In-Plane Shear Testing of Flexlock Concrete Masonry Walls

for

Cercorp Initiatives Incorporated

Conducted by:

NATIONAL CONCRETE MASONRY ASSOCIATION
RESEARCH & DEVELOPMENT LABORATORY

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RESEARCH AND DEVELOPMENT LABORATORY

The Research and Development Laboratory is devoted to the scientific research and testing of concrete masonry products and systems. Professional engineers and technicians with many years of experience in the concrete masonry industry staff the Laboratory. The Laboratory is equipped to perform nearly any physical research or testing of concrete masonry units and assemblages. The Laboratory performs research and development work for both the Association and individual companies.

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1.0—INTRODUCTION

This report describes the results of in-plane shear strength testing of Flexlock®, hereinafter called "Flexlock", concrete masonry wall assemblies by the National Concrete Masonry Association's Research and Development Laboratory. The testing was performed for, and funded by, Cercorp Initiatives Inc.

The primary objective of this research was to measure the in-plane shear capacity of Flexlock concrete masonry wall assemblies that are dry-stacked and post-tensioned. The wall assemblies were post-tensioned using Williams Form post-tensioning tendons and hardware. Four wall assemblies were constructed and tested in accordance with ASTM E 72, *Standard Test Method of Conducting Strength Tests of Panels for Building Construction*. The walls were constructed using 13 courses of Flexlock (8 feet, 8 inches) for two wall lengths. The scope of this research is shown in Table 1 below.

Table 1—Scope of Research

Panel Designation	Wall Length (in)	Aspect Ratio	Tendon Spacing
Shear wall #1	72	1.4	2@ 48 inches c/c
Shear wall #2	72	1.4	2@ 48 inches c/c 1@ 28 inches from right
Shear wall #3	56	1.9	2@ 32 inches c/c
Shear wall #4	56	1.9	2@ 32 inches c/c 1@ 28 inches from right

2.0—CONCRETE MASONRY UNITS

All of the concrete masonry units used in the research program were hollow 8 ? 8 ? 16-inch Flexlock concrete masonry units (Figure 1). All of these units were manufactured simultaneously to reduce any possible variations due to batching, mixing, or molding of the Flexlock units. The units were delivered to the laboratory in ready-to-build condition.

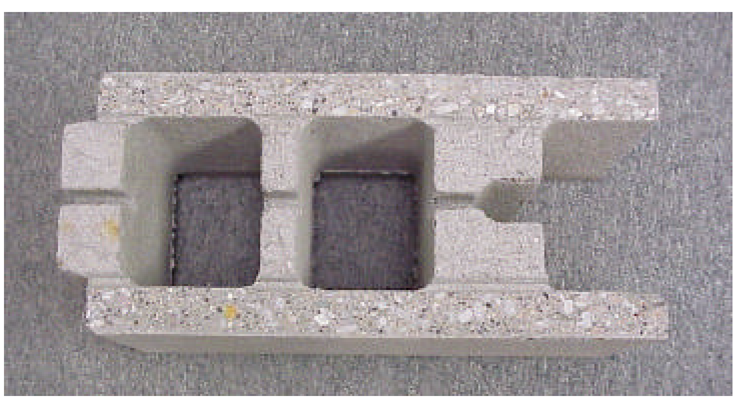


Figure 1—Flexlock CMU

Flexlock concrete masonry units have webs that extend above the face shell when the block is orientated in the as-laid position. The webs were saw cut to the elevation of the faceshells in order to conduct a full-unit compression test. The webs, with the units in the as-laid position, are recessed from the bottom faceshells. The face shells were left intact, and Figure 2 shows the unit, as tested. Therefore, net area for the determination of compressive strength used the thickness of the face shells and not any web area. Each unit was gypsum-capped prior to testing in compression.

Six full units, modified as described above, were tested in accordance with ASTM C 140, *Standard Methods of Sampling and Testing Concrete Masonry Units* and the results are shown in Table 2. Average, standard deviation, and coefficient of variation were calculated and are also shown in the table. For these tests, the coefficient of variation was calculated to equal 8.7 percent and the range of the data was 1014 psi. The data spread appears to be moderately high. Testing procedures were reviewed and showed no deviation from established practices.

Figure 2—Flexlock CMU Showing Compression Testing Orientation

Table 2—Full Unit Compression Strengths

Specimen Number	Load (lb)	Unit Strength (psi) [(1)]	Specimen Number	Load (lb)	Unit Strength (psi) [(1)]
1	216320	5185	4	182700	4379
2	210220	5038	5	193620	4641
3	182280	4369	6	174020	4171
Average (psi)		4630			
Standard Deviation (psi)		404			
COV (%)		8.7			

Note 1—net area = 41.72 in^2

3.0—WALL PANEL CONSTRUCTION AND TESTING PROCEDURES

This section describes the construction of the wall assemblies and the in-plane shear test procedures.

3.1—Wall Panel Construction

All panels were constructed using good construction techniques in accordance with ACI 530.1/ASCE 6/TMS 602 *Specification for Masonry Structures*. All panels were constructed by a journeyman mason with a minimum of 15 years experience in concrete masonry construction.

Four wall panels were constructed, two 56 inches and two 72 inches wide, with a finished panel height of 104 inches. The panels were constructed by dry stacking CMU using a running bond pattern on 10-inch bottom channel sections. Once the specified height was attained, a top 10-inch channel section was placed onto the top units to finish the wall assembly.

Two or three ¾ inch diameter steel rod tendons were placed in the wall assembly at the specified tendons spacing. The top and bottom channels had a hole to receive the tendons and the channels were used as a bearing surface for the tendon washers. Direct tension with a hydraulic jack was applied to each tendon to achieve 11 kips of tensile force. As tension force was applied, the tendon nut was tightened until the specified tensile force was reached. Figure 3 shows a wall specimen with the hydraulic jack in place to load a tendon.

Figure 3—Wall Specimen with Hydraulic Jack

During the tensioning of the 56-inch wide wall specimens, cracking occurred within the CMUs. The cracks were observed to be small hairline cracks and an example of one of the cracks is shown in Figure 4. Figure 5 shows the location of the cracking in the 56-inch wide wall specimens. Cracking was not observed during the tensioning of the 72-inch wide wall specimens. A few CMU specimens were observed to have high spots, but a detailed measurement of each block height was not conducted. The 56-inch wide wall specimens were tested in this condition.

Figure 4—Hairline Crack in CMU

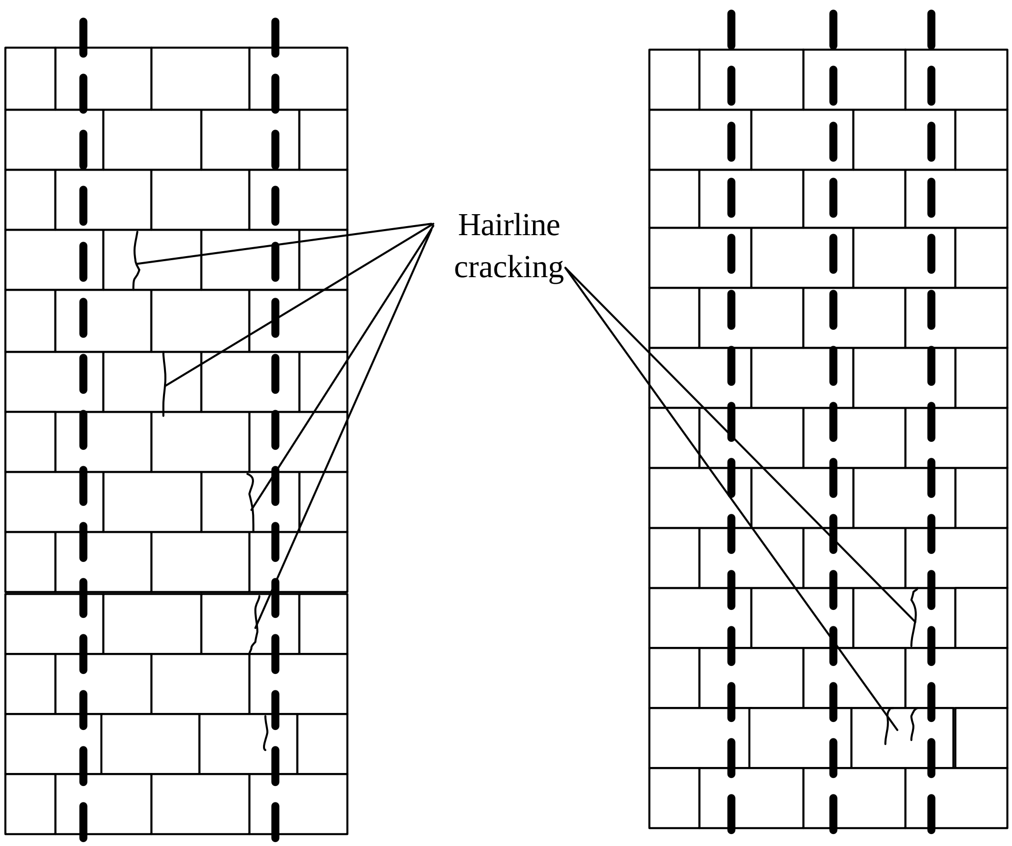


Figure 5—Locations of Hairline Crack in 56-inch Wide Wall Specimens

3.2—Test Procedures

The in-plane shear test involved the application of horizontal load to the top of the panel in its own plane while the base was held rigid. The test frame, shown in Figure 6, consisted of three W12 ? 96 steel sections: one horizontal floor beam, one vertical column, and one diagonal brace. The Research and Development Laboratory is equipped with a strong floor that has connection plates spaced at 8 feet on center. Consequently, the horizontal floor beam and the diagonal support were attached to connection plates. The vertical load column was connected to the horizontal floor beam.

Lateral load was applied to the wall specimen by means of a hydraulic ram of 100-kip capacity. The magnitude of the applied load was measured with a 100 kip load cell that was placed between the hydraulic ram and the wall test panel. Linear displacement meters were placed in two locations to measure the displacement and drift of the wall specimens. Figure 7 shows the placement of the linear displacement meters, called dashpots, to measure the displacement (dashpot #1) and drift (dashpot #2).

Both lateral load and dashpot measurements were made using the computer data acquisition. Lateral load was applied by loading and unloading in 1000 lbs increments and at each 1000 lbs increment the load was held to observe a cracking in the wall panels. The wall panels were loaded to failure in this manner. The testing was also photographed and video recorded.

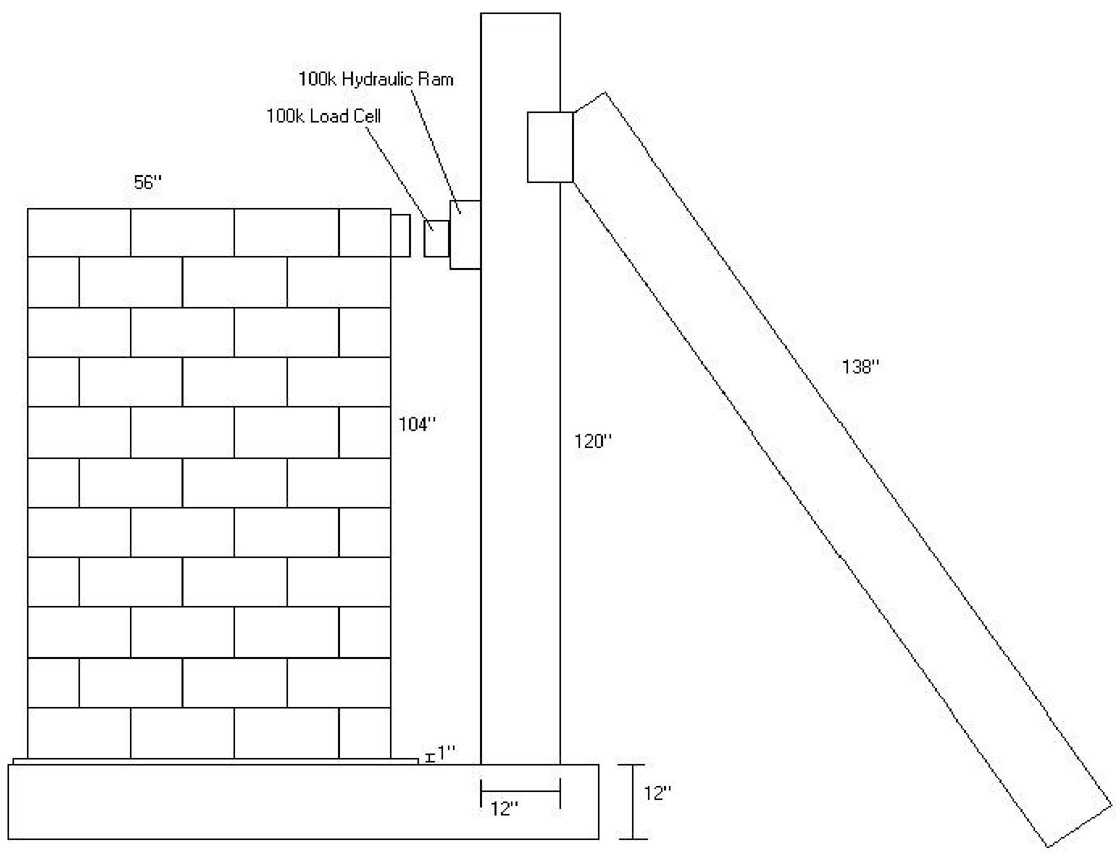


Figure 6—In-plane Shear Testing Frame

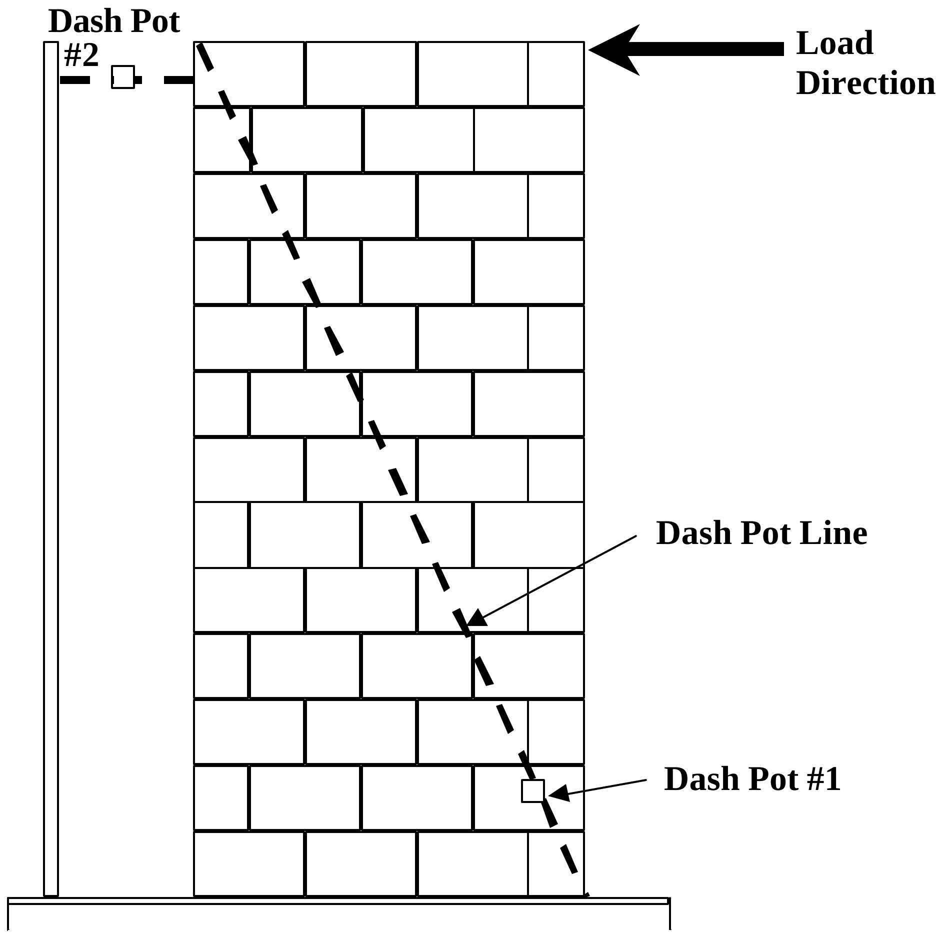


Figure 7—Location of Displacement Measurements

4.0—RESULTS OF IN-PLANE SHEAR TESTS

Four Flexlock walls were tested by applying a lateral load as described above. All of the shear wall panels were 8 feet 8 inches high. These walls were tested by loading in 1000 lbs increments and observations were made with regard to crack pattern, drift and displacement measurement. The results of the tests are summarized in Table 5.

Table 5—Test Results of In-plane Walls

Panel Designation	Wall Length (in)	Maximum Lateral Load (lbs)	Displacement Dashpot #1 (in)	Drift, ? ? Dashpot #2 (in)	Drift Ratio ? ?h (%)
Shear wall #1	72	8025	0.24	0.97	0.9
Shear wall #2	72	10884	0.27	0.90	0.9
Shear wall #3	56	7025	0.08	0.99	1.0
Shear wall #4	56	10000	0.14	1.17	1.1

As the walls were subject to lateral force, cracking in the CMU and slippage along the joints were observed. In Figures 8 and 9, the cracking and slippage locations in the wall specimens are sketched. CMU slippage was more prevalent in the wider wall assemblies – 72 inch wide – than the 56-inch wide panels. Toe crush was observed only in the 72-inch wide specimens having three tendons. Photographs of the wall specimens at failure are found in Appendix A.

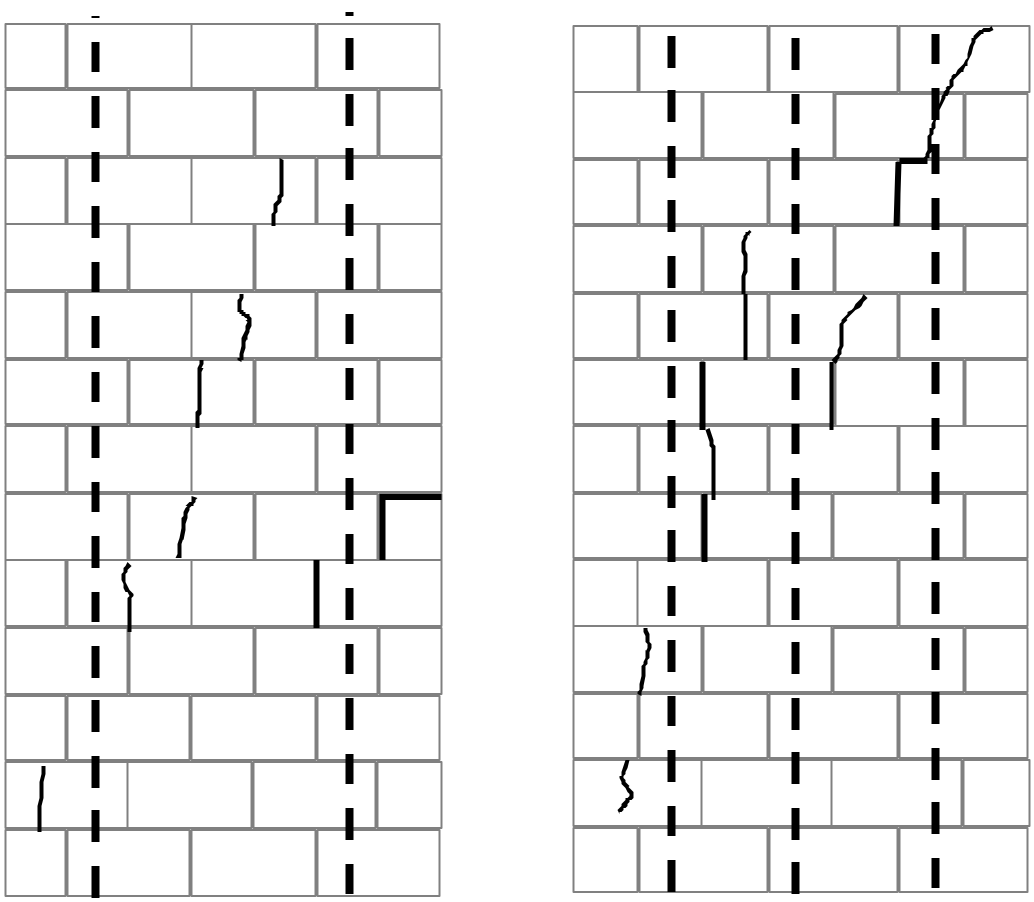


Figure 8—Cracking and Slippage Locations for 56 inch Wide Wall Assemblies

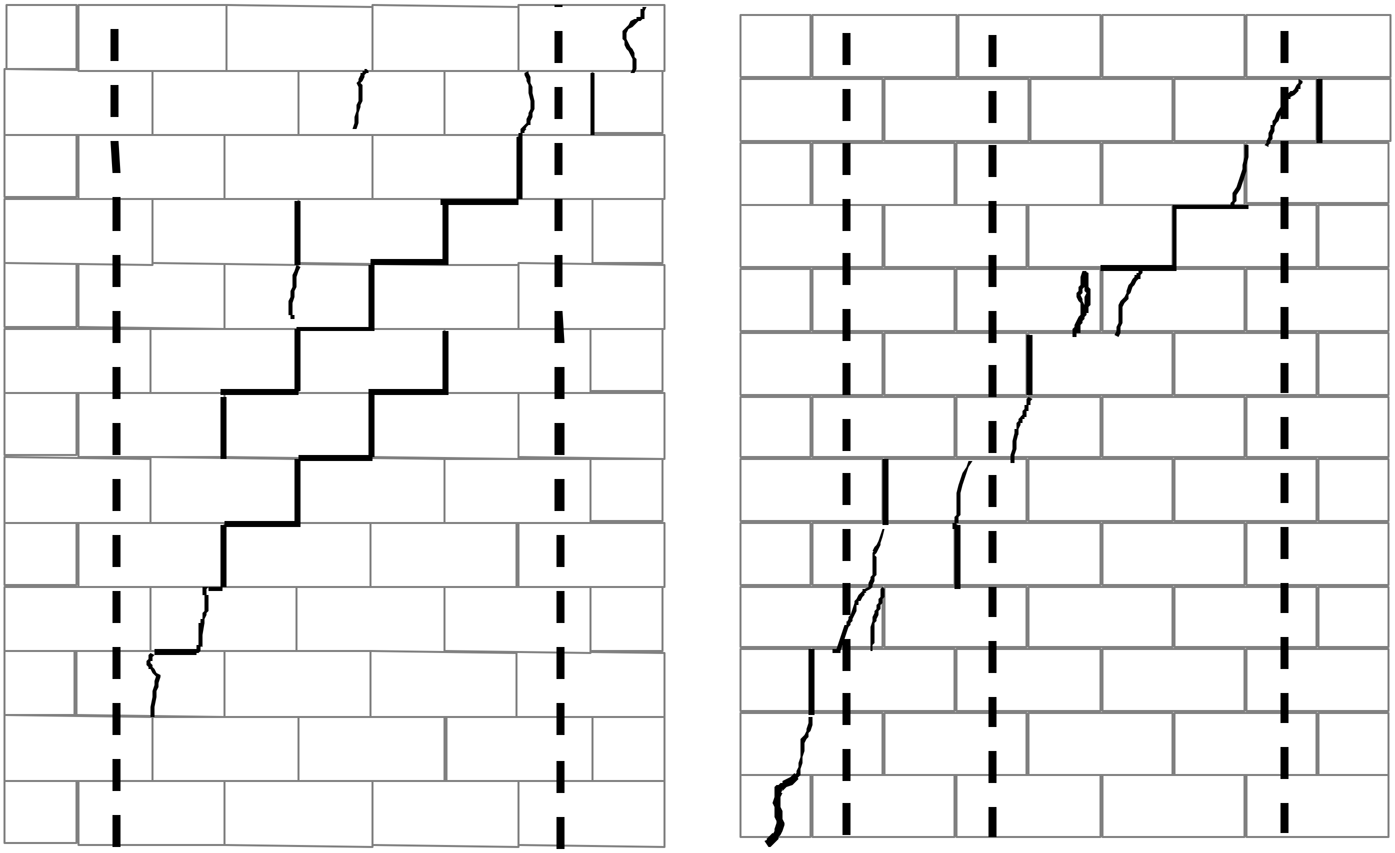


Figure 9—Cracking and Slippage Locations for 72 inch Wide Wall Assemblies

Figures 10, 11, 12, and 13 present the data showing the shear load as a function of the wall specimens drift. The wall was loaded in 1000 lbs increments and each increment is shown as an individual curve in each graph. Additionally, an envelope was plotted showing the maximum drift and lateral load for each load cycle.

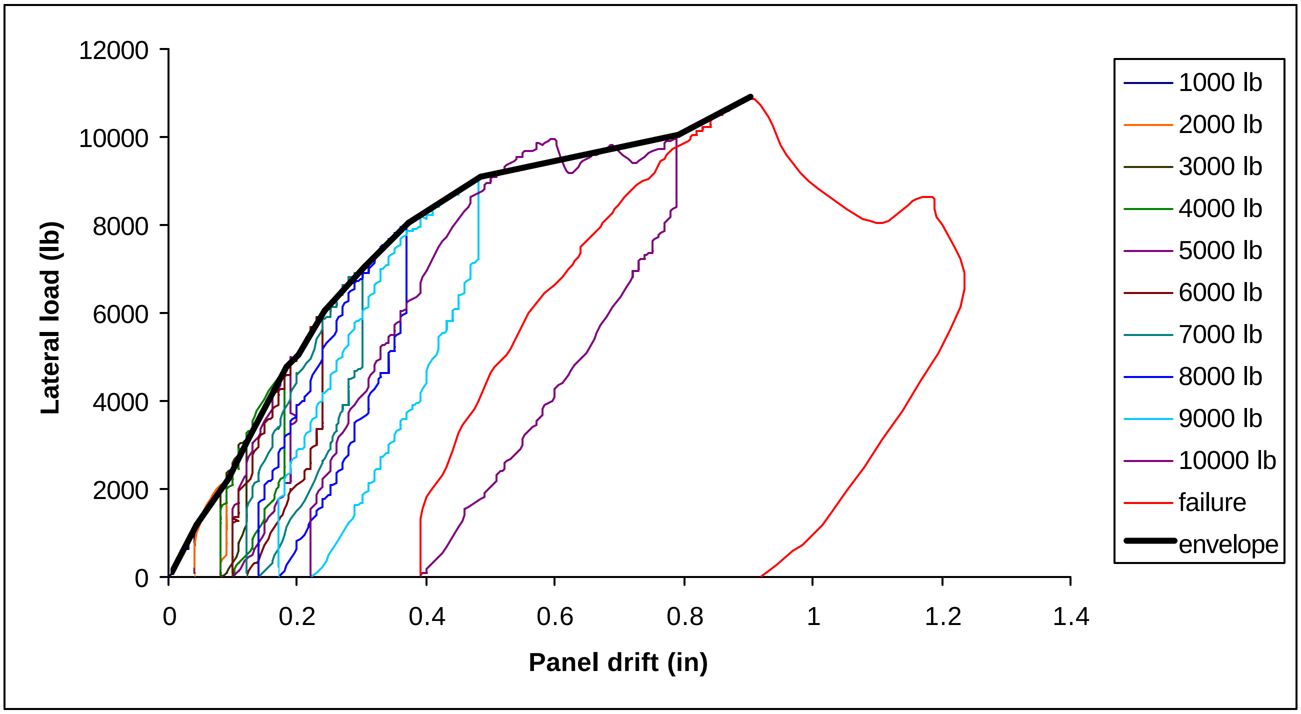


Figure 10—Wall Specimen 72-inch Wide, 3 Tendons

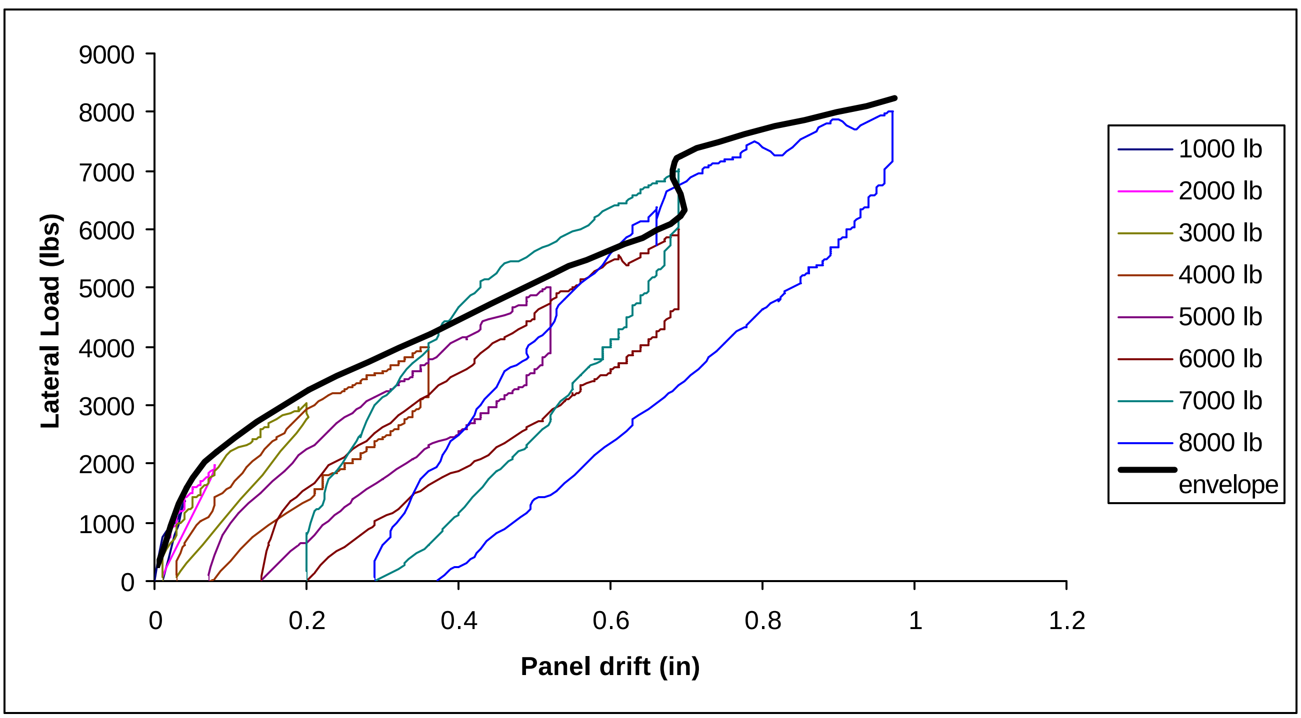


Figure 11—Wall Specimen 72-inch Wide, 2 Tendons

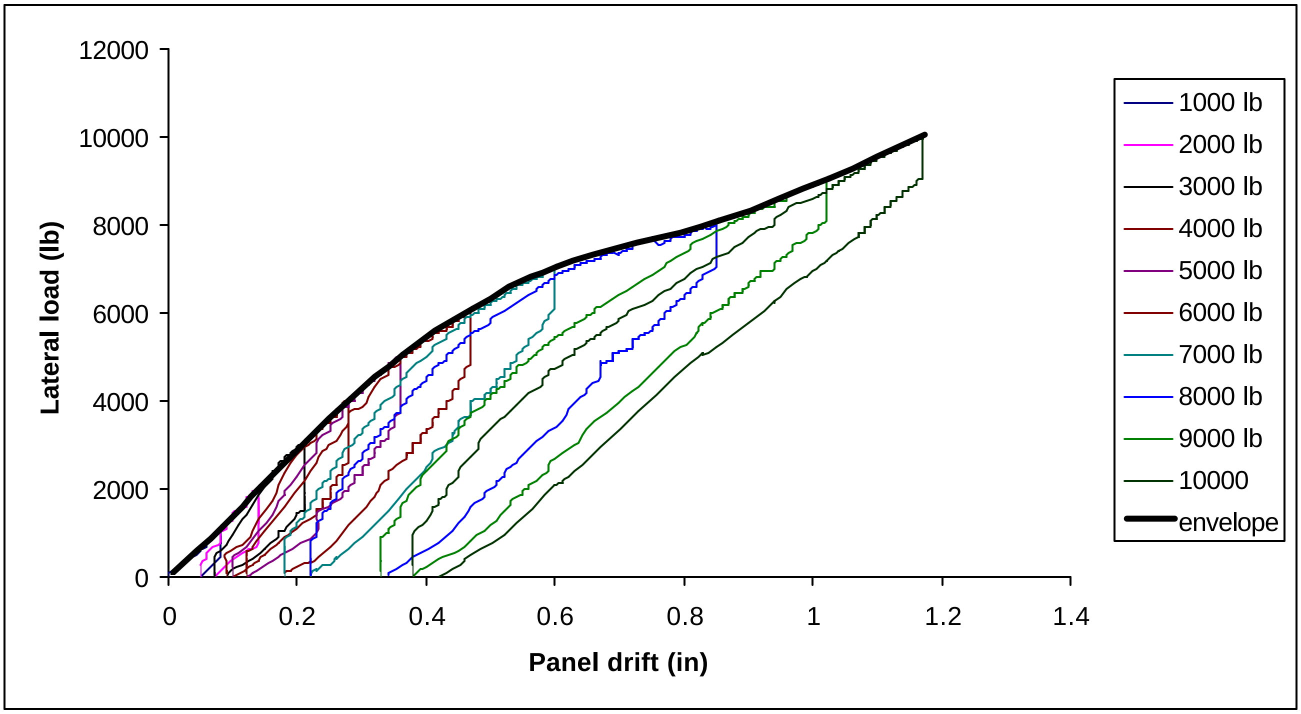


Figure 12—Wall Specimen 56-inch Wide, 3 Tendons

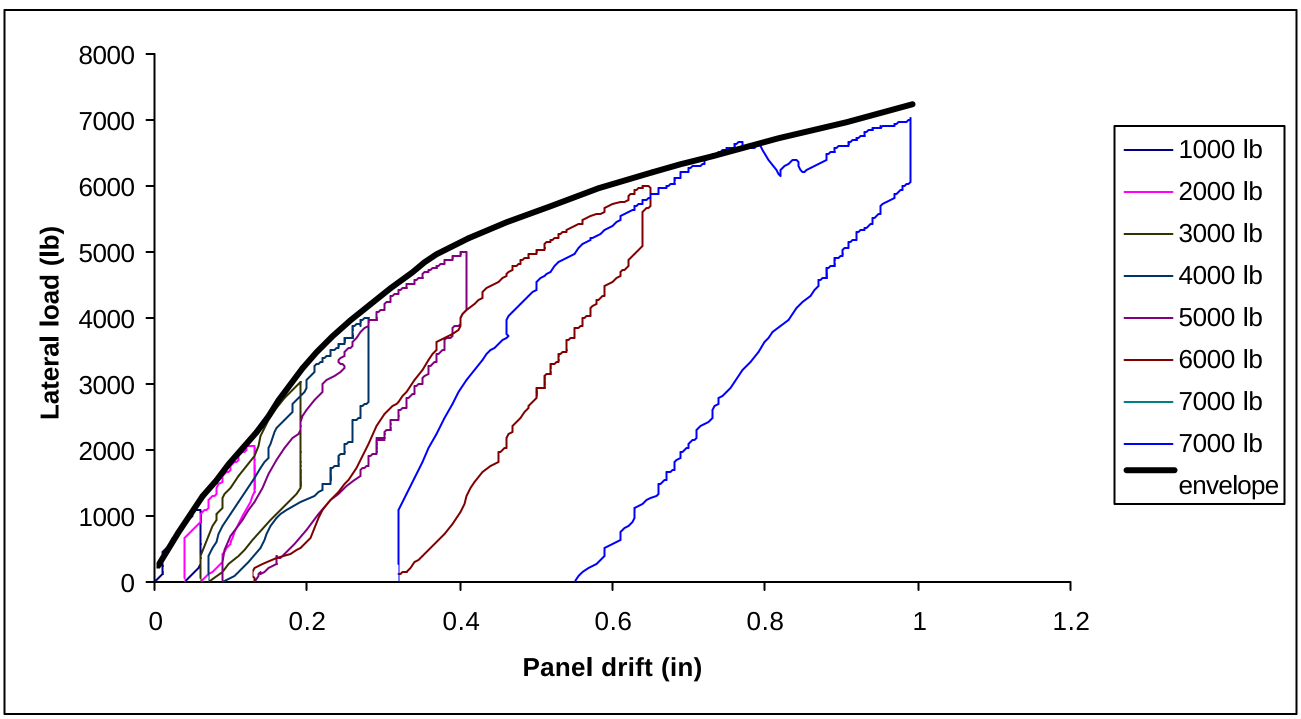
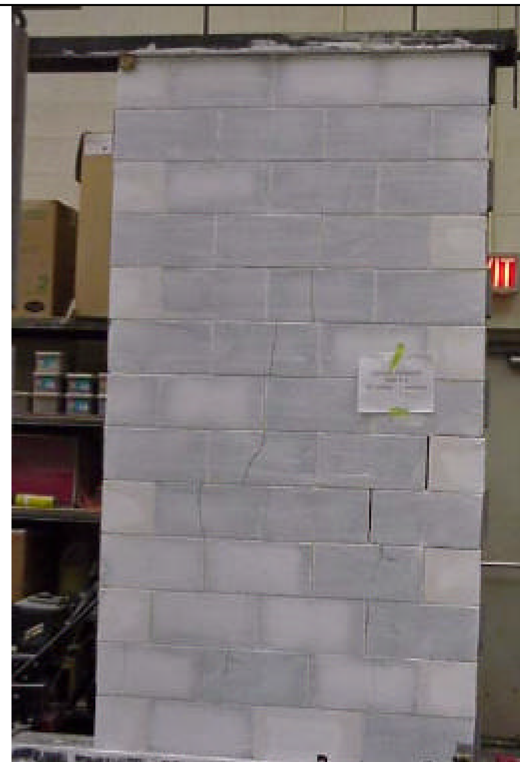


Figure 13—Wall Specimen 56-inch Wide, 2 Tendons

5.0—CONCLUSION

Four wall specimens constructed with FlexLock CMU were tested to failure under lateral loading. Lateral load, wall panel drift, and wall displacement were measured. Additionally, observations were made using photographs of the cracking or CMU slippage that occurred, as the wall specimens were loaded. The shearing capacity for the wall specimens under consideration was characterized by either sliding along bed joints or cracking of the Flexlock CMU.

Appendix A—Wall Specimens Photographs

	72 inch wide	56 inch wide
2 tendons		
3 tendons