WJE

LOK-N-BLOK

Test Report
Load Test of Home Show Booth Mockup

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TEST REPORT

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INTRODUCTION

At your request, Wiss, Janney, Elstner, Associates (WJE) has constructed and performed load testing of a mockup of the Lok-N-Blok home show booth (booth). The objective of the load testing was to evaluate the strength and stability of the booth in accordance with the evaluation procedures in Section 1708 of the 2015 *International Building Code* (2015 IBC). This report summarizes the results of the load testing, which was completed in January 2018.

DESCRIPTION

The booth was designed as a two-story structure, with design plan dimensions of 19 feet 6 inches by 12 feet 6 inches and an overall height of approximately 14 feet. The second level is designed to be open above, with a floor elevation of approximately 10 feet and a 4 foot high parapet wall around the perimeter. An opening in the second level floor structure will permit access via a staircase. Preliminary construction plans are provided in Appendix A, and photos of the booth constructed for the load test are shown in Figures 1 through 11. Due to limited availability of Lok-N-Bloks at the time of the load test, the second level parapet wall was not constructed to its design height. The overall height of the booth constructed for the load test was approximately 11 feet.

The four walls of the booth were constructed with Lok-N-Bloks, with two doorway openings in one of the long walls and one doorway opening in a short wall. Lok-N-Blok walls are designed to be reinforced with vertical steel rods placed within the block wall cavities and anchored to the base and top of the walls. The vertical rods provide overturning resistance, flexural resistance, and add stiffness to the walls. In typical construction, the steel rods would likely be anchored in concrete foundations; however, because the booth will typically be constructed on a finished concrete floor, the rods were anchored to tapped steel base plates placed under the bottom course of wall blocks. At the top of the walls, the Lok-N-Blok posts were cut off the top course of blocks to create a flat surface, and 2x6 wood top plates were installed around the wall perimeter. The steel rods were installed through the top plates and fastened with nuts and plate washers that bear on the top surface of the wood plates.

The second-floor structure was constructed with engineered lumber I-joists that span between the two shorter walls of the booth. The I-joists were supported on the walls with Simpson Strong-Tie light gage metal joist hangers. Two methods were used to attach the joist hangers to the block walls: at one end, the hangers were screwed directly into the blocks (Type 1, Figure 5), and, at the other end, a 2x12 wood rim joist was screwed into the block wall, and the joist hangers were screwed into the rim joist (Type 2, Figure 7). The joists were covered with plywood decking, which was attached with wood screws to the supporting framing. Wood 2x12 rim joists were also installed along the long walls, to provide edge support for the plywood decking and lateral connectivity between the plywood decking and block walls. At the short wall where the joist hangers were attached directly to the blocks, wood blocking was attached to the block walls between the joists to provide a lateral connection between the decking and walls. As described above, three doorway openings were constructed in the booth walls. Solid steel rods were installed through the blocks over the openings to reinforce them as headers, one rod above each opening in the long walls and two rods above the opening in the short wall. The number and size of the steel rods were determined based on the orientation of the second floor framing, width of the door openings, and estimated demands during the load test.

LOAD TEST

The load test was performed in accordance with the 2015 IBC, Section 1708 In-Situ Load Tests, which prescribes the test procedures and acceptance criteria. The testing was performed from January 16 to January 18, 2018.

Loads

The test load was determined in accordance with the 2015 IBC Section 1708.3.2, which indicates that "at a minimum the test load shall be equal to the specified factored design loads." The primary applicable load on the second floor framing is gravity live load; for assembly areas or occupiable roofs, both of which appear to be reasonable occupancy classifications for the booth, IBC prescribes a uniform design live load of 100 pounds per square foot (psf). Considering the applicable load factor of 1.6 for live load, the required test live load was 160 pounds per square foot.

Test Loads and Procedure

Before the test load was applied to the second floor structure, the steel tie-down rods were each initially pre-tensioned to approximately 10,000 pounds using a hydraulic ram in combination with a standard wrench. The test load was applied using twelve caged plastic water tanks, each with a 275-gallon capacity. Wood 4x4 members were placed on the plywood floor decking, perpendicular to the floor joists and underneath the water tank rails, to distribute the test load to the joists as uniformly as possible. The twelve tanks each weighed approximately 125 pounds, corresponding to about 8 pounds per square foot applied over the second floor area. The tanks were filled with water over a period of about 1-1/2 hours to a height of 2 feet, 10-1/2 inches (Figure 15 through Figure 17). The water height corresponded to a load of 152 pounds per square foot applied over the second floor area, for a total applied load of 160 pounds per square foot. IBC 1708.3.2 prescribes that the test load shall be left in place at least 24 hours. The final test load remained on the structure for 45 hours, following which the water was drained over a period of about 3-1/2 hours. The structural response was monitored during the filling of the tanks, during the 45-hour holding period, and for 24 hours after unloading to evaluate any permanent deformation of the structure.

Monitoring and Inspection

The tensile forces in two of the twenty steel tie-down rods, one on a short wall supporting the floor joists and one on a long wall (Figure 12), were monitored continuously using 20,000-pound load cells. Vertical displacements of the walls and joists were also monitored continuously using fifteen electronic displacement transducers (stringpots) attached at various locations throughout the booth. Wires attached to the walls and joists were extended downward and attached to the displacement transducers on the floor below. Figure 13 shows a wire attached to an angle mounted to a wall and a wire attached to an eye-hook screwed into the bottom flange of a joist near a joist hanger. Figure 14 shows two displacement transducers installed on the floor below. A plan view of the booth with instrumentation locations is shown in Appendix B. Inspections for signs of distress in the walls and floor structure were made during the load test, and at the end of the 45-hour holding period.

TEST RESULTS AND DISCUSSION

Acceptance Criteria

The 2015 IBC specifies the following three primary acceptance criteria for an in-situ structural load test.

1. Under the design load, the deflection shall not exceed the specified limitations.
2. Within 24 hours after removal of the test load, the structure shall have recovered not less than 75% of the maximum deflection.
3. During and immediately after the test, the structure shall not show evidence of failure.

Measured Deflections

A comparison of the measured deflections for floor joists and door opening headers and the IBC acceptance criteria is summarized in the table below. The maximum measured deflections as well as the measured residual deflections are shown.

Measured Deflections vs IBC Acceptance Criteria

Tested Structural Member	Deflection			IBC Criteria		
	Loading (in)	Unloading (in)	Rebound (%)	Span (ft)	IBC Deflection Limit (in)	Passed Load Test per IBC Criteria?
Bearing Wall	0.08	0.06	77%	N/A	N/A	YES
Structural Header	0.16	0.13	77%	4.00	0.20	YES
Single Joist Hanger Type 1	0.08	0.06	82%	N/A	N/A	YES
Single Joist Hanger Type 2	0.21	0.17	84%	N/A	N/A	YES
Double Joist Hanger	0.23	0.17	74%	N/A	N/A	YES
Non-Bearing Wall w/ Ledger	0.06	0.04	78%	N/A	N/A	YES
Floor Joist 1	0.65	0.62	94%	18.50	0.93	YES
Floor Joist 2	0.53	0.55	104%	18.50	0.93	YES

Note: IBC deflection limit corresponds to L/240 for mid-span deflection under dead and live loads.

The measured rebound for all tested structural members, except for the double joist hanger, is greater than 75 percent. The rebound for the double joist hanger is 74 percent, slightly less than the IBC-prescribed limit. However, our analysis of the difference between the initial “immediate” deflection and the time-dependent deflection which occurred over the duration of the test suggests that had the load test been stopped at 24 hours, per the IBC load test criteria, the rebound percentage would likely have been greater than 75 percent. Therefore, in our opinion, the test results for the double joist hanger satisfy the IBC criteria. Based on our observations, the majority of the deflection measured for the joist hangers is the result of local bending of the joist hanger bottom plate (Figures 19 and 20). This was more pronounced for the double joist hangers, but was observed for the single joist hangers as well. Although this behavior does impact the evaluation of the booth per the IBC load test criteria, it is not related to the performance of the block walls or the attachment of the joist hangers to the walls.

Observations

The only evidence of block distress observed following the load test was a minor amount of crushing or buckling of the top edge wall of one of the upper corner blocks (Figure 18). No other distress was observed in the block in question. Upon further review, it was determined that the crushing observed had very likely not occurred during the load test. Our client, who supplied the blocks, indicated that individual blocks which had been previously used for compression testing may have been included on the pallets with new blocks. Upon examining the pallets, we found several other blocks which were not used for the load test, or any other test performed by WJE, which exhibited similar crushing at the block edge, indicating they had been used for compression testing previously performed by others. We believe that due to the minor amount of distress, the condition was not identified during the assembly of the booth and the block was used inadvertently.

This scenario appears likely for several other reasons. While the compressive stress in the blocks in this region was likely greater than in a typical wall section due to the placement of two pre-tensioned steel rods near the corner, this loading condition was similar for all corners of the booth and similar distress was not observed at any other location. In addition, in our preliminary block compression tests, the upper section of the block sidewalls did not exhibit similar distress until two to three times the load estimated to have been applied to the booth corner blocks during the load test. Further, the second-floor structure was supported on the inside face of the blocks, and if crushing were to occur the inside block face below the connection of the second-floor structure would seem to be a more likely location. Lastly, the tension in the adjacent rods was not affected. Had crushing occurred during the load test, a decrease in rod tension greater than other rods would have been expected due to the deformation of the block.

LOAD TEST CONCLUSIONS

Each structural element of the booth which was tested during the load test satisfied the performance requirements outlined in Section 1708 of the 2015 IBC. These requirements were satisfied in the booth load test as follows.

1. As shown in the table above, the test load deflections of the header and floor spans measured less than the IBC limit for structural components supporting non-plaster finishes.
2. All the structural components that exhibited significant deflection during the load test rebounded 75 percent or more of their total deflection by 24 hours after unloading (see table above and discussion).
3. Although one of the upper corner blocks exhibited a minor amount of localized distress, in our opinion this did not occur during the load test. A block which had been previously used for compressive testing appears to have been inadvertently used in the booth structure.
4. No distress in or failures of any structural component of the booth were observed during or after the load test.

FIGURES

Figure 1. Completed booth mock-up, from southeast

Figure 2. East wall with two door openings

Figure 3. Elevated floor framing into north over door opening. Stairwell opening on left.

Figure 4. Elevated floor framing into south wall. Stairwell opening on right.

Figure 5. Type 1 joist hanger connected directly to south wall blocks without rim joist. Blocking installed between joists.

Figure 6. Type 1 joist hanger connected directly to south wall blocks without rim joist. Blocking installed between joists.

Figure 7. Type 2 joist hanger connected to rim joist, attached to north wall blocks.

Figure 8. Type 2 joist hanger connected to rim joist, attached to north wall blocks.

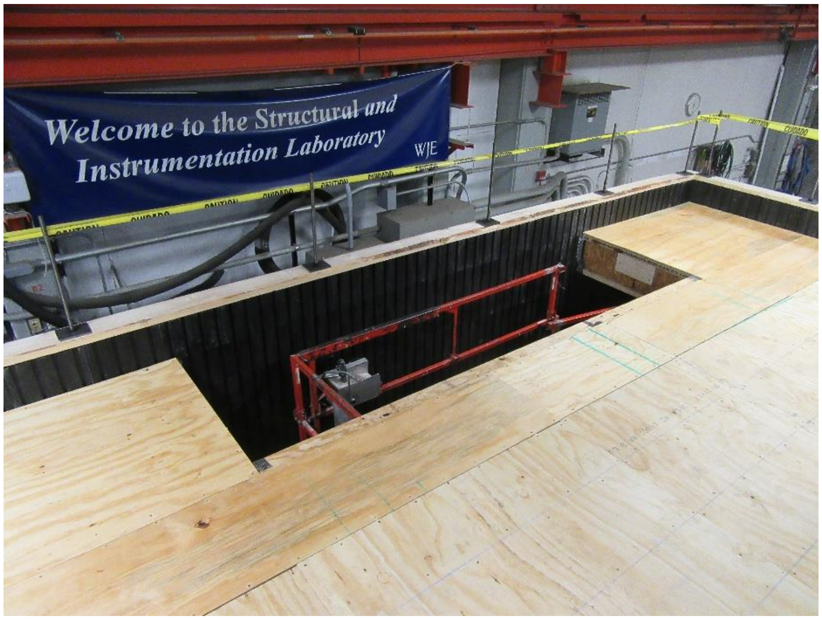

Figure 9. Stairwell opening from above, plywood decking, and west wall.

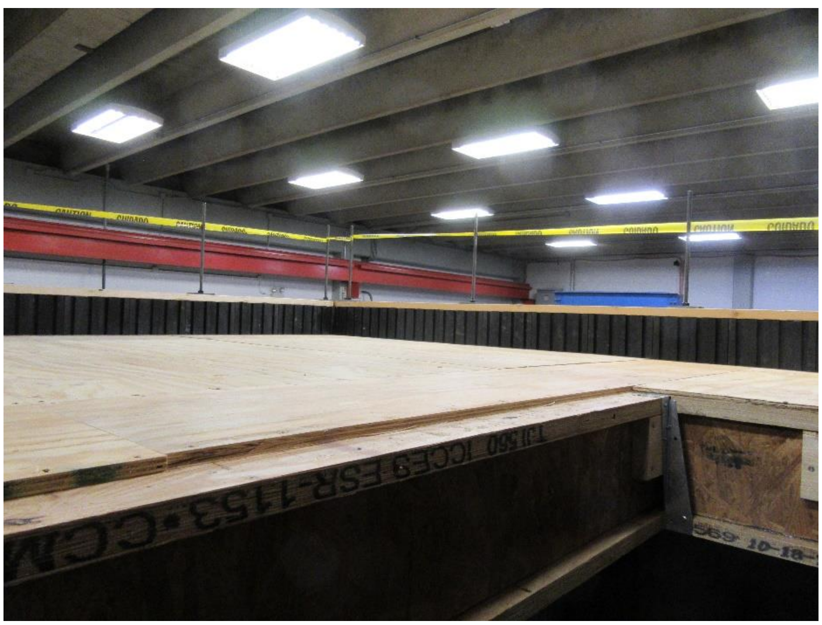

Figure 10. Plywood decking and top of south and east walls from stairwell opening.

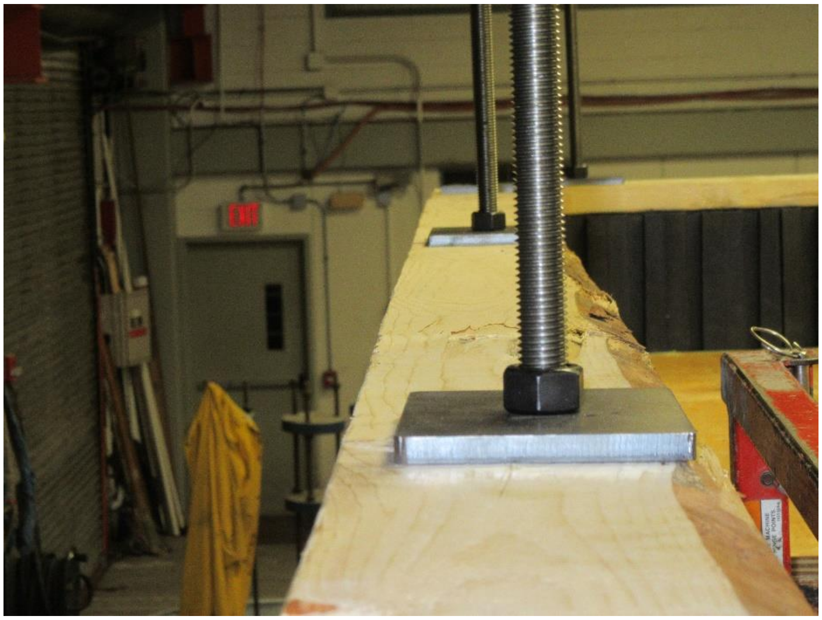

Figure 11. Wood top plate with steel tension rod, nut, and plate washer.

Figure 12. Load Cell 3 on south bearing wall, tensioning equipment on plywood decking.

Figure 13. Displacement instrumentation attached to wall and joist.

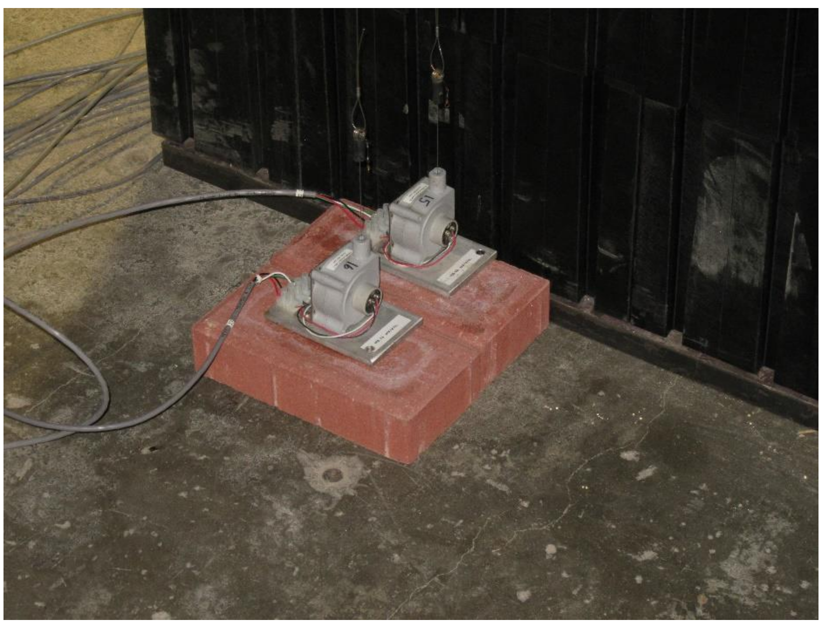

Figure 14. Displacement transducers (stringpots) on floor.

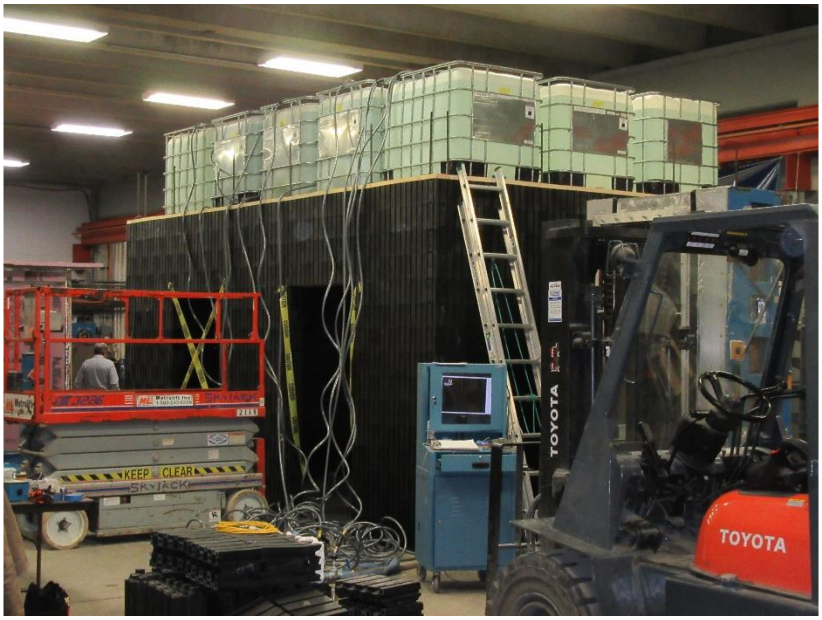

Figure 15. Booth fully loaded during load test with water weight, from northeast.

Figure 16. Booth fully loaded during load test with water weight, from north.

Figure 17. Booth fully loaded during load test with water weight, from east.

Figure 18. Local block exterior wall buckling/crushing at upper northeast corner block.

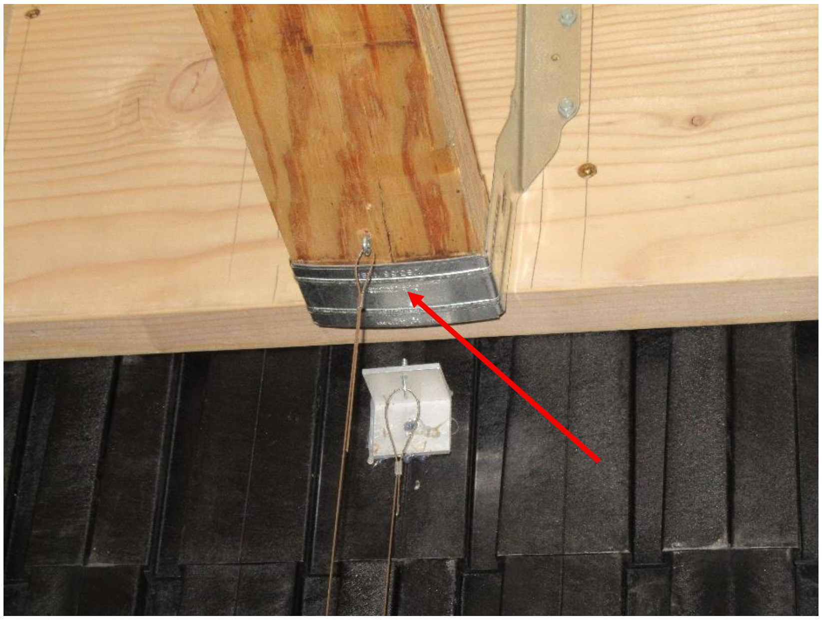

Figure 19. Local bending of single Type 2 joist hanger bottom plate (red arrow) during load test.

Figure 20. Local bending of double Type 2 joist hanger bottom plate (red arrow) during load test.