam
5 vertical load cell
6 air bag
7 spacers
8 London Boulder block
9 shear lug removed

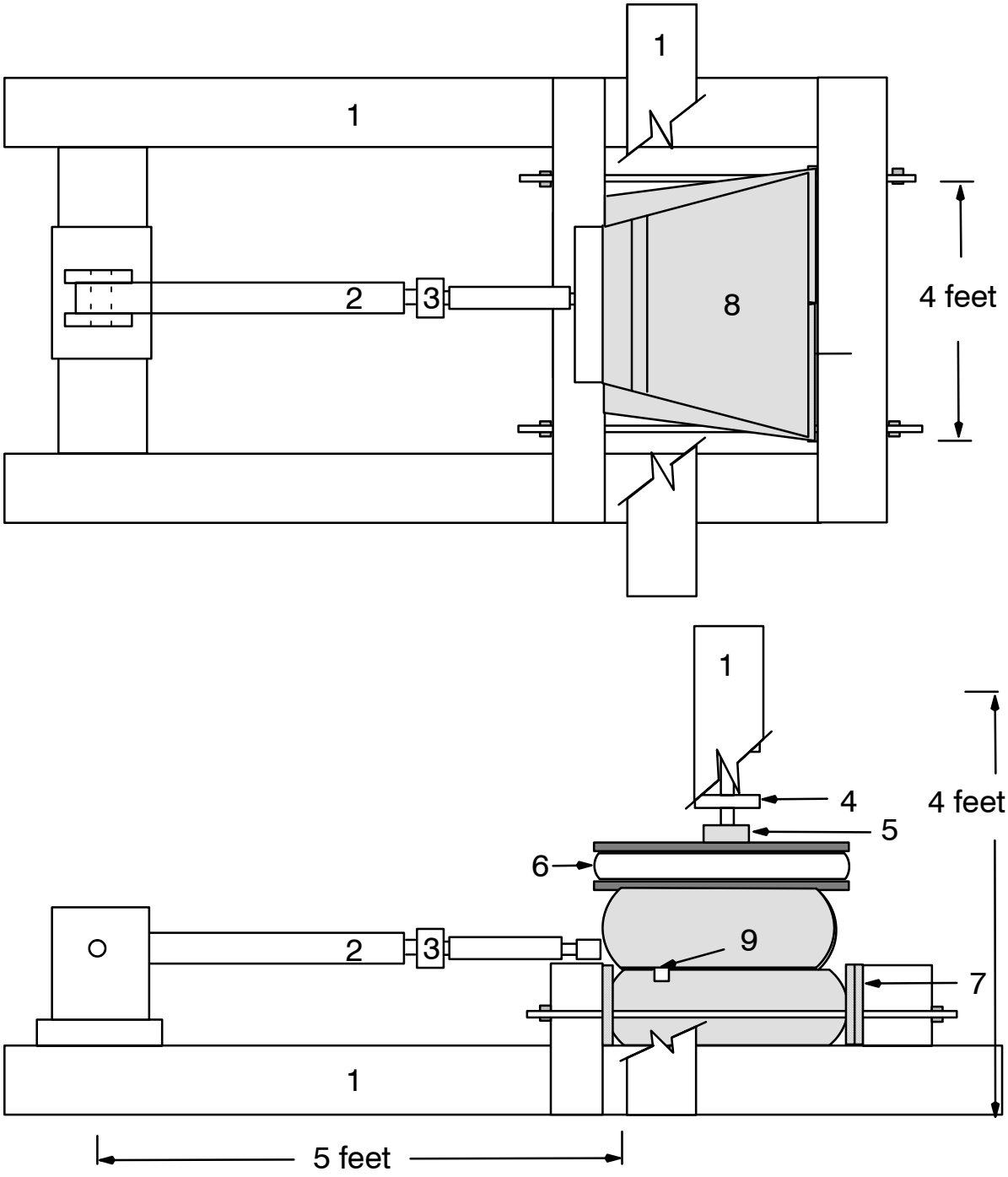


Figure 1: Schematic of shear capacity test apparatus showing London Boulder segmental concrete block units

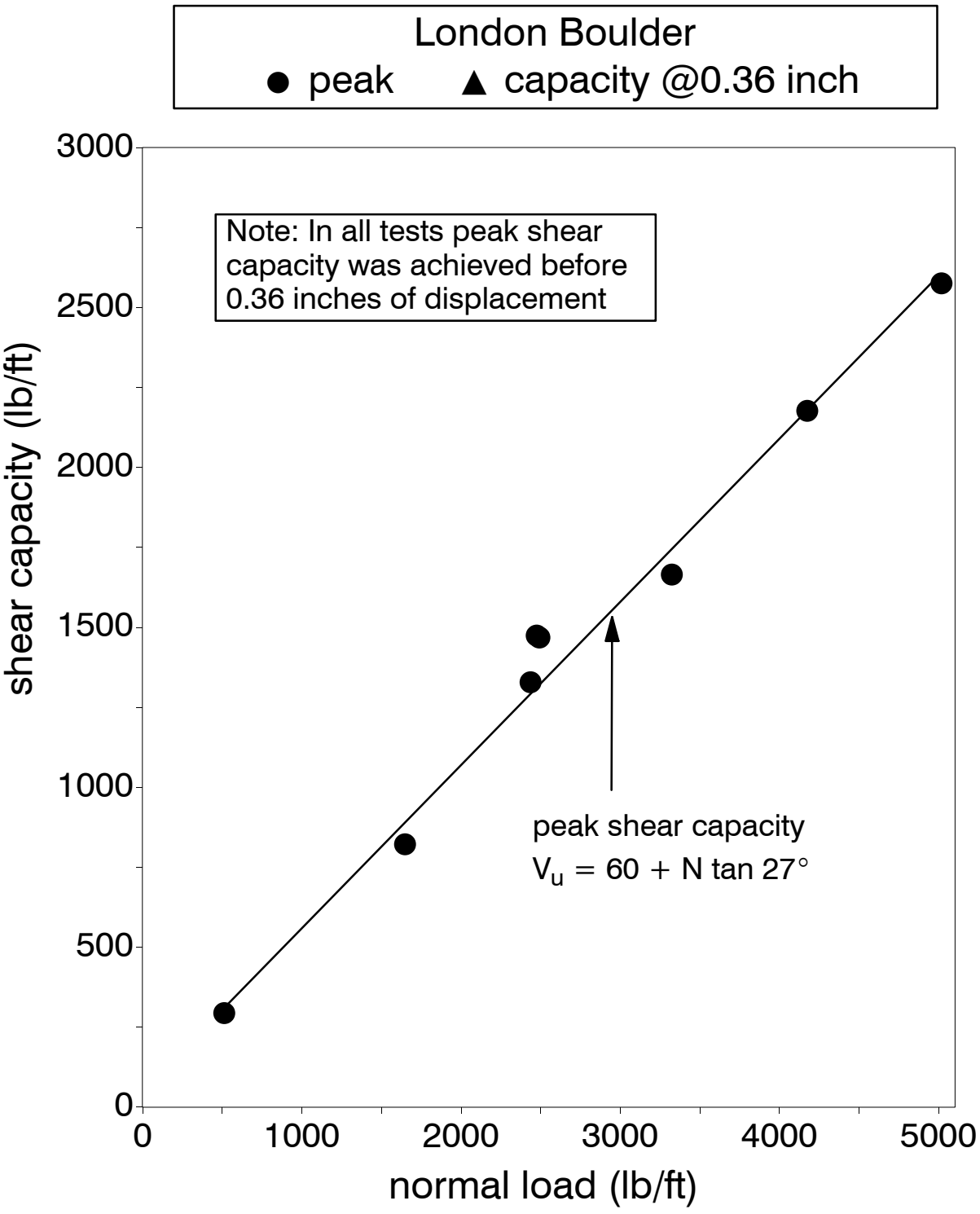


Figure 2: Interface shear versus normal load for London Boulder (without shear lugs) block tests

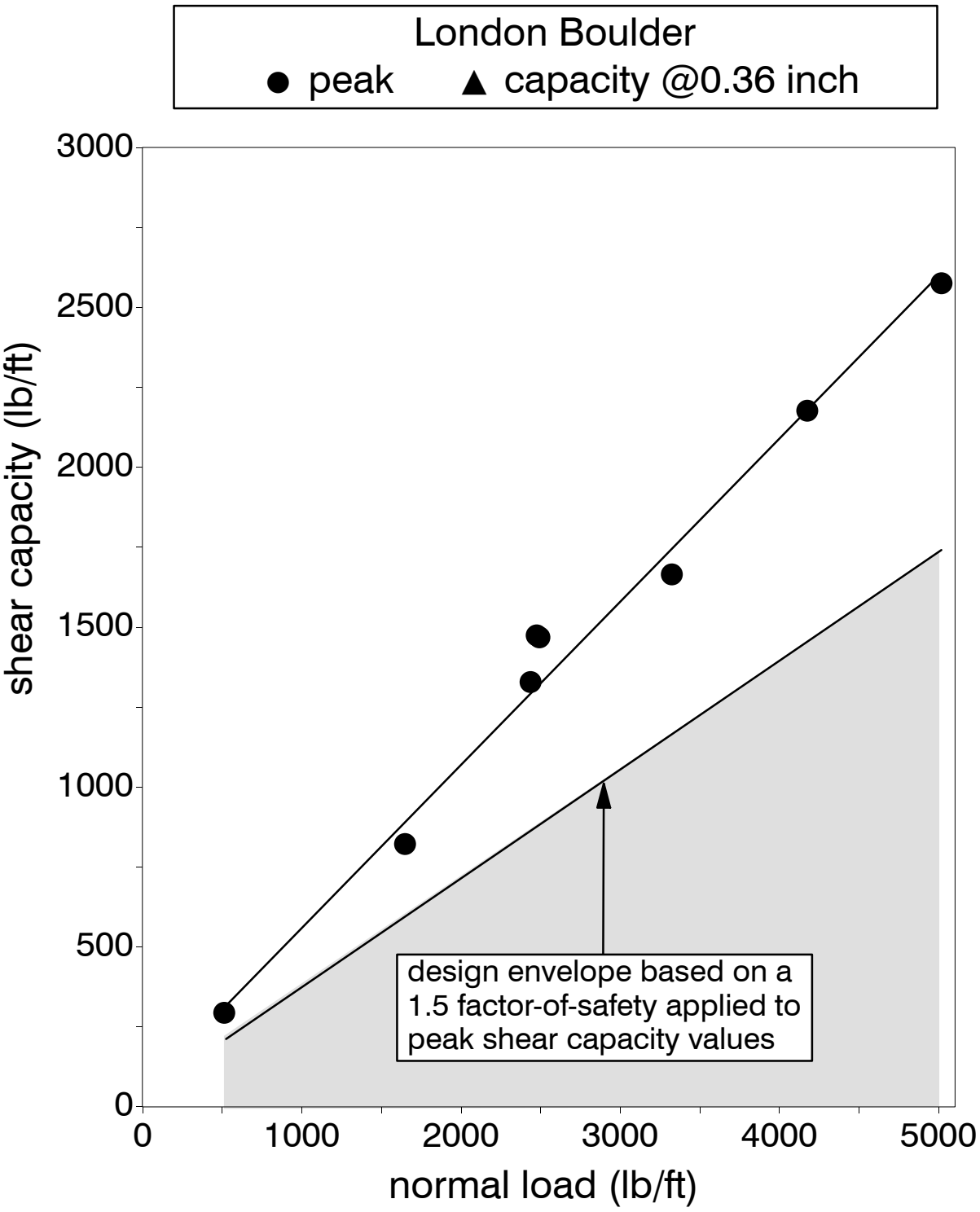


Figure 3: Preliminary design curve for shear capacity versus normal load for London Boulder block units (without shear lugs)