TEST REPORT:

REDI-ROCK BARRIER TESTING:
PHASE TWO Hollow Core Freestanding Unit (F-HC) Beam Test Results

Tested By:
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1.0 Introduction

This report documents the performance and bending capacity of a barrier wall stem constructed from standard hollow core Redi-Rock system blocks. Test wall samples consisted of two courses of Redi-Rock Hollow Core Freestanding blocks (F-HC), as shown in **Figure 1**. Walls were dry-stacked, steel reinforcing bars were placed, and then the cores were filled with concrete to create a solid barrier wall stem section. In this study two identical wall samples were constructed and tested.

Construction and testing was performed by Aster Brands at its testing facility located in Charlevoix, Michigan throughout the months of February, March, and May 2020. Redi-Rock is an Aster Brands company.

Figure 1 - Sample test wall from

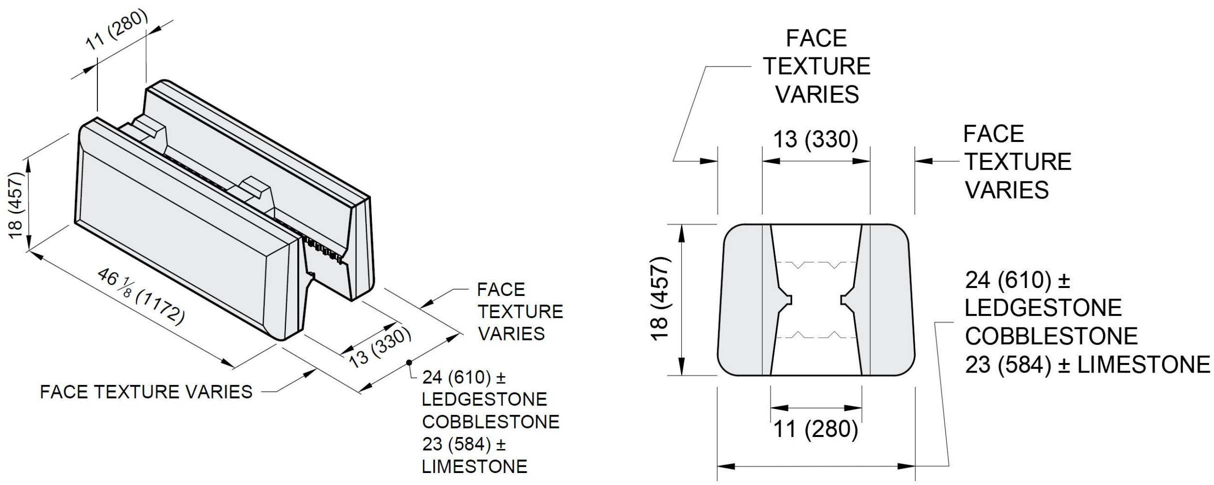
2.0 Purpose

The objective of this test program was to verify the static, in-plane, flexural load capacity, and performance of a “unit beam” section of barrier wall stem. Secondary objectives included exploring possible failure mechanisms and providing data to calibrate mathematical models.

3.0 Materials

Typical barrier wall cross sections consist of a wall base moment slab connected to a wall stem. This test project focused on the bending capacity of the stem of the barrier wall constructed from two courses of Redi-Rock Hollow Core Freestanding Blocks (F-HC).

Redi-Rock F-HC blocks **(Figure 2)** are wet-cast concrete, precast modular block (PMB) units with a nominal width of 24 inches (610 mm), length of 46⅛ inches (1172 mm), and height of 18 inches (457 mm). These blocks are cast in a standard freestanding block form with inserts to create cores through the block. Test blocks were cast with a low-profile, smooth-face face texture. No attempt has been made to account for any contribution from the extra concrete in a standard Redi-Rock face texture. Block weight (with Ledgestone texture) is about 770 lb (350 kg). Average test block weight was 440 lb (200 kg). Precast blocks do not contain reinforcing steel.



Note: Drawing dimensions are in inches (mm)

Figure 2 - F-HC Block and Cross Sectional Depiction

Concrete blocks used in this series of testing were produced by Aster Brands at its testing facility located in Charlevoix, Michigan. Blocks were cast from redi-mix concrete with a target compressive strength of 4,000 psi (27.6 MPa). The blocks were cast and cured inside a heated facility for a minimum 14 days before construction of the walls began. All blocks were cured a minimum 28 days before the wall samples were tested. Compressive strength of the concrete used to produce the test blocks taken at the actual test date ranged from 3,600 psi (24.8 MPa) to 4,500 psi (31.0 MPa), as determined by ASTM C39 on 4-inch by 8-inch (102 mm by 203 mm) field-cured concrete cylinder specimens. Block strengths for each test wall are shown in **Figure 3**.

Concrete infill used to fill the cores of the wall samples was a pumpable concrete mix with a target compressive strength of 4,000 psi (27.6 MPa). Wall cores were filled on 2/26/2020 and allowed to cure a minimum of 28 days before barrier wall testing began. The concrete infill compressive strength at the actual test dates was 5,576 psi (38.4 MPa), as determined by ASTM C39 on 4-inch by 8-inch (102 mm by 203 mm) field-cured concrete cylinder specimens. Concrete infill strengths for each test wall are shown in **Figure 3**.

Reinforcing steel used in the construction of the test walls was specified as ASTM A615 - Grade 60, uncoated bars. Structural reinforcement was specified as #6 (19.1 mm) bar. Stirrups were fabricated from #4 (12.7 mm) bar. Reinforcement was cut and bent per specified drawings by Striker Concrete Supply located in Traverse City, Michigan. None of the rebar was field cut or bent.

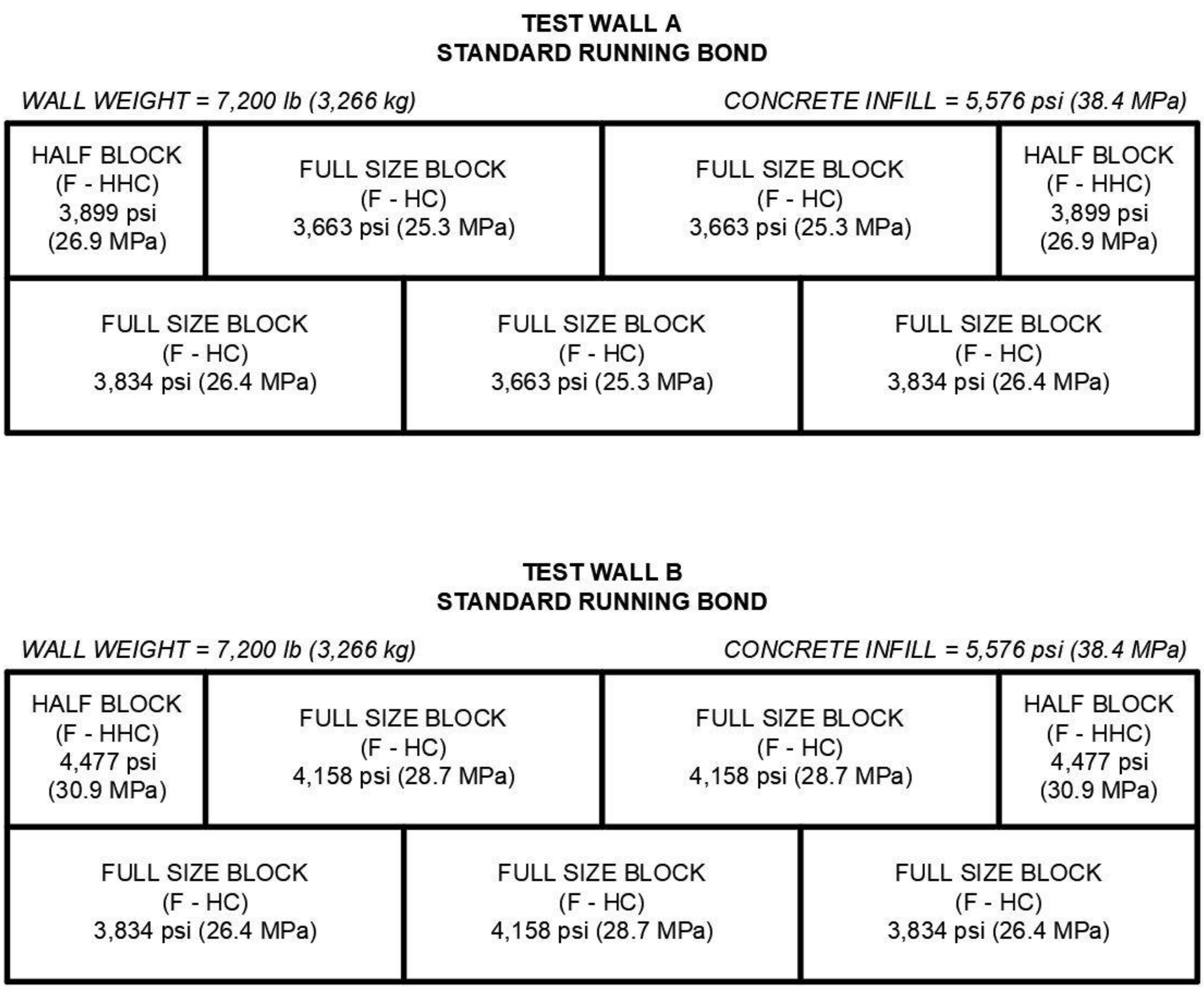


Figure 3 - Concrete Compressive Strengths (looking from the front of the wall sample)

4.0 Barrier Wall Design

A total of two test walls were constructed for this portion of the test, both with identical arrangement and reinforcement configurations. See **Figures 4 through 6** for block patterns, reinforcement layouts and actual dimensions of wall samples constructed.

Test Walls A and B had a standard running bond with a joint centered in the middle of the test specimen. Test samples were reinforced both horizontally and vertically with with #6 (19.1mm) reinforcement. Two bars were placed horizontally in each of the two courses through the horizontal cores of the F-HC blocks. There were also twenty four #6 vertical bars spaced in twelve pairs equally spaced along the length of the wall. This reinforcement helps to spread load laterally throughout the beam section. Twelve #4 (12.7 mm) U-shaped stirrups finish the top of the wall and are placed 1-inch (25 mm) clear from the top.

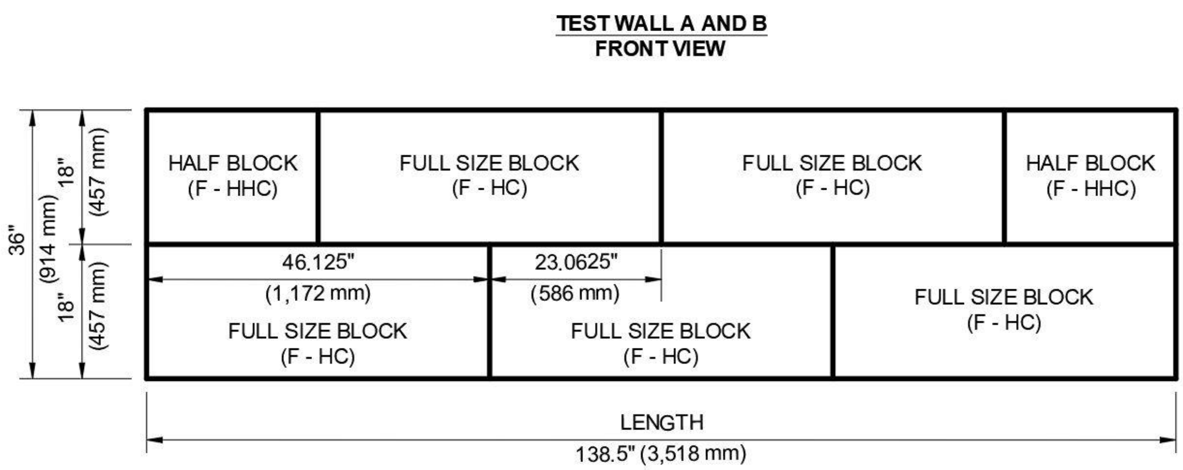


Figure 4 - Test Block Layout

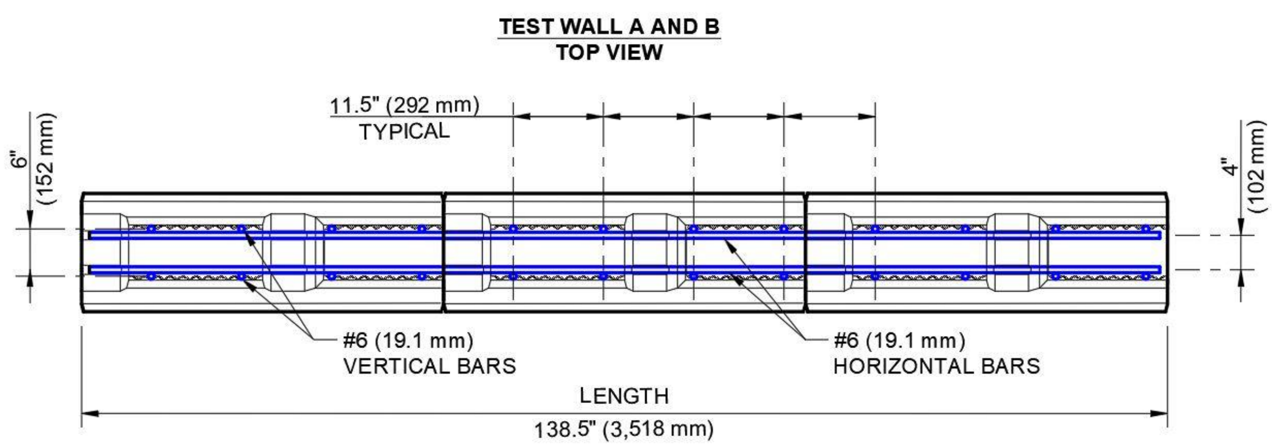


Figure 5 - Reinforcement Layout

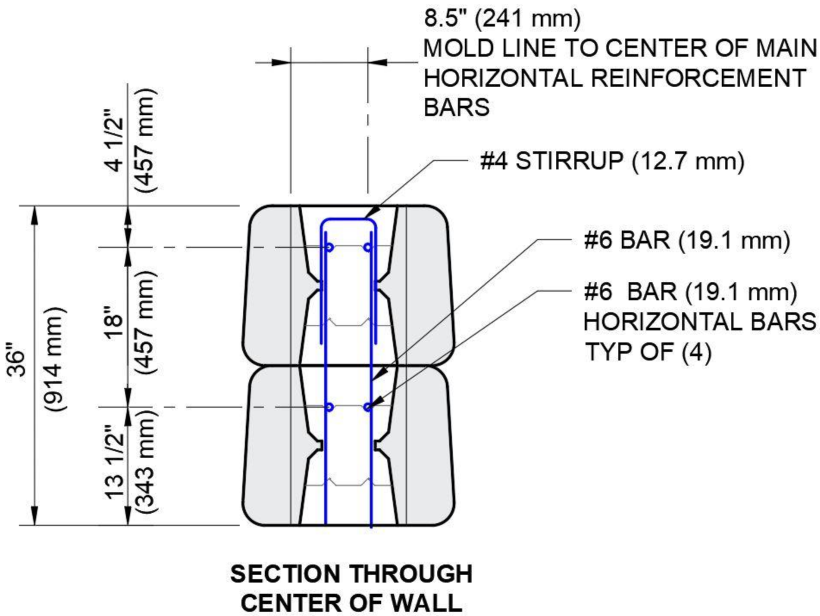


Figure 6 - Wall Cross Section

4.0 Barrier Wall Construction

Barrier wall sections were constructed directly adjacent to the testing frame in the Aster Brands testing facility. Size of the wall specimens was such that they could be moved into and out of the testing frame by an overhead crane. Walls were constructed by placing the first course of F-HC hollow core freestanding blocks on a leveled plywood platform topped with a ⅛-inch (3 mm) plastic sheet. The second course of F-HC blocks was then stacked on top of the first to form the barrier section. After the walls were dry stacked, rebar was placed in the cores and tied in place with standard, uncoated wire ties. The outside edges of the walls were then formed and braced with plywood formwork. Joints were lightly tuck pointed on the outside with non-shrink grout to seal all joints before filling the cores with infill concrete.

Once both of the wall test specimens were constructed, they were infilled from a single pour of concrete. Concrete infill was placed by pump and the walls were vibrated while filling to ensure all of the voids were filled. Lifting anchors were cast into the tops of the walls to facilitate moving test wall sections into and out of the testing frame. Forms were stripped the next day and wall samples were left undisturbed for a minimum of (28) days before moving or testing. See **Figure 7** for photos taken during construction.

Figure 7 - Construction Photos of Barrier Walls

4.0 Testing Methodology
The intent of the test procedure was to verify the failure modes and flexural capacity of the barrier wall stem along the length of the wall. Two different loading scenarios were tried. Test Wall A was loaded at the center of the wall span with the load applied uniformly over the width of the beam section. Test Wall B was loaded at the center of the wall span with a concentrated point load applied over an 8-inch by 8-inch (203 mm by 203 mm) area.

Wall samples were loaded into the test frame standing vertically in their normal orientation as installed in the field. Walls were supported from below on graphited plates to minimize friction along the bottom of the wall. Walls were supported vertically on the ends with fixed pipe mounts allowing rotation of the beam section during loading. A load was then applied horizontally to the wall stem to force a flexural failure of the wall. The test set-up is illustrated in **Figure 8** and shown in **Figure 9**.

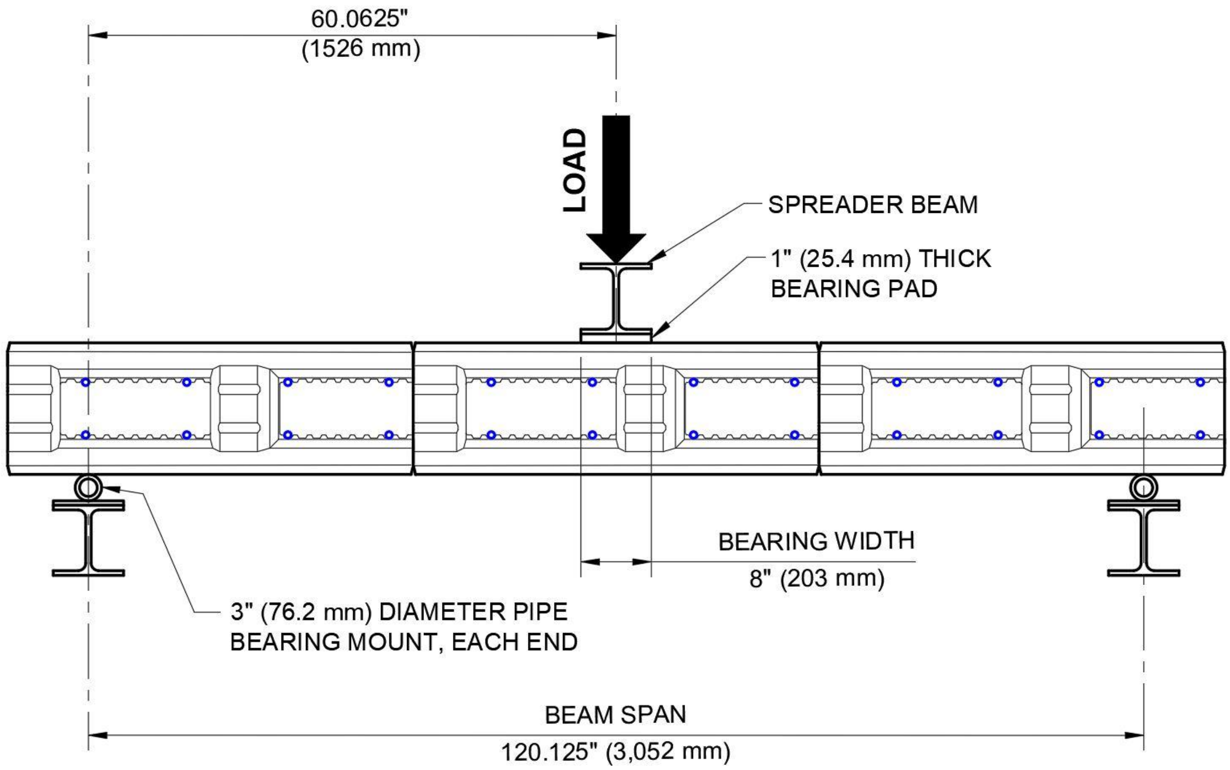


Figure 8 - Test Set-up (looking down from above)

Figure 9 - Test Set-up (looking from the front

Load was applied to the test sample using the horizontal hydraulic actuator mounted in Aster Brands' structural test frame. Two 100 kip (445 kN) capacity load cells were installed in series at the end of the hydraulic actuator. A hardened, spherical load button was attached to the load cells and pushed against a set of hardened, graphited plates which allowed for rotation and lateral movement at the point of application of the load. Load was spread to the bearing area on the wall sample with a 8-inch (203 mm) wide steel beam backed by a 1-inch (25 mm) thick polyurethane bearing pad. Load was applied at mid-span, centered vertically on the wall. Horizontal displacements of the wall were measured at the point of load application with an LDT displacement gauge mounted inside the hydraulic cylinder.

A preload of approximately 1,000 lbs (4.4 kN) was applied to each wall sample to seat the wall in the test frame before recording displacements. The preload was held for approximately one minute before loading of the wall commenced. Displacement measurements were zeroed at the end of the preload period. Walls were then pushed until failure with a slowly increasing, pseudo-static, load-controlled rate of approximately 2,000 lb per minute (20.5 kN per minute), which correlates to an approximate 0.25-inch per minute (2.5 mm per minute) displacement rate of the actuator. This load rate was maintained until the wall failed and load dropped off significantly (approximately at 4.75-inch (12.7 mm) of actuator displacement). After significant load drop, the test was switched to a displacement-control rate of approximately 0.75-inch (10 mm) per minute until the end of the test. Walls were then pushed to a final actuator displacement of approximately 9-inch (229 mm).

Test data was recorded at 1-second intervals with a National Instruments brand data acquisition system and Labview DAQ software. Both load cells, horizontal hydraulic cylinder displacement, pump speed, horizontal cylinder velocity, and time were recorded. In addition to this data, video was taken from multiple angles to evaluate failure modes of the wall assembly.

5.0 Results

Results from this test program can be seen in **Table 1** and the graph shown in **Figure 13**. Load and deflection data (at the point of application of the load) was tabulated for two distinct points: yield and peak. Yield denotes a dip in the graph and corresponds to initial cracking in the wall section. Peak corresponds to the point of maximum load that the wall was able to sustain. The yield and peak points are annotated in **Figure 13**. Both of the walls failed by cracking in the tension face of the beam and failure of at least one of the main horizontal reinforcement bars. Flexural cracking patterns can be seen **Figures 10 - 12**.

Figure 10 - Typical Failure Mode (taken from Test Wall A)

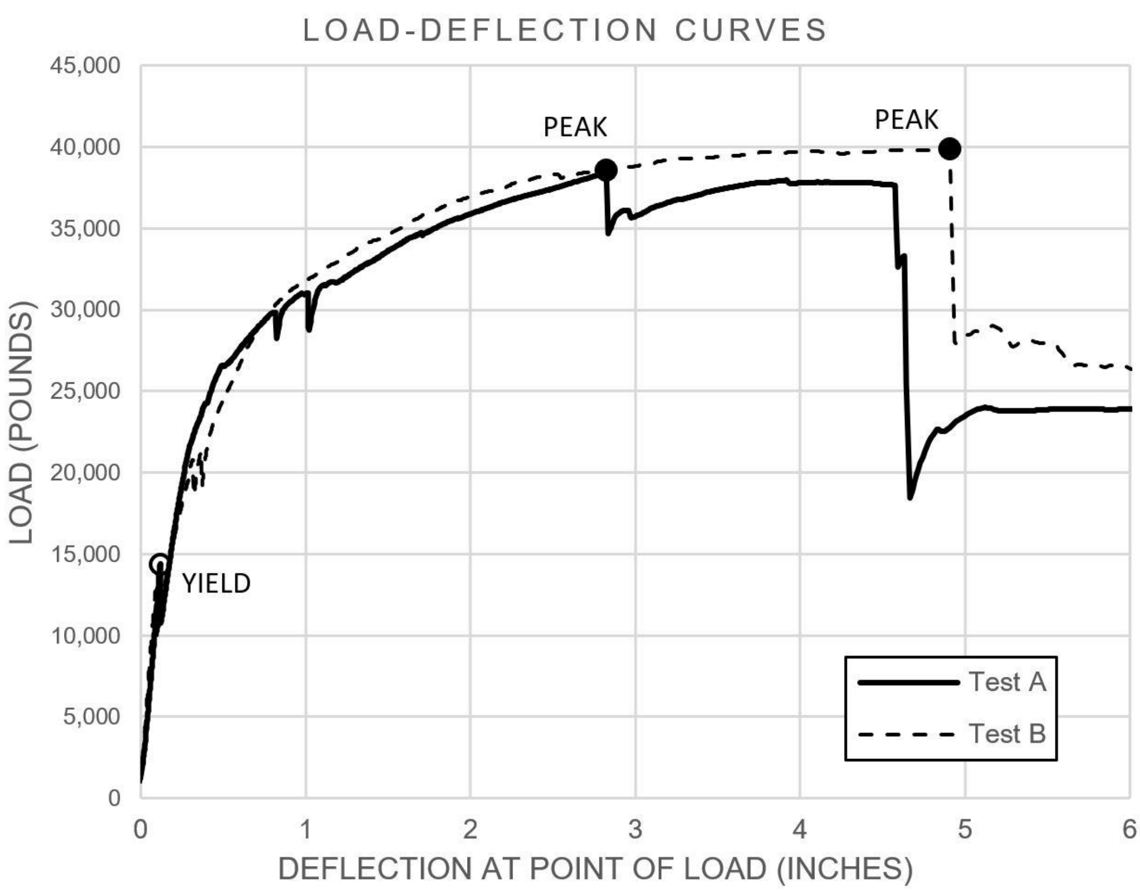
Figure 11 - Typical Failure Mode (taken from Test Wall B)

Figure 12 - Typical Failure Mode (taken from Test Wall B)

Table 1 - Results

Test Wall	Yield Load lb (kN)	Deflection at Yield inch (mm)	Peak Load lb (kN)	Deflection at Peak inch (mm)	Notes
A	14,402 (64.1)	0.12 (3.0)	38,402 (170.8)	2.82 (72)	Tensile cracks on outside face of wall
B	12,772 (56.8)	0.09 (2.3)	39,863 (177.3)	4.86 (123)	Tensile cracks on outside face of wall

Figure 13 - Test Results



6.0 Closure

This data and conclusions should be used with care. The user should verify that project conditions are equivalent to laboratory conditions and account for variations.

This test data is accurate to the best of our knowledge. It is the responsibility of the user to determine suitability for the intended use.

ASTER BRANDS

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