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Summary of New Mexico ASTM E-119 Small Scale Fire Tests On Straw Bale Wall Assemblies

The attached document is a compilation of information regarding testing done by SHB Agra Engineering and Environmental Services Laboratory in Albuquerque, New Mexico in 1993. Two ASTM E-119 Small Scale Fire Tests were conducted, the first on a bare (unplastered) bale wall panel consisting of two-string wheat straw bales (18"thick) and the second on a wall panel which had gypsum plaster on the interior (heated) side and cement stucco on the outside surface. A video of this testing, "Building With Straw, Volume III – Straw Bale Code Testing" is available from Black Range Films (http://www.strawbalecentral.com/).

The results of the fire tests were very impressive, in that the bare bale panel survived for over 34 minutes before the test was stopped due to a burn-through at the center seam between two bales and at one corner of the wall assembly. At the point that the test was stopped, the bales were charred only 8" of the 18" thickness. The maximum temperature recorded on the heated side of the wall was 1691º F at 30 minutes.

The plastered bale panel was tested for over 2 hours and withstood temperatures that reached 1942º F. The temperature rise on the unheated side of the test panel, after 2 hours, averaged less than 10º F, with the highest rise being 21º F. The plaster on the heated side of the panel cracked and where the cracks were there was approximately 2" of charring.

Included in this information package is a report on other testing that was done in addition to the fire testing, but only the fire test data is included here. Of the two tables included for the fire test, the one that shows the time by minutes up to 30 minutes is the temperature data for the unplastered wall assembly. The other is labeled "Small Scale E-119 Tests on Stucco Panels".

Also included is a copy of a report by Manuel Fernandez, who at the time was the State Architect and head of Permitting and Plan Review for the State of New Mexico Construction Industries Division. As you will see from his report, he stated these tests proved that a plastered straw bale wall assembly is superior to a wood frame wall assembly with the same finishes, in terms of its fire resistivity. These test results are very similar to those from the testing that was conducted in Canada, through the Canadian Government testing programs. It is clear from these results that fire resistivity is one of the advantages, rather than a problem for plastered straw bale wall systems.

<u>SUMMARY REPORT ON STRAW BALE CONSTRUCTION ACTIVITY</u>

Date: February 4, 1994

Prepared by: Manuel A. Fernandez, Achitect,CID

On Febuary 3, 1994, the New Mexico Home Builders Associaiton, Technical Advisory Committee held its monthly meeting. Straw Bale Construction was added to the agenda and discussed. Members of the Straw Bale Construction Association attended the meeting to answer questions and to request a recommendation be presented to the Construction Industries Commission from the Technical Advisory Committee to move forward with a public hearing on code language written by the Association.

The Technical Advisory Committee moved and passed the following motion:

> The New Mexico Home Builders Association Technical Advisory Committee supports the Straw Bale Construction Associations efforts to advance straw bale construction as an alternate building material under Section 105, "Alternative Methods and Materials of the New Mexico Building Code".

In a letter dated May 7, 1993, CIC informed the Straw Bale Construction Association of required tests on straw bale construction before issuing further experimental permits. In that letter, a criteria was established for acceptance of an alternate building material or method under provisions of Section 105 and 107 of the New Mexico Building Code. CID's evaluation of the Association's response to the criteria for straw bale construction is as follows:

1. Define the material and its application and limitations.

   Evaluation: A great deal of information has been written about straw bale as a building material. From this knowledge and understanding of the material a clear definition of "straw bale" for Post & Beam/Straw Bale Infill construction has been written into the standards presented with this report.

2. Test results of ASTM E-72 tests for evaluating transverse loading, compressive loading, and racking shear.

   Evaluation: ASTM tests for evaluating transverse loading have been completed and presented to the Commission at their regular meeting, December 17, 1993. The results of the tests have proven satisfactory for Post & Beam/Straw Bale Infill construction. ASTM tests for evaluating compressive loading and racking shear have been determined necessary only for load bearing straw bale construction and therefore not a criteria for Post & Beam/Straw Bale Infill. ASTM test for compressive loading and racking shear have been postponed for future consideration of standards that will be written for load bearing construction.

3. Test results for ASTM E-119 for fire-resistance.

Evaluation: ASTM tests for fire-resistance have been completed and presented to the Commission at their December 17, 1993 meeting. The results of these tests have proven that a straw bale infill wall assembly is a far greater fire resistive assembly than a wood frame wall assembly using the same finishes.

4. Test results for ASTM E-331 testing for wind-driven rain.

Evaluation: This series of testing was not performed. The Straw Bale Construction Association met with the CID Director and Architect and asked to be released from performing this test.The reason given was the very high cost of testing that would essentially test the moisture resistance of stucco which is already an acceptable material in the State Building Code. Their request was granted.

5. Compliance with Model Energy Code.

Evaluation: There was no specific testing performed that would address the R value of a straw bale wall. It is assumed that the R value of a straw bale wall far exceeds frame wall construction. This is based on test results conducted for fire resistance. Those tests showed a sustained difference in temperature from the fire side of the wall at 1,942 degrees F. to 63.1 degrees F. at the opposite side for a period of 120 minutes.

6. Establish criteria for the wall's natural transpiration.

Evaluation: It has been determined by the Association that in order to achieve natural transpiration of straw bale walls it is important to omit any form of vapor barrier as a part of stucco or plaster finish. This omission also provides better bonding of stucco and plaster to the wall.

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December 17, 1993
SHB Job No: C93-9914

DRAFT

REPORT TO: NEW MEXICO COMMUNITY FOUNDATION
Straw Bale Construction Association
P.O. Box 149
227 Otero Street
Santa Fe, NM 87504-0149

Attention: Mr. Bruce H. Rolstad

REPORT OF: Transverse Load Test and Small Scale E-119 Fire Test on Un-Coated Straw Bale Wall Panels and Stucco Coated Straw Bale Wall Panels

1. INTRODUCTION

In accordance with your request, a transverse load test and a small scale E-119 fire test was performed on sample wall panels at our laboratory facilities. These panels were constructed from conventional bales of straw, and were reinforced with concrete reinforcing steel. The purpose of this program was to determine whether the reinforced Straw Bale wall panels could successfully pass these tests without being finished in any other way. Additional tests were performed on Stucco-Finished Straw Bales to assess the difference in performance. The transverse load tests were performed on the unreinforced straw bales on November 3-4, 1993; the small scale E-119 test was performed on the unreinforced straw bales on November 10, 1993; the transverse and fire tests were performed on the stuccoed straw bales on December 9-10, 1993.

2. PROCEDURE

TRANSVERSE TEST

The wall panels which were tested in this test program were fabricated at our laboratory facilities in Albuquerque, New Mexico. All steps of the construction of these panels was observed by SHB Agra personnel.

The Transverse Load Test was performed in accordance with ASTM E-330. The purpose of this test is to measure the amount of deflection of the test specimen when the panel is subjected to uniform loads perpendicular to the face of the test specimen (simulated wind loads).

Each individual test specimen was braced against an air-tight test chamber, and sealed so that no outside air could pass through the test specimen. A vacuum pump was then connected to the test chamber, and the inside air evacuated until the specified pressure was achieved. This vacuum effectively reproduces the same strains on the test panel as would a wind blowing against the outside of the test panel.

Deflections were measured by placing a vertical wire in front of the test panel, but free from any contact with the test panel or other test apparatus. A rigid disc was attached to the face of the test panel at quarter points, with one being at the top quarter of the test panel, one at the center, and one at the bottom quarter of the test panel. The distance between the vertical wire and rigid disc was measured at the initial no-load condition, and at each increment of 5 pounds per square foot (psf) until the ultimate designated load had been achieved. Initial readings were taken only after the panel had been pre-loaded to remove any slack from the system. For the purposes of this test, the maximum designated load by our client was 20 psf.

The third unreinforced panel was loaded to 26 psf in an effort to determine what might happen at loads greater than the designated load. The stucco-coated panel was loaded to 50 psf, since there was no apparent sign of structural distress or failure.

SMALL SCALE E-119 FIRE TEST

The small scale E-119 test was performed on test panels which contained single bales of straw on the top and bottom of three levels of straw, with the middle level composed of two half-bales, intersecting at the middle of the test panel. This configuration was used to represent a typical cross section for this type of wall. These bales were reinforced in a manner similar to that used for the transverse test panels.

Each test panel was inserted into an existing CMU wall and sealed into the test frame with Kaolinite wool. The exposure met the test standard requirement for exposing one face of the specimen to 1000 ^{O}F in five minutes, increasing to 1550 ^{O}F at thirty minutes, and 1750 °F at 1 hour (+/- 10%).

The furnace is made of scoria aggregate-alumnite cement. It has a 10' x 10' opening through which the test specimens are exposed to the combustion chamber. Openings in the side walls admit the burners and combustion air. High temperature ceramic fiber is used to seal the joint between the furnace and the removable test frames.

The furnace temperature is measured using nine Type K thermocouples installed within protective tubes in the combustion chamber. The thermocouple time constant is within the range of 5.0 and 7.2 minutes. The exposed length of the tubes in the furnace is twelve inches. The thermocouples were calibrated by Cleveland Electric Labs., Inc.

Natural gas is used to fuel the three burners on each side of the combustion chamber. The lower burners on each side of the chamber are 12 inches from the bottom of the chamber, the middle burners are 48 inches from the bottom of the chamber, and the upper burners are 84 inches from the bottom of the chamber. Geometrically, each burner is at the vertical quarter points of the combustion chamber. Each of the six burners can be controlled by separate fuel feed valves. A twenty-four inch diameter flue equipped with a controllable damper is installed above the furnace.

The unexposed face of the test panel was instrumented with nine Type K thermocouples covered with fiberglass sheathing. Each thermocouple junction was soldered. Three thermocouples were placed on each course of straw bales, with one at the right quarter point, one at the center, and one at the left quarter point for each course of the test specimen. The thermocouples were designated as TC 10 through TC 12, for the thermocouples on the bottom course (from left to right); TC 13 through TC 15 for the middle course (from left to right); and TC 16 through TC 18 for the top course (from left to right).

All temperatures measured during the course of this test were recorded by a Fluke 2240 Datalogger.

The pressure inside the combustion chamber was measured by a vacuum-pressure gauge attached to a hollow tube extending through the back wall of the chamber. The gauge scale is graduated to read in 0.01 psi increments. Furnace pressure is regulated when required by opening or closing the flue damper.

3. RESULTS

TRANSVERSE LOAD TESTS

The Transverse Load Test results for the unreinforced straw bales are shown in the attached Table I, and Figures 1 through 3. All of the test panels survived the maximum designated loads for a minimum of three minutes without any visible sign of structural distress or permanent displacement. The deflections were somewhat variable, from panel to panel. However, this is not unusual for this type of construction.

The stucco covered straw bale results are shown in Figures 4 and 5. It can be seen that minimal deflections were noted, even though the load was increased to over twice the designated maximum load of the un-reinforced straw bails.

SMALL SCALE E-119 FIRE TEST

Transmission of heat through the unreinforced straw bale during this test was not sufficient to raise the average temperature at the exterior face of this wall to 250 °F above the initial temperature (the governing criteria for ASTM E-119). The highest average temperature recorded on the unexposed face of the unreinforced straw was 52.8 °F at thirty minutes. Transmission of heat through the wall did not exceed the allowable limit for any single thermocouple. Additionally, there was no penetration of flames or hot gasses through the unreinforced straw bale wall during the thirty minute test period.

The burning characteristics of the unreinforced straw bales were observed through observation ports during the test. The test panel was also examined after it was removed from the combustion chamber. The straw was observed to burn slowly, and the charred material tended to remain in place. The residual charred material appeared to protect the underlying straw from heat and ventilation, thereby delaying combustion. The maximum temperature recorded inside the furnace was 1,691 °F at thirty minutes. Upon removal, the bales did not burst into flames, but slowly smoldered. The fire was easily extinguished with a small quantity of water.

The test was continued beyond the thirty minute time period until flame penetration occurred at the central vertical joint after a time of thirty four minutes.

The highest temperature recorded on the exterior face of the stuccoed straw bales after 120 minutes of exposure was 63.1 °F. The highest average furnace temperature recorded during this period was 1,942 °F. There was no penetration of flames or hot gasses through the stuccoed straw bale wall. Additionally, the stuccoed straw bale wall was impinged by a blast of water from a 2 1/2 inch fire hose upon completion of the test. There was no resulting indication of distress or failure.

The burning characteristics of the stuccoed straw bales was also observed. The reaction consisted of initial cracking of the stucco surface as the heat was applied, with little further evidence of distress.

4. CONCLUSIONS

4.1 The Straw Bale test panels submitted for Transverse Load Testing successfully sustained the designated load of 20 psf.

4.2 The magnitude of deflection measured during this test is not unusual for this type of construction. However, the addition of the stucco to each face increased the rigidity of the bales substantially. Deflections of the magnitude noted for the stuccoed panels are very normal for the industry.

4.2 The unreinforced Straw Bales submitted for the Small Scale E-119 Fire test resisted flame penetration for at least thirty minutes. The stuccoed straw bales resisted flame penetration for over two hours.

Bryce Simons, P.E.
Director, Special Materials Testing

SHB AGRA, INC.

Small Scale E-119 Fire Test
Exterior Skin Temperatures

Time	Bottom Course			Middle Course			Top Course		
(Min.)	TC 10 (left)	TC 11 (middle)	TC12 (right)	TC13 (left)	TC14 (middle)	TC15 (right)	TC16 (left)	TC17 (middle)	TC18 (right)
1	49.0	49.3	50.2	49.3	49.8	49.4	47.9	48.1	49.5
2	49.3	49.6	50.2	49.3	50.0	49.7	47.9	48.1	49.7
3	49.4	49.6	50.3	49.5	50.0	49.7	47.9	48.1	49.7
4	49.4	49.7	50.3	49.6	49.8	49.7	47.9	48.2	49.7
5	49.4	49.7	50.3	49.7	49.8	49.7	47.9	48.2	49.7
6	49.3	49.7	50.2	49.4	49.7	49.8	47.9	48.1	49.6
7	49.4	49.7	50.2	49.6	49.8	49.7	47.9	48.1	49.6
8	49.5	49.7	50.1	49.6	49.8	49.7	47.8	48.2	49.7
9	49.6	49.8	50.2	49.7	50.0	49.8	47.9	48.3	49.7
10	49.5	49.7	50.2	49.7	49.8	49.7	47.9	48.3	49.6
11	49.6	49.8	50.1	49.7	50.0	49.7	47.8	48.2	49.7
12	49.6	49.7	50.2	49.7	49.8	49.7	47.9	48.3	49.7
13	49.3	49.8	50.2	49.9	49.9	49.9	48.5	48.2	49.7
14	49.7	49.8	50.2	49.8	50.1	49.7	47.9	48.3	49.8
15	49.7	50.0	50.3	49.7	50.1	49.7	48.0	48.3	49.8
16	49.7	49.9	50.4	49.8	50.1	49.8	48.0	48.4	49.9
17	49.7	49.8	50.3	49.8	50.2	49.7	47.9	48.4	50.0
18	49.7	49.9	50.4	49.8	50.2	49.8	48.0	48.3	50.0
19	49.7	49.9	50.5	49.8	50.2	49.8	48.1	48.4	50.1
20	49.7	50.0	50.5	49.9	50.3	50.0	48.2	48.4	50.2
21	49.7	50.0	50.6	49.9	50.4	50.0	48.3	48.5	50.3
22	49.8	50.1	50.7	49.9	50.5	50.0	48.5	48.6	50.3
23	49.8	50.1	50.7	49.9	50.6	50.1	48.7	48.7	50.5
24	49.9	50.2	50.8	49.9	50.7	50.3	48.8	48.8	50.7
25	49.9	50.2	50.9	50.0	50.9	50.3	48.8	49.2	50.9
26	50.2	50.4	51.0	50.0	51.1	50.4	48.9	49.5	51.1
27	50.1	50.3	51.1	50.1	51.3	50.5	49.1	50.1	51.4
28	50.1	50.3	51.3	50.0	51.5	50.6	49.2	50.7	51.6
29	50.2	50.3	51.4	50.1	51.9	50.7	49.4	51.5	52.1
30	50.3	50.4	51.5	50.1	52.5	50.8	49.7	52.2	52.8

SHB AGRA, INC.

Small Scale E-119 Tests
on Stucco Panels

Exterior Skin Temperatures

Time (Min.)	Furnace Temperature (Degrees F)	Bottom Course TC10 (left)	Bottom Course TC11 (middle)	Bottom Course TC12 (right)	Middle Course TC13 (left)	Middle Course TC14 (middle)	Middle Course TC15 (right)	Top Course TC16 (left)	Top Course TC17 (middle)	Top Course TC18 (right)
0	43.0	42.3	42.1	41.6	42.6	42.3	41.4	41.6	42.3	46.7
5	1068.0	49.1	49.2	49.0	47.2	46.1	46.0	46.3	46.8	46.7
10	1323.4	48.9	49.3	48.8	47.0	47.9	45.9	46.2	46.6	46.5
15	1319.0	49.0	49.1	48.8	47.0	47.9	45.9	46.1	46.6	46.5
20	1336.6	49.0	49.2	49.0	47.0	47.9	45.9	46.1	46.6	46.5
25	1380.1	48.9	48.8	49.3	47.1	47.6	45.8	46.1	46.6	46.4
30	1408.8	48.9	49.1	49.2	47.1	47.7	45.8	46.2	46.7	46.4
35	1368.2	48.8	49.2	49.1	47.0	47.6	45.9	46.0	46.6	46.4
40	1500.6	48.9	49.3	49.1	47.0	47.6	45.8	46.1	46.5	46.3
45	1622.1	48.8	49.3	48.9	47.0	47.3	45.6	46.1	46.5	46.2
50	1659.9	48.9	49.5	48.9	47.0	47.4	45.8	46.2	46.6	46.5
55	1732.2	48.9	49.7	48.9	47.0	47.5	45.8	46.3	46.5	46.6
60	1795.2	49.1	49.9	48.9	47.1	47.6	45.9	46.5	46.7	46.8
65	1823.6	48.8	49.9	48.8	47.0	47.5	46.1	46.8	46.6	46.8
70	1838.9	49.0	49.9	48.8	47.1	47.7	46.1	46.8	46.8	46.9
75	1852.9	49.1	50.2	48.6	47.1	47.9	46.1	47.0	46.8	47.0
80	1865.8	49.5	50.7	48.9	47.2	48.0	46.3	47.0	47.0	47.3
85	1886.5	49.3	50.3	49.0	47.3	48.3	46.5	47.3	47.1	47.5
90	1894.1	49.3	50.3	49.1	47.4	48.4	46.6	47.4	47.3	47.6
95	1896.4	49.5	50.4	49.3	47.6	48.9	46.9	47.7	47.9	47.9
100	1905.2	49.4	50.4	49.2	47.7	49.9	46.9	47.8	48.8	47.9
105	1916.7	49.6	50.6	49.7	47.8	51.6	47.2	48.0	50.6	48.3
110	1926.5	49.8	50.7	49.5	47.9	54.3	47.4	48.1	52.6	48.6
115	1930.4	49.8	50.7	49.7	48.1	58.3	47.6	48.4	55.5	48.7
120	1942.0	50.0	50.8	49.7	48.4	63.1	47.8	48.7	58.6	48.9

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