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A Cold-Formed Wall Panel for Building Construction -A Case Study

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Abstract

In the spring of 2002, Old Dominion University, though our Technology Applications Center was asked to perform testing on a new type of structural wall panel. These panels will be used in interior and exterior applications and for load bearing and non-load bearing conditions. This testing was done in accordance with the criteria established by the owner's Engineer.

The test involved positioning the wall panel in a testing apparatus and applying lateral, axial and shear loads and measuring the deflections and other performance indicators. The paper will outline the procedures and results used in the investigation.

The paper will present the investigation in the format of a case study for several reasons. It is essential that students be exposed to code loadings for structures. The paper will evaluate the criteria and evaluate its appropriateness for the test being done. The paper will also introduce to students the procedure used to evaluate structural elements prior to their introduction into the marketplace. Another benefit to this case study is that it introduces the students to a new and evolving method of building construction.

Introduction

Old Dominion University has performed a program of wall panel testing for a firm located in the Eastern Virginia area. This testing has been performed in accordance with the criteria established by the manufacturing firm's Professional Engineering Consultant (Engineer) as modified in the course of testing with the approval of the Engineer. The manufacturing firm provided all specimens tested. In general, the testing was in accordance with ASTM E72-98[1]. This document has been replaced by ASTM E72-02, November 1, 2002, but was current at the time of the testing program described in this paper.

This testing is of interest to students because it illustrates one method by which new products enter the marketplace. Traditional institutional thinking is that research by universities or professional organizations such as the Steel Framing Alliance develop new building construction methods and materials. In this case the wall panel was conceived and developed by the manufacturer and presented by the manufacturer for testing.

The Engineer required three modes of testing: an axial test, a lateral load test (wind) and a shear (racking) load test. The axial test applies vertical loads in the plane of the specimen modeling building floor loads, etcetera, in a load bearing condition. The lateral load places bending loads on the specimen modeling wind loads against the panel such that the specimens bend about their weak axis over a span approximately equal to the specimen height. The shear load test applies load in the plane of the specimen at its top corner to model lateral loads from wing on the main force resisting elements of buildings. For each of the tests deflections were measured at numerous locations. The results of each type of test are discussed below.

An important issue with the process was a conflict with the criteria presented by the Engineer and the expectations of the University community. The panels were suitable for use as interior and exterior bearing walls. It was our opinion that the critical loading condition should be a combination of axial load and wind on the panel. These concerns will be addressed in the conclusion of this paper.

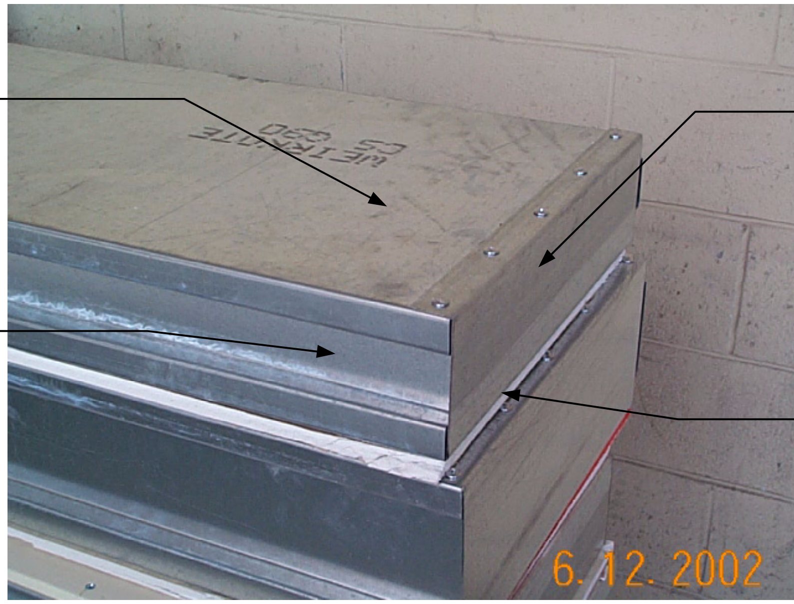
Description of Specimens

The wall panel test specimens were constructed of 20 gage galvanized sheet steel. The steel had been formed into wall panels including individual panels and assemblies four and six inches thick, eight to 12 feet tall and 16 to 48 inches long. The long sides of the panels have a tongue or groove for mating panels together into assemblies. The open side of the panels was closed with a sheet of ½ inch gypsum board. The method of attaching the individual panels together was not visible, but it is our understanding that sheet metal screws were used. A typical panel is shown in Photograph 1 on page 3.

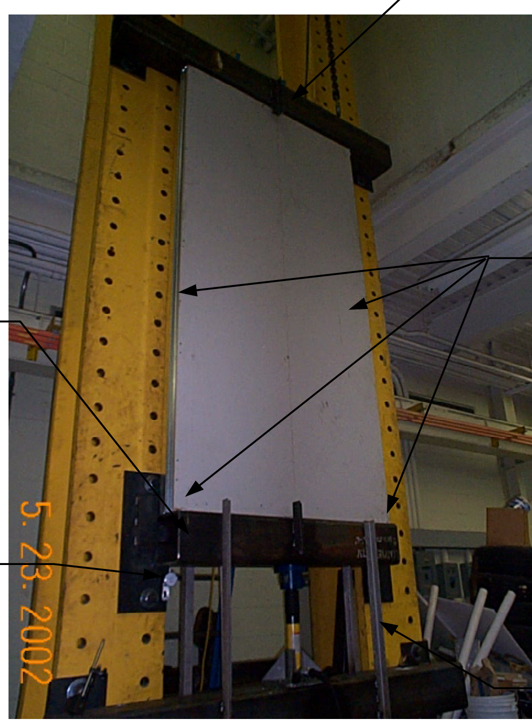
Axial Load Test

The apparatus for the axial load test is shown in Photograph 2 on page 3. The specimen was actually loaded from the bottom, with gages measuring the vertical (in-plane) deflection at each end, and the out-of-plane deflection at the bottom and mid-height of the specimen.

The first two specimens were eight feet tall, 48 inches long and 4 inches thick and were an assembly of two-14 inch long panels. The maximum specified load was 3,000 pounds per foot (plf), for a maximum of 12,000 pounds. The assemblies supported the load with no signs of failure, but in both cases exceeded the vertical deflection criteria of .100 inch by a factor of approximately two. The out-of-plane deflection also exceeded its criteria of .250 inch. This result was discussed with the Engineer who indicated that the criteria was conservative and may be subject to future modification. Testing continued.



Photograph 1



Photograph 2

The next three specimens tested were single panels 12 feet tall, 16 inches long and 4 inches thick. These specimens were not the four-foot length assemblies anticipated, so the maximum load was factored down in proportion to the reduction in length to a maximum value of 4,000 pounds. These three specimens met the criteria for deflection with the exception of vertical deflection, which ranged from approximately 30 to 50 percent above the criteria.

The final three specimens tested for axial loads were single panels 12 feet tall, 16 inches long and 6 inches thick. The load for these panels was also reduced in proportion to the reduced length of the panels. The deflection for the three panels was less than the original criteria with the exception of one panel, which was 4% over the criteria.

Shear Load Test

The apparatus for the shear (racking) load test is shown in Photograph 3 on page 5. The test specimens consisted of two 16-inch panels attached together. The assemblies were blocked at the bottom to prevent movement along the plane of the panel, and tied at the loaded side to the apparatus with threaded rods to prevent overturning. Loads were applied in the plane of the panels and concentrated at the top right corner. Since the assemblies for this test were 32 inches long, rather than the 48-inch length anticipated, the lateral loads were reduced from the 1,000 pounds listed in the criteria, to maximum of 667 pounds with the Engineer's concurrence.
The first three shear load tests were performed on assemblies of two panels 12 feet tall, 16 inches long and four inches thick. The lateral movement of these panels exceeded the criterion of .1 inch by a factor ranging from six to nine. The vertical movement at the loaded corner was small and the out-of plane deflection was within its criterion of .25 inches.

The next three tests were on assemblies of two panels 12 feet tall, 16 inches long and six inches thick. The lateral movement of these panels exceeded the criterion of .1 inch by a factor of 10 or more. The vertical movement of the loaded corner was small, and the out-of-plane movement was within its criterion of .25 inches.

Lateral Load Test

The apparatus used for the lateral load test is shown in Photograph 4 on page 5. All specimens for this test were single panels were laid flat and supported at each end. The gypsum board closure was placed on the down side. The support spacing was very close to the full height of the panels. The original criteria called for the load to be applied at the center of the specimen with a member specified to carry the load equally across its four-foot width. The specimens provided were all 16 inches long, hence the load was factored down in proportion to the panel width to a maximum value of 883 pounds. Loads were applied to the solid metal side since this was the most likely application scenario.

Deflection measured laterally this corner

Vertical deflection measured this location

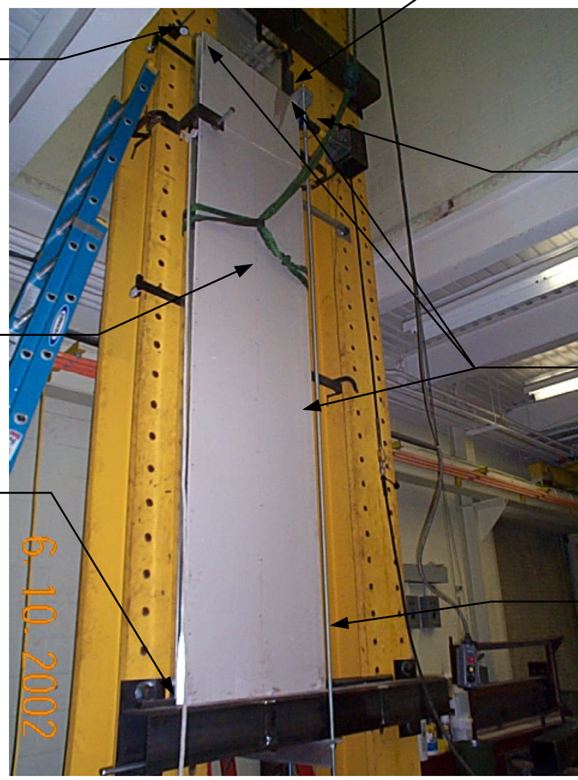
Hydraulic cylinder and load cell apply lateral load

Panel being tested

Out-of-plane deflection measured four locations

Clip prevents lateral movement

Hold-down rods



Photograph 3

Hydraulic cylinder and load cell

Tube member extends load over the width of the panel (single line of load shown)

Panel being tested

Deflection measured each side of the panel at mid-span

Photograph 4

The first two panels tested were single panels 16 inches long, 12 feet tall and four inches thick. These two specimens exceeded the deflection criteria in the second and third increment of load respectively, and failed to resist load beyond the sixth and seventy increment of load respectively. The second set of panels were single panels 16 inches long, 12 feet tall and six inches thick. These panels exceeded the deflection criteria in the fifth increment of load and failed to resist load in the ninth increment of load.

Following these failures, the load criterion was discussed with the Engineer. It was decided to change the load pattern to place loads at the third points of the panel in an effort to assure that local buckling did not aggravate the failure. In the course of re-computing the loads it was determined that the original load specified in the criteria was twice the correct load, and therefore the first four specimens tested for lateral load were actually overloaded by a factor of two.

The loadings were corrected and applied at the third points of the panel as shown in Photograph 5 below. The load used exceeded one half of the original load, because the loads were moved to the third points and the loads shown in the table will produce one-half of the original bending moment in the specimen.

Load applied along two lines

Panel being tested

Photograph 5

Two additional specimens (16" x 12' x 4") and (16" x 12" x 6") were tested using the revised apparatus. The first specimen supported the revised loading, but exceeded the deflection criteria in the fourth increment of load. The second specimen also supported the load, but exceeded the deflection criteria in the seventh increment of load.

Summary of Results

The tests indicate the specimens performed the best when the panels are loaded axially. Our only concern is that the track on the ends of the assemblies was not compressed prior to the installation of the screws. The result was that the screws showed signs of twisting indicative of movement of the track relative to the specimen wall.

The deflection of the specimens under the racking load exceeds the criteria significantly. The data indicates that the specimens did in fact move out of square, as the vertical movement that accompanied the lateral in-plane movement was small and could be attributed to elongation of the hold-down rods.

The only failure of the specimens was in the lateral loading case. The deflection increased incrementally with the loads, and in our opinion, the failure of the specimens in this loading condition was directly attributable to the characteristics of the specimens, and was not influenced significantly by the test apparatus.

At times out-of-plane measurements for the axial and shear load tests were somewhat erratic. It is our opinion that this erratic movement was due to the tendency of the panel metal faces to "oil can" under compression and axial loads.

Conclusion

The panel test was completed and the results forwarded to the manufacturing firm. At the time of the writing of this paper, the manufacturing firm has decided to proceed with the construction of a prototype structure. The structure will be a series of two-story town homes. The university has expressed its concern with the criteria, in particular the omission of a combined wind and axial loading from the test.

Several issues are important for students that may encounter in later practice a development process such as the one discussed in this paper. Questions concerning the performance of the panels remain. The axial deflection criterion appears in our opinion to be too restricting, while the shear deflection limit does not. Neither was reconsidered. In our opinion the panels have an inherent resistance to shear (in-plane) movements. Multiple panels may produce adequate shear resistance for a two-story structure.

Other issues that the writer's experience dictates as relevant must be examined. Moisture is often present in the cavity space of framed walls with masonry veneer. Metal-framed walls are susceptible to rusting and deterioration. Protecting the panel from water that may enter or condense in this cavity must be removed.

The panels were tested in shear by anchoring the panels with rods to prevent uplift. In an actual application, the tie-down rods cannot be accommodated. Hardware to anchor wood-framed walls for overturning exists, but its use for the steel-framed panels discussed in this paper has not been demonstrated.

The use of partial panels at openings was not addresses. Although panels spanning across openings similar to those used in precast concrete can be used, the panels as tested have not demonstrated the capacity to support the bending and shear loads from floor and roof loads.

The final issue to be considered is of an ethical nature. The testing agency was tasked to evaluate the panel for the criteria provided by the Engineer. The assumption can be made that a registered engineer would be required to provide an engineer's seal before the plans could receive a building permit. In an instance where the criteria are in question, public safety is an issue. An engineer's certification was not required for the test, and no liability for the final application was assumed.

Bibliography

1. ASTM E72-98, Standard Testing Methods of Conduction Strength Tests of Panels for Building Construction, ASTM International, November 1, 1998

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