STRAW BALE FIRE SAFETY

A review of testing and experience to date
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ABSTRACT

The ability of plastered and unplastered straw bale walls to resist fire is presented, based on a number of tests and field reports to date. Field and laboratory experience show plastered bale walls to be highly resistant to fire damage, flame spread and combustion.

INTRODUCTION

We are accustomed to building with extremely flammable materials. For example, wood studs with air spaces around each one burn extremely well. With this as the cultural baseline, our building codes do not typically concern themselves with, "Does it burn?" as much as they ask, "Can people escape while it's burning?"

These building codes express the fire safety of walls as a function of fire *resistance*, meaning how long a conflagration can exist on one side of the wall in question before enough heat is transmitted through the wall to ignite materials on the other side, even if fire has not actually breached the wall. So while a wall made, say, of a single slab of steel is not going to burn under normal fire conditions, it is not fire resistive because the heat of the fire would pass so quickly through it. The fire resistivity of a wall is expressed as a function of this time of heat transmission: a "one hour wall" has kept a set of flame throwers heating a furnace to over 1500 ˚F (840 ˚C) from heating the opposite side of the wall 250 ˚F (139 ˚C) over its initial temperature for one hour.

BALES BURN BADLY

It seems counterintuitive to suppose that a bale wall would increase the fire safety of a building, as the straw is so obviously flammable. However, fire requires high temperature, fuel, and oxygen; compressing the straw into a dense block dramatically decreases the ability of oxygen to feed a fire at the straw. After the surface of a bale or bale wall has been charred (providing that the wall of exposed bales remains intact), the worst it will generally do is smolder. Fire departments actually utilize this quality, and ignite wire-tied bales as smoke generators for training exercises. This resistance to rapid combustion has been observed during a few accidental fires during construction of bale buildings, and during a lab test, called a "corner test", on unplastered bales at the Richmond Field Station of the University of California in March 1996.

The author was present for this corner test, which was meant to simulate what a burning wastebasket would do to the walls of an adjacent corner. When exposed to the fire source, the surfaces of the bales rapidly charred, after which there was no observable effect. This was said by the fire experts present to be comparable to how drywall performs in such a test. At the test's completion, we were asked to remove the charred bales from the test chamber to a dumpster—without first subjecting the chamber to a soaking down. When we did, we saw firsthand that when the bales fell apart, sparks inside the straw then had sufficient oxygen to develop into open flame.

A remaining question on this issue concerns the fire performance of bales laid on edge, as in this arrangement the plastic baling twine commonly in use is not buried 4 to 6 inches within the wall, but is out on the bale's surface. No lab tests of this configuration have yet been made, but in at least one instance a construction fire did indeed melt the twine holding the bales together, allowing flakes from the bales to drop out of the unplastered wall and feed the fire. Since exposed bales are only a temporary condition during construction, the predominant questions are (1) how well protected from melting is the twine on the straw surface once the wall has been plastered; and, (2) if the strings *do* melt beneath the plaster, how much structural integrity the wall will retain.

PLASTER PRODUCES PERMANENCE—LABORATORY TEST RESULTS

In general, once a bale wall has been plastered on both faces, the combination of an incombustible surface and an insulating interior that neither burns well nor melts makes a straw bale wall a very fire-resistive assembly. This has been verified in the lab tests to date:

1. 1993 Two small scale ASTM E-119 fire tests at the SHB Agra lab in Sandia, New Mexico—one test wall with plastered faces, the other unplastered—showed bales to be very fire-resistant. The unplastered bale wall withstood the heat and flames of the furnace for 30 minutes before flames penetrated a joint between bales. The plastered bale wall was naturally much better, resisting the transmission of flame and heat for two hours.

2. 1996 A full scale ASTM E-119 fire test at the University of California Richmond Field Station easily passed the criteria to qualify as a one hour wall. In the opinion of the experts present at the test [personal communication with R. Brady Williamson], the wall would probably have passed as a two hour assembly.

3. 2001 The Appropriate Technology Group at Vienna Technical Institute conducted an F90 test (similar to the ASTM E-119 test), which gave a plastered straw bale wall a 90 minute (1 -1/2 hour) rating.

4. 2001 The Danish Fire Technical Institute tested a plastered straw bale wall with exposed studs on the fire side as a worst-case scenario, and got these results: in a 30 minute test with a 1832 ˚F. (1000 ˚C) fire on the exposed side, the unexposed side rose just 1.8 ˚F (1 ˚C). The maximum average increase permitted to in order to pass that test is 144 ˚F (80 ˚C).

5. 2002 Bohdan Dorniak and members of AUSBALE tested individually plastered bales to the Australian standard simulating the heat of a bushfire. Subjected to a maximum heat intensity of 29 kilowatts per square meter, none of the nine plastered bales ignited, or even developed visible cracks. According to Mr. Dorniak, this qualifies them as non-combustible under the current Australian Bushfire Code AS 3959.

FLAME SPREAD and SMOKE DENSITY

The issue has sometimes been raised that bales inside a wall should conform to the code criteria for insulation, which specifies minimum surface burning characteristics based on a standard test (ASTM E84-98). According to Professor R. Brady Williamson (one of the authors of this section of the Uniform Building Code (UBC) section 707), this notion is misguided, as this part of the code is meant to address insulation installed within a cavity in a wall. In typical straw bale construction the straw bale insulation *is* the wall, more like the situation in a log cabin. With no concealed draft tunnels for fire to rise up through, surface burning characteristics, as measured in what is commonly called a “tunnel test”, are not especially relevant.

In some buildings, though, people have indeed inserted bales between extra deep “studs” to construct walls. With that in mind, Katrina Hayes sponsored an ASTM E84-98 test on unplastered straw bales in 2000 at the Omega Point Laboratories. They passed the test easily; where the Uniform Building Code allows a flame spread of no more than 25 , the test produced a flame spread of 10; where the codes allows a smoke density of no more than 450, the bales produced a smoke density of 350.

STILL, IT BURNS; FIELD REPORTS

The author has collected 14 reports of fires in straw bale buildings during and after construction. These range in severity from the inconsequential flash of flames across the loose surface straw of an unplastered wall, to the complete loss of the structure.

The sources of the fire break down as follows:

1 was caused by a votive candle breaking in a recess in a wall.
1 was caused by candles at a party in an unplastered bale house.
1 was caused by a fireplace with no air gap separating it from an adjacent bale wall.
1 was caused by a portable electric heater in a crawl space.
2 were deliberate arson.
2 were electrical short circuits.
6 were caused by construction activity (welding , soldering, grinding).

This field data begins to indicate where the most fire danger resides in straw bale construction. If sorted by stage of construction and extent of damage:

11 fires occurred during construction; of them,
- 6 had local damage.
- 5 were a total loss.

3 fires occurred after occupancy; of them,
- 2 had local damage
- 1 was a total loss.

However, the best single correlation with extent of damage seems to be whether the plaster was in place at the time of the fire:

6 fires occurred after plastering; of them,
- 5 had local damage
- 1 was a total loss (in which the fire began in the roof framing)

8 fires occurred before plastering; of them,
- 2 had local damage
- 6 were a total loss

The most typical pattern of fire, reported in five instances, was where a construction activity ignited loose straw on the ground, which ignited loose straw on the surface of an adjacent wall. Regardless of the source of fire, in all five instances in which a fire climbed an unplastered wall on which framing lumber stood unprotected, the framing ignited, and complete loss of the structure resulted. In the two instances that were timed, the collapse of the roof occurred within 25 minutes of the fire's beginning.

In at least five of the reported fires, the fire smoldered in the spaces between bales, and was difficult or impossible to fully extinguish with a water hose. New protocols for dealing with this new kind of fire are evidently necessary, because in most of these smoldering instances, substantial sections of sound wall were demolished simply to get at the fire in the crevices.

Most needed, however, is the spread of knowledge of the basic safety measures that have become standard on straw bale construction sites:

1. Make certain everyone on site, but especially tradespeople, understand the flammability of exposed straw, and that extra precautions are required.

2. The straw on the ground must be removed continuously during the bale raising, and as a cleanup two to four times a day until the walls are plastered.

3. Have pressurized water hoses at ready everywhere on site. They must be within one minutes' access to make the difference in controlling the start of a fire.

4. Stuff all cracks between bales, and between bales and framing, with clay-coated (not loose) straw to reduce its ability to smolder. Trimming the bulges at the ends of bales prior to stacking substantially reduces the amount of this stuffing required.

5. Get the initial plaster coat on the bales as soon as possible. The practice of pre-coating the bale surfaces that will remain exposed, *prior* to stacking, while not yet widely practiced, would reduce fire vulnerability tremendously.

CONCLUSIONS

Our knowledge of the fire-resistive properties of straw bale construction is incomplete, but tests and field experience to date have been very encouraging. Most of straw bale construction to date has been low density single family dwellings, which the building code allows to be built with essentially zero fire resistance. Within this context, fire safety concerns usually don't come up as a significant issue; the standard, as set by wood frame construction, is very low.

Fire safety concerns rise as building and population density increase, but straw bale construction would require little or no additional testing to be readily acceptable for uses such as urban infill, row housing, commercial, retail, and educational buildings. There, additional attributes such as its excellent acoustic insulation would be of great value.

Straw bale construction has achieved its remarkable growth in use largely due to its aesthetic characteristics, its environmental credentials, and its excellent insulation value. In all these aspects , it compares favorably with stud wall construction. Those of us who have worked with it for years find it , in fact, a far **superior** wall system, whose potentials are barely tapped. When its fire-resistive qualities are better known, we may see new economies realized where it can, for example, be substituted for concrete block, or remove the need for fire safety measures such as sprinklers.

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APPENDIX

published straw bale fire tests

1. **Transverse Load Test and Small Scale E-119 Fire Test on Uncoated Straw Bale Wall Panels and Stucco Coated Wall Panels** 1993 by Bryce Simons, P.E. of SHB Agra, Inc. Available from Natural Building Resources, 119 Main Street Kingston, NM 88042; ph 505-895-5652; www.strawbalecentral.com

2. **ASTM E84-98 Surface Burning Characteristics, (on) Straw Bale** 2000 by Guy Haby and William E. Fitch, P.E. of Omega Point Laboratories, Inc. Available from Development Center for Appropriate Technology (DCAT) P.O. Box 27513, Tucson, AZ 85726-7513; ph 520-624-6628; www.azstarnet.com/~dcat

3. **Wall Systems of Renewable Resources (**"Wandsysteme aus nachwachsenden Rohstoffen") which includes an **F90** (European fire resistivity test)) **and B2** (European flammability test) 2001 by Robert Wimmer, Hannes Hohensinner, Luise Janisch and Manfred Drack of the Gruppe Angepasste Technologie (GrAT) an der TU Wein (the Appropriate Technology Group at Vienna Technological University); posted (in German) as a PDF document at www.grat.tuwein.ac.at