The Strawbale House Project at Swarthmore College (1994-1998)

This building was an environmentally innovative structure, constructed mainly out of load-bearing strawbales. It was built by student volunteers, and by undergraduate student members of the 1995 Environmental Studies Capstone Seminar. The building was designed by students in this seminar under the direction of Professor E. Carr Everbach (Engineering Department). The course is open to senior Environmental Studies concentrators, and in 1995 it focused on the various ways people can live in the world while minimizing damage to their natural environment.

The house was dismantled during the summer of 1998. For a detailed description of what we learned as we took it down, click here.

The straw bale house simulated a dwelling for a small family, possibly one living in a rural area or Indian reservation. The floor plan consisted of a circular living room, a kitchen, bathroom, utility room, and bedroom; the interior spaces (other than the circular living room) were never implemented. Feasibility studies were performed for several subsystems and designs were produced, but after the building envelope was completed, interest in "finishing" the house waned. The main purpose of the project was for the students in the Environmental Studies Capstone Seminar to learn about straw bale construction by actually building one, and more generally to investigate the tradeoffs between environmental benefits and practical considerations. The house was not built to serve a need for housing on campus, and ended up serving as a laboratory for analyzing straw bale construction in the northeastern U.S.

If you'd like to know how we built the structure, click here.

As we were preparting to dismantle the house, we undertook an experiment to see if bales could be replaced in-situ, as the walls were still intact. This process simulates what would have to occur if bales were damaged by moisture in a strawbale residence.

During the four years that the house stood, we measured temperature and humidity using data loggers implanted in the bale walls. We are compiling the data into meaningful measurements of the performance of our structure.

If you would like to know exactly where the site was on Swarthmore's campus, see this map.

Frequently Asked Questions about our project:

Why straw?

Building from straw is an ancient technique recently rediscovered by environmentalists. The bales are relatively inexpensive and very thermally insulating (about R=2.1 per inch of wall thickness). There are few other uses for straw, since, unlike hay, it cannot be used by animals for feed. Furthermore, because it decomposes very slowly, it isn't often used for composting. Every year, millions of tons of straw are discarded or burned in the U.S.

How long will it last?

The same things that make straw hard to use for other purposes make it ideal for building. When kept dry, straw is very sturdy. Straw has been found, completely intact, in ancient Egyptian tombs. Properly taken care of, a straw house could conceivably last as long. The biggest enemy of our house is moisture, and the walls have already suffered slight damage when the bales were wetted for several months during construction. On the positive side, however, the straw has already proved able to hold up well to extreme weather conditions, even in an unfinished state. Mildew on the wetted portions of the bales dried and became dormant, with no measurable degradation in strength or insulating ability of the bales.

Does it burn easily?

Because the straw is packed so tightly together (our 46 in. by 22 in. by 16 in. two-string bales weigh about 54 lbs. each, double the density of regular bales), oxygen cannot get into the middle of the bales, and so they do not burn easily. Exposed to enough heat, they will, of course, burn, but less easily than a comparable house built of conventional construction materials.

Additional Environmental Costs and Benefits

Although far superior to traditional building methods, the house was far from perfect, environmentally speaking.. The foundation used concrete and polyethylene foam, environmentally costly substances. However, the foundation was designed to use less concrete than conventional buildings do (see Technical Details, below). There was also a small amount of concrete mixed into the stucco placed on the walls. On the positive side, our straw walls had an average insulation value of R45, which means that it took very little energy to heat or cool the house.

The Future of the Project

The Straw Bale House was begun in late Summer, 1994, and the building envelope complete in late Summer, 1995. Prof. Everbach and his students measured temperature, humidity, moisture content of the walls, and other relevant parameters continuously since November, 1995. Our goal was to conduct an extended research project on the performance of such structures and on related techniques that promote a more "sustainable" use of resources. Since there are few straw bale houses in areas with cold wet winters, we hope that the information gathered will be very useful to anyone in interested in building a straw house on the East Coast. When the House was dismantled, the building materials were recycled.

How we built it

1. The foundation was poured, and steel rods (#4 rebar) were embedded into it.
2. Bales were impaled on the rebar, and stacked upwards in staggered rows like bricks. At each level two stakes of bamboo (grown on campus), wood dowels, or steel rebar were pounded in and through at least the course below to give the wall strength and stability.
3. A plywood frame called a bond beam was placed on the top course of bales upon which the roof beams bear. The bond beam provides extra stiffness in the walls, especially in the direction perpendicular to the plane of the wall.
4. Galvanized steel diamond mesh was pinned around the outside of the walls using "Robert pins" (big Bobby pins), and stucco (a plaster made from of 7 parts common bar sand, 2 parts lime, and 1/2 part Portland cement) was applied to protect the walls from moisture.
5. The roof was constructed using new and recycled wood. First a "bond beam" was laid on top of the walls for additional support. Then "I-beams" (14" TGI) were laid over the entire top of the structure. Next boards (3/8" OSB) were placed on top of the I-beams, and asphalt roll roofing applied to the roof. The roof was then attached firmly to the foundation with a series of long rods (#3 rebar with zinc-plated allthread rod welded to the upper end). Finally, the roof was insulated with 14 in. blown cellulose insulation made from recycled newspaper (R = 45). The final building was quite strong, and would have lasted decades had we not had to remove it.

Technical Details

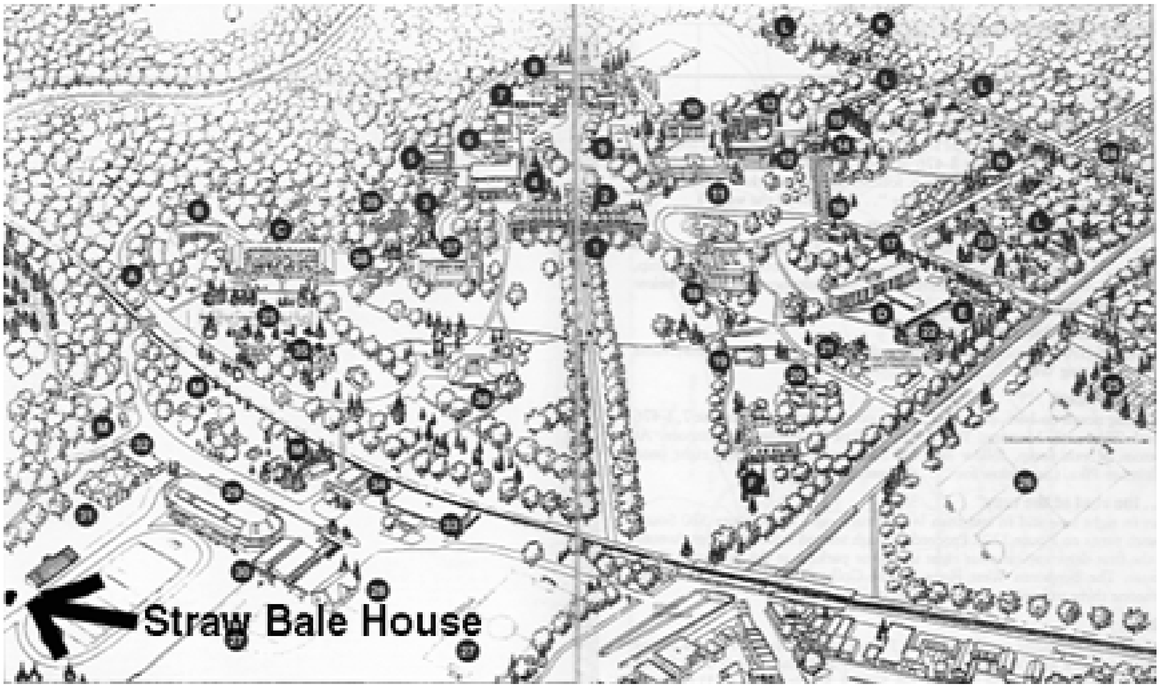
The concrete foundation of the straw bale house is a variation of a design used by Frank Lloyd Wright: a beam of reinforced concrete cast on a shallow gravel-filled footer with external insulation. Straw bales were used as forms during the casting process, as shown in the accompanying diagram. The (pink) extruded polyethylene insulation, though not a very environmentally-friendly material, allows the internal heat of the building to keep the ground from freezing under the foundation and obviates the need for a deep concrete footing. This shallow frost-protected foundation design has been in use in Scandinavian countries and performed excellently in our application. There was no measureable frost-heaving, despite solid 4-foot-deep freezes of the ground outside the house.

The bales, which were harvested from a field near Allentown, were laid like bricks in courses around the concrete foundation. The lowest courses were impaled upon the vertical reinforcing bar of the foundation; higher courses were pierced with bamboo rods harvested from Swarthmore College's own bamboo groves, as well as with wood and steel rebar spikes. Wire lath holding sand-and-lime stucco covered the exterior, and minimizes flammability. Conventional doors and windows were built into the strawbale walls, and a flat shed roof in two oppositely-pitched sections rested on the bondbeams of the uppermost course of wall bales. Twin telephone poles provided stabilization at the juncture of the circular and rectangular sections, and served to support the upper windows of the clearstory.

The Environmental Studies Straw Bale House Project was funded by a generous grant from the Educational Foundation of America, as well as the Roberts Engineering Fund of Swarthmore College. Special thanks are due the Swarthmore administration, Athletics department, Rainbow Awnings, and Scott Arboretum, for allowing temporary use of the site and other College resources. If you wish more information about the project, please contact Prof. Carr Everbach .

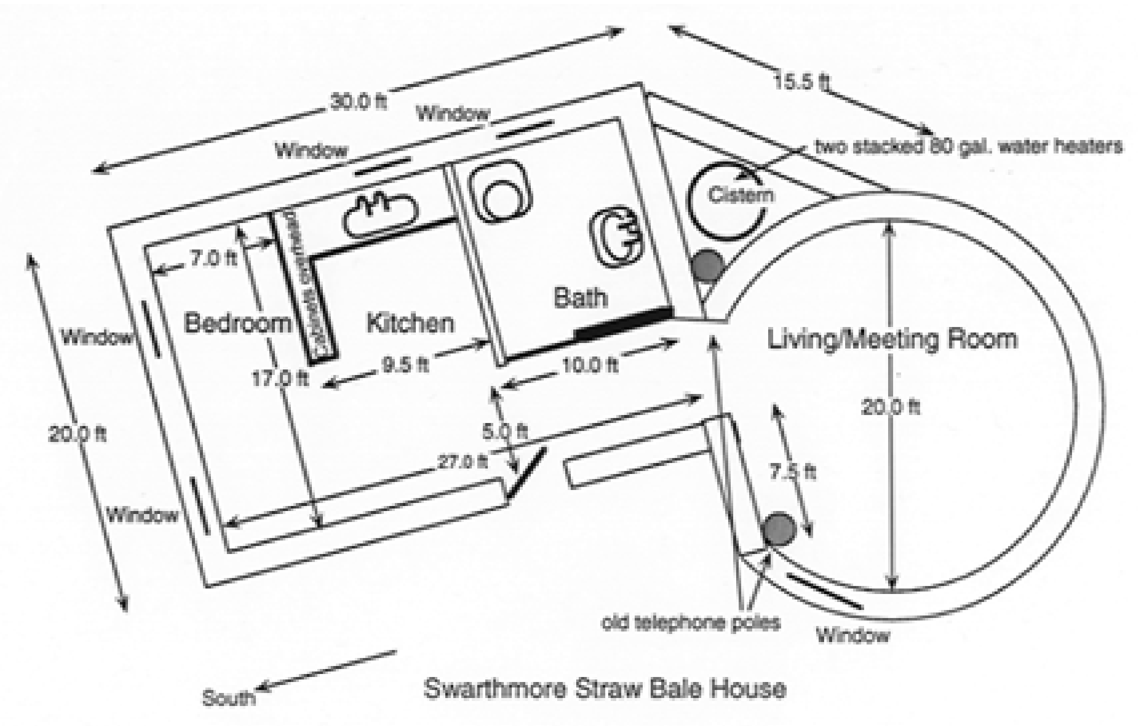
Campus Map showing Straw Bale House

The Straw Bale House at Swarthmore College was located next to the outdoor track, just South of the grandstand.



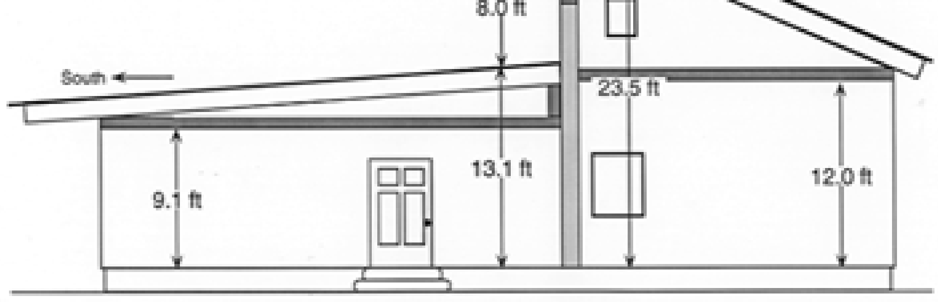
Straw Bale House Construction Details

We began by designing the floor plan and sectional elevation on a napkin during a mealtime brainstorming session in Spring, 1994. The rectangular part of the house mirrors that of Steve McDonald's straw bale house, and the round part was added for fun and to mirror the round architecture favored by many tribes of the Lakota and other Native Americans.



(Prof. Everbach had spent the Fall semester of 1993 teaching mathematics at Oglala Lakota College, located on the Pine Ridge Reservation near Rapid City, SD). The plans you see here shows the interior as finished, with interior walls and plumbing facilities (they were never added, since money and student interest largely dried up after the building envelope was complete). The wall dimensions are accurate.

Due to a suggestion by a local architect, who worried that the mating of our round room to the rectangular room would be a weak spot, we obtained two telephone poles from a local electric company and used them as stabilizers (as it happens, the straw walls they were meant to stabilize were never connected to them, and in fact, the walls were very stable without the extra support). Having the poles in place, however, allowed us to create a larger clerestory than we had originally envisioned, providing more light and solar heating gain in a more cathedral-like space.



The walls are thus mostly load-bearing, except for the part of the round room from the clerestory to the diameter. Without the two telephone poles, the 12-foot round room wall would probably have been too unstable to bear the asymmetrical weight of the shed roof.

For our foundation, we used a shallow frost-protected foundation consisting of a reinforced concrete beam poured on grade. The 2-in. thick polystyrene foamboard sunk into the ground about two feet deep provided sufficient thermal insulation to prevent water under the foundation from freezing

and causing heaving. Polystyrene is an environmentally undesirable material, but a small amount of it allowed us to avoid the four-foot-deep concrete foundations we would otherwise have had to employ. (For more info about this foundation system, call NAHB at (301) 249-4000).

You can see in the above photo that we used straw bales, staked into the ground with rebar, for forms for the foundation concrete pour. The first two courses were impaled on the rebar we left sticking up through the foundation, and subsequent courses were pinned with two stakes per bale of rebar, wood dowels, and bamboo from a local bamboo grove (thanks to the Scott Arboretum). For the round room, bales were bent by placing them over a rock and jumping on them. A plywood bond beam, with two-by-six ears hanging down, was fashioned to sit on top of the top course of bales.

Windows and doors were pinned in place with sharpened wooden dowels and had lintels placed over them to help them bear the roof loads. Lintels consisted of bale-width plywood pieces with steel angle-iron screwed to both (longer) edges. Racking has turned out not to be a problem, probably because the bales we used were especially good (double density: 56 lbs/ bale for a 2-string bale).

The bales had galvanized steel diamond mesh pinned (with "Robert" pins, since like big bobby pins) to the outside and covered in sand-and-lime stucco (troweled on). We tried various stucco recipies, and our best was: 7 parts bar sand, 2 parts lime, 1/2 part Portland cement, with enough water to reach the right consistency. The cement is environmentally undesirable, but a small amount of it goes a long way to keep the sand and lime together.

You can see Sylvia Kwake '98 cutting bamboo for pinning bale courses together, below. The roof system was long pieces of pressed wood "I" beams (TGI), which are very strong and lightweight in the vertical direciton, bearing upon the bond beams sitting atop the straw walls. Oriented strandboard decking was screwed into place on top, drywall (gypsum board) screwed in underneath, and the gap filled with blown cellulose insulation made from recycled newspapers. Since the TGI beams were 14-in. deep, the R-value of the blown cellulose was calculated to be around 48 (although settling of the cellulose eventually produced a depth of 11 inches, R = 40).

As you can see in the image to the left, the telephone poles were spanned by some two-by-twelves which in turn were used as the bearing surfaces for the upper ends of the round room TGI roof members. Highly energy efficient windows were installed in the clerestory and any wall spaces infilled with straw bales. The roof decking was covered in asphalt roll roofing (neither esthetically or environmentally desirable, but cheap and relatively easy to install with student and volunteer labor). A whitewash-with-pigment color coat was applied to part of the exterior stucco to provide a more uniform appearance, but student (and professor!) energies for esthetic niceties gradually waned as the building envelope was complete.

In the interior (round room shown here), slate flagstones were potted in rock dust (for later easy removal) over 6-mil poly vapor barrier sitting on 4-in. gravel. The flagstones provide a concrete-free solid surface as well as a heat storage element, since sunlight from the clearstory warms them during the day and they re-radiate the heat at night. The walls are currently un-stuccoed, but something like a nice light blue pigment would give the interior space a more homey look. Rebar tiedowns connect some of the TGI roof beams with the concrete foundation and run up the inside walls from floor to ceiling. The are currently exposed but could be encased in plastic pipe or other interior finish.

Temperature and humidity sensors were implanted in the walls and data collected during four winters provided an estimate of the net R-value of the house: R-45. The building was used as a laboratory for the study of Straw Bale construction in the northeastern U.S. and occationally as a meeting, rehearsal, and party venue.

Proposed subsystems of the Swarthmore Straw Bale House

The house was designed to be independent of the energy and water "grid". Water could have been kept in a refillable cistern consisting of two 80-gallon hot water tanks that the Buildings and Grounds staff had no more use for. Passive solar hot water heaters could have been implemented to circulate and heat the water in one of the tanks. Likewise wind turbines could have been added to each of the two tops of the telephone poles (records of wind speed at the site showed that such a system could have been practical) and photovoltaic arrays could have provided DC electrical power to heat or light the interior. The bathroom, which was never implemented, could have contained a waterless "composting" toilet, either purchased or of our own design. Food wastes comparable to what a small family would produce were actually composted both on-site (using a worm-based process: red wigglers) and off-site (using an aerated outdoor heap in the Swarthmore College's Nursery area). A natural landscaping plan was devised and a proposed graywater treatment facility were considered for the project. No one actually lived in this building due to zoning and College liability issues but over 3000 people visited it during its four years of existance, including building code officials, potential owner-builders of strawbale houses, and many schoolgroups.

The main reason these subsystems were never implemented was that, after the building envelope was completed, the students who had built it had graduated or had moved on to other projects. The professor, who had put in over 1000 hours of his own time on the project, was too exhausted to push the finishing touches. The house served its primary purpose of educating those who built it and also served as a laboratory for the study of the performance of a load-bearing strawbale house in Pennsylvania. There seemed little point in making the interior into a livable space since no one was to live there, and, with the exception of two student dance parties and one staff Holiday party, there was little interest in the College community in using the structure for meetings or rehearsals. However meaningful data on performance of the house itself in our climate was taken and the disassembly process documented for the benefit of the straw-bale community.

Straw Bale Replacement Experiments

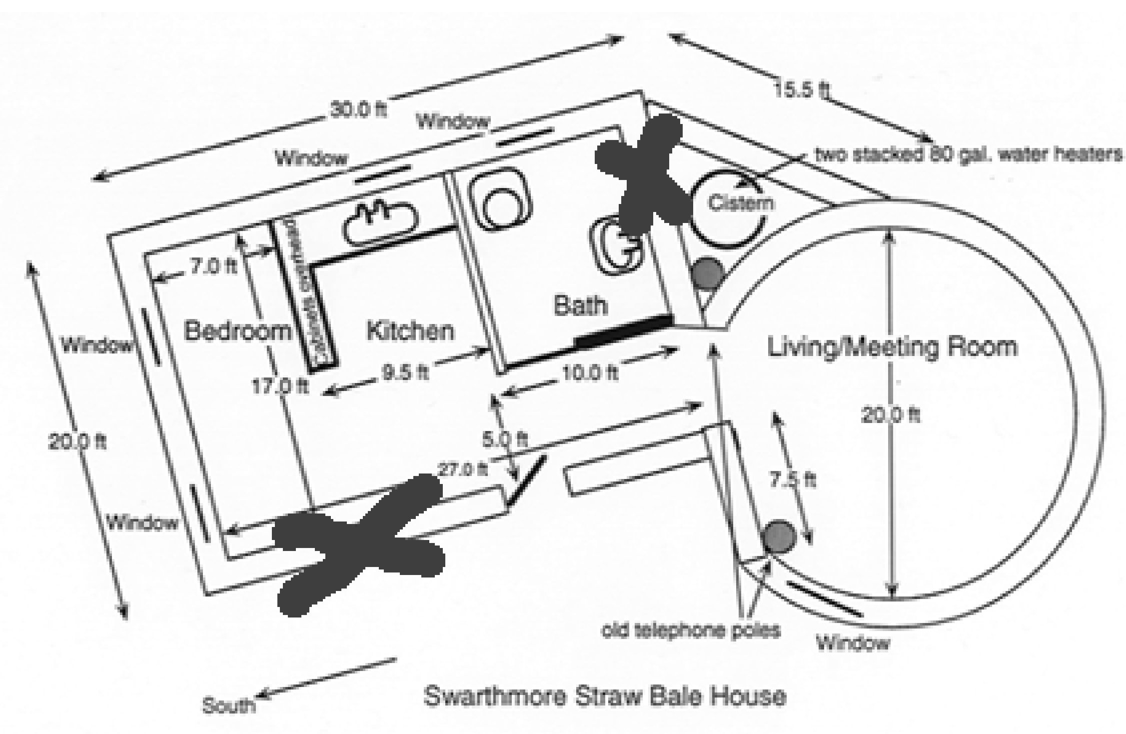
by John Leary '00, Adrian Wilson '00, and Prof. E. Carr Everbach

work performed June June 3-4, 1998, writeup June 5, 1998

Introduction

In straw bale structures, mold infestations can become very problematic. In the presence of moisture, molds can readily attack and degrade the cellulose fibers of which straw bales are made, weakening the supporting walls. If left uninhibited, and if moisture remains, mold spores may spread, further weakening walls while inviting infestations of mold-devouring insects. Any water leakage into bale walls, therefore, may necessitate the prompt removal of the plagued bales (unless complete drying is possible) before wall conditions degrade to a dangerous degree. These experiments investigated the possibility of *in situ* straw bale replacement on load-bearing and non-load-bearing walls in the (Nebraska-style) Straw Bale House at Swarthmore College.

Two walls were selected in the Straw Bale House; in each wall, four bales from were designated for removal and replacement, as indicated with X's on the floor plan.



Non-load-bearing wall bale replacement

In the non-load bearing wall, Professor E. Carr Everbach selected four adjacent bales (Figure 1).

Workers ascertained the location of the imbedded support rods within the bales (wood tomato stakes, bamboo poles, or steel rebar) by probing the bales with a thin metal strip. Once pinpointed, the locations of the rods were marked with spray paint on the interior bale surface. Before beginning the bale removal process, the bond beam above the non-load bearing wall was propped up by four ten-foot-long two-by-fours, two on either side of the wall. The two-by-fours provided just enough lift to support any of the minimal roof weight. Access to the four marked bales was limited to the interior side of the wall, as the stucco and diamond lathe barrier covered the exterior side (Figure 2).

Figure 1, showing non-load-bearing wall marked for in-situ bale replacement. This wall is stuccoed only on the outside surface.

Figure 2, showing non-load-bearing wall outside stucco surface prior to in-situ bale replacement.

Bale extraction

Before removing any individual bales, workers needed to cut the bamboo, wood, and steel spikes that were driven through the bales. These rods were located approximately 6-8 inches from the surface of the wall. To reach these supporting rods, the straw constituting the first bale had to be picked out by hand (handsaws aided in loosening the straw to allow for easier access to the rods). Once the rods were exposed, they were cut with an electric saw ("SawsAll"). Sacrificing the first bale allowed for more complete removal of the remaining bales (i.e. maintaining as much of the bales' integrity as possible). The hole left by the removal of the first bale was instrumental in pulling and bending (to a slight degree) the second bale to expose the closest supporting stake. This stake was cut with the electric saw, and a similar bending and pulling technique was employed to reach remaining support rods. Workers were able to pull the second bale up off of the last support rod projecting from underneath to complete its removal. This second bale was completely intact. The third and fourth bales were removed in similar fashion, using pulling and bending techniques to expose supporting rods. Many of these rods could now be pulled out by hand due to the space created by the absence of bales one and two. Rods not loose enough to be pulled were cut as before. Both binding twines of the third bale (upper left) snapped (or were accidentally cut) during the removal procedure. The bale was recovered in a few large pieces. Because of the large gap created by the three missing bales, bales on the upper tier of the wall required additional support to inhibit collapse. Workers used vertical supports of cut wooden stakes or bamboo poles which had been previously extracted before attempting removal of the fourth bale. The fourth bale was then successfully removed.

Figure 3, showing four bales removed, with poles (and plastic milk crate) holding up weight of bales above removed ones. Visible in the hole is the underside of the galvanized diamond lathe holding exterior stucco.

Figure 4, showing outside stuccoed wall after removal of bales. The stucco is cracked and would have to be re-laid after the operation.

Bale replacement

The four bales in the non-load bearing wall were replaced in the same order in which they were extracted. Firm, thin metal sheets placed around the new bales were utilized to reduce friction as they were slid into place. The first bale fit easily into the bottom gap, with minimal force. Previously recovered steel rebar spikes were then driven through the new bale to reestablish out-of-plane support. Replacing the second bale required an adjustment of our temporary vertical supports to free the gap. The bale was then shoehorned into place, using the metal sheets as guides, in a similar manner as the first. It was also spiked into place. The third and fourth bales required manual, vertical support of upper bales by one worker as a second fitted the replacement bales into place. The spaces left in which new bales would be positioned were significantly smaller than the previous two gaps, and greater amounts of force were necessary to drive the bales into place (the reduced vertical clearance indicates that compression/settling had made the original bales somwhat less thick vertically than the replacement bales). The new bales were then spiked diagonally from their facing sides up and down into the adjacent bales (Figure 5).

Figure 5, showing completed wall with four new bales inserted. When two-by-fours were removed, the wall settled back to its original configuration with no obvious negative consequences.

Labor

Bale removal and replacement for the non-load bearing wall was accomplished by two workers in approximately 7.5 hours. It should be noted that the primitive tools used for this project, as well as our attempts to keep bales intact, slowed progress tremendously. One additional worker would have been useful for this bale removal and replacement experiment, especially during the replacement procedure.

Load bearing wall bale replacement

Figures 6 and 7, showing hole in load-bearing wall after removal of five bales, and completed wall with new bales inserted.

Bales were selected for removal and replacement in the load bearing wall in a similar manner as for the non-load bearing wall, while avoiding bales extending into the corner or under the main supporting lintel above the inner doorway. The bond beam was once again propped up by four two-by-fours, two on either side of the wall. A temporary support lintel was manufactured using a board, approximately six feet long, and a corresponding length of 2-inch angle iron. The board was bevelled using a belt sander on the side opposite the angle iron and driven into the bale wall (until meeting the support rods within the bales) above the bales designated for removal. Two additional two-by-fours propped up the temporary lintel. This temporary lintel solved the support problem we faced while trying to replace bales previously in the non-load bearing wall, by not only keeping higher bales from falling, but also distributing some of the load to adjacent bales.

Bale extraction

Bales were removed from the load bearing wall in a similar manner to those removed in the non-load bearing wall, except the workers were not concerned with keeping these bales intact. Extracting bales in smaller portions expedited the process, and also allowed for easier access to hidden support rods. This extraction process was also aided by an additional two workers (for a total of four) and access to the bales from both sides of the wall (Figure 6).

Bale replacement

Bales in the load bearing wall were replaced in a similar manner as those in the non-load bearing wall had been. However, the bales in the load-bearing wall had supported a greater weight than those in the non-load bearing walls. Consequently, bales seemed even more tightly compacted. The vertical gaps for new bales appeared to be significantly smaller than the actual size of the replacement bales (which had not been under such constant and prolonged pressure). Accordingly, more force was required to place the new bales. Again, the advantages provided by four workers and access to both sides of the wall were manifest. Replacement bales were spiked as before with supporting rods. The temporary lintel successfully braced bales on the upper tier, since they did not require additional support as the upper bales in the non-load bearing wall had. When all four bales were in place and the two-by-fours propping up the bond beam were removed, the new bales assumed a noticeably tighter configuration (Figure 7).

Labor

Bale removal and replacement for the load bearing wall was accomplished by three to four workers in approximately 5-6 hours. Progress was aided in this experiment by the existance of the temporary lintel, more workers, and access to both sides of the load-bearing wall.

Additional Observations

Insects discovered during preliminary investigations of the straw bale house include the cellar spider, blue-bottle fly, carpet beetles, a species of social wasp, roughback stink bug, and a small unidentified moth. Swarthmore College instructor Tom Valente identified the specimens recovered, and indicated, in accordance with our description of the straw bale house, that the cellar spider and the carpet beetles were probably permanent dwellers,while many of the other insects were "just passing through". The cellar spider lives in dimly lit, dry environments, making the unoccupied Straw Bale House a perfect home. Carpet beetles feed on dead animal tissue, glues, and even the adhesive on the underside of carpets (hence, their common name). They were most likely feeding on other insects that had visited the straw bale house and died there. While their presence could be an indication that other insect species may be dwelling in the straw bale house, we have yet to document any such infestation. Neither have we witnessed any rodent nests within the straw walls. It was noted during construction that some water leakage into the straw bale house resulted in the formation of mold. As the mold traveled farther down the walls, it was accompanied by hosts of spider nests, apparently following the small insects that may feed on the mold.

The Dismantling of Swarthmore's Straw Bale House

Starting in June, 1998, we began dismantling the Straw Bale House at Swarthmore College. We did this because we felt we had obtained all the information we would likely obtain, other than the very long-term performance of the structure (there was negligible settling or other problems in four years after the initial few weeks of wall compression). A new tennis facility was to be constructed by the College nearby, and the Athletics Department, who had graciously loaned us the site for the Straw Bale House, was interested in reclaiming their land for use as a shot-put and archery area. And finally, the responsibility for maintaining the house (fixing broken windows vandalized by local hoodlums) rested with the professor, who had grown weary of worrying about what might happen in or to the house, as it was policed infrequently.

We began with removing the floor, because we did not want the rain to puddle on the moisture barrier in the floor. Once establishing a way to drain the house, we focused our efforts on dismantling the roofs on the rectangular and circular rooms. Our next step was to tear down the walls of the circular room, and then the entire triangle room. We were then able to take down the walls of the rectangular room. Finally, all that remained was the concrete foundation which outlined the shape of the two rooms. Our final task was to find new homes for all the materials.

While no humans ever lived in this straw bale house, we found several natural inhabitants.

Here is a picture of three of the Straw Bale House Destruction Crew: from left to right, John Leary, Josh Bramucci, and Holly Blanchard.

Removing the Floor

The floor consisted of 6 in. of unwashed gravel overlain with 6-mil polyurethane sheet, topped with flagstone slabs potted in about 1/2 in. rock dust (see Figure 1). We began by prying up the flagstone slabs with a crowbar and transporting them outside with wheelbarrows. The slabs had been sealed down in concrete in one small section of the rectangular room, so we broke those slabs free with a sledge hammer.

Figure 1: The four layers in the floor: 6 in. of unwashed gravel overlain with 6-mil polyurethane sheet, topped with flagstone slabs potted in about 1/2 in. rock dust

Once the flagstone had been removed, we removed the thousands of pounds of stone dust. The layer of stone dust ranged from .5" to 2" in depth. In areas with the least dust, we cut squares in the plastic underneath and carried the stone dust out in little sections. In areas with thicker layers of stone dust, we shoveled the dust into a wheel barrrow. The plastic sheets underneath were easily pulled up.

Once the stone dust and plastic sheets had been removed, we were left with a gravel floor which allowed rain to drain out and humidity to permeate up into the once cool, dry room.

Taking off the Roof

The main components of the roof were tar paper, decking, insulation, and the framework (I-beams and facia). Small roofing nails and hardened tar held the asphalt roofing over 4' by 8' sheets of oriented-strand-board (OSB). Larger 3" nails firmly secured the sheets of wood to the I-beam framework. The decking was secured on 35 foot long I-beams. Sheets of drywall lined the ceiling beneath the I-beams. The drywall supported channels of insulation (blown cellulose newspaper treated with boric acid) which lay among the I-beams. The ends of the channels were sealed by facia made of extra sections of I-beams. All removed materials were separated and stored for recycling purposes.

We started on the western-most side of the rectangle room which was the lowest section of the roof. We first began unpealing the roofing paper to reveal where each of the unweathered 4' by 8' decking started and stopped. We then removed the 3" nails with hammers and used a crow bar to pry up the large sheets of wood. Next we moved up the gradual incline continually removing decking and eventually revealing channels of insulation which lay between the I-beams (see Figure 1).

Figure 1: student workers peel off asphalt roll-roofing and pry up oriented-strand-board four-by-eight sheets (1/2 in. thick) to reveal channels holding blown cellulose insulation.

We used some of the 4' by 8' Oriented Strand Board (OSB) decking as platforms to stand on while shoveling the insulation (see Figure 2). The top layer of insulation had been noticeably discolored, and it had settled tightly in the channel, leaving a 3-inch gap (out of 14 inches total vertical space between drywall ceiling and OSB decking).

Figure 2. The insulation is shoveled into plastic trash bags.

After placing the insulation in bags (see Figure 3), we attempted to remove the drywall sheets on the ceiling of the rectangle room. Because of the fragility of the drywall and the countless nails holding the sheets to the bottom of the I-beams, we were unsuccessful at keeping them in reusable condition (see Figure 4). We removed all the decking, roofing material, insulation, and drywall on the rectangle room with the exception of one small section next to the circular room which we kept for accesss to the slanted roof (see Figure 5).

Figure 3: Shown here are bags of blown cellulose insullation ready to be transported for reuse.

Figure 4: Seen at the bottom of the channels are the sheets of drywall which were too fragile to be taken down in complete pieces.

Figure 5: The remaining roof at the top of the picture was left intact to support a ladder which would lead to the top of the roof of the circular room.

The roof above the circular room posed many more complications. The roof was at a 30 degree slant and was up to 10 feet higher from the ground than the rectangular room (see Figure 6). We secured ourselves with body harnesses to the two telephone poles. We also nailed small pieces of 2 by 4's to the decking to serve as foot holds.

Figure 6: Removing the roof on the circular room was a formidable task because of the steep incline.

Similar to the rectangle room, we began at the lowest part of the roof and worked our way up. The first priority was to use hammers and crowbars to pry up the 4' by 8' decking, revealing the insulation. It was too much of a struggle to shovel and bag large quantities of insulation at such a great angle, so I came up with an alternative method. We smashed large holes through the drywall at the lowest points on the ceiling. The insulation was then able to slide down the channel made by the I-beams and drywall and through the holes in the ceiling creating one large pile of cellulose on the floor twenty feet down. It then did not take long to bag the insulation on solid ground.

Once all the drywall, decking, and insulation was removed from the entire house, it was time to remove the I-beams (see Figure 7). But before we could remove them, we first had to remove an overhang off the west side of the circular room. We cut through the 3 or 4 posts supporting it from the bottom, and then we cut through the hinges holding the top of it to the side of the roof. It fell with a tremendous crash.

Figure 7: The roof of the circular room after all decking and insulation had been removed.

The 14 inch I-beams were supported by three methods: 1) facia (cut pieces of I-beams 1.5 feet long which filled the gaps between beams on both ends), 2) the I-beams were screwed into the bond beam and extensions from it, and 3) thin metal bracing which zig-zagged among the middle of the I-beams to prevent racking. While there were only nails holding the decking to the I-beams, there were only screws supporting the I-beams in all three of the methods listed above. We started with the beams on the edges and moved inward simply removing all the screws using a phillips head drill bit. We then tossed the 25 feet long I-beams off the roof by pulling them off with rope and by lifting an edge, walking along the bond beam, and tossing the end off the side of the roof (see Figure 8).

Figure 8: We began removing the I-beams from the side and worked our way toward the middle.

Dismantling the Straw Bale Walls of the Circular Room

Before we could dismantle the walls, we first had to remove the four clearstory windows at the top of the wall of the circular room (see Figures 1 and 2). Each window sat in a type of 'box' of wood which comprised of 4-6 pieces of wood. The wood was connected to the window on all four sides and acted as a brace in which the window could be secured into the wall. We removed the window on the right by cutting two 2 by 4's; one was slightly longer than the width of the window, and one was slightly longer than the height of the window. The two pieces of wood were hammered into the 'box' to relieve the pressure exerted on the windows by the surrounding wood. The window could then be pushed out. The other three windows were removed by simply cutting all rubber cement, nails, wire lathe, and screws holding them to the surrounding wood. We then tied ropes around the large windows after gently rocking them out of their confinements, and we lowered them to the ground. After removing all the windows, it was easy to remove all the wood and bales which supported the top part of the wall.

Figure 1: At the top of the Straw Bale House, the four windows comprising the clearstory.

Figure 2: The clearstory windows from the opposite direction. Wooden frames held the window in the walls of straw and wooden beams.

Figure 3: The bond beam which encompassed the top of the circular wall.

Our next step was to remove the bond beam which encompassed the the top of the circular wall (see Figure 3). We cut it into six large sections and heaved each part off the wall, bringing some of the connected wire lathe with them (see Figure 4). The wire lathe plastered with stucko covered all the walls, yet it came off rahter easily when we pulled it down in large sections. Most of the stucko crumbled off as soon as the lathe bent a little.

Figure 4: A worker cuts the bond beam into sections. As the bond beam is pushed of the top of the wall, it would pull down the wire lather conneceted to it.

Eventually, all that was seen was a large open cylinder of straw bales. Each 40" by 21" by 16", 54 lbs bale had approximately two or three lengths of steel, wood, or bamboo supporting it into the bales below. With one person on both sides of the bale pulling up on the plastic string, the bales could be yanked straight up out of their confinement (see Figures 5a and 5b). The removed bales were stacked and covered with a tarp.

We preceded removing bales in a counterclockwise direction around the room (see Figure 6) until we reached the area where the triangle room meets the circular room. We then concentrated our efforts on removing the triangle room before we finished with the circular wall.

Figure 5a: A Straw Bale worker removes the very first bale.

Figure 5b: Straw Bale workers John Leary (L) and Josh Bramucci (R) remove a bale.

Figure 6: The wall was removed in a counterclockwise direction.

Deconstructing the Triangle Room

The decking of the triangle room was removed in a similar manner as all the other decking. 2 by 4's, supporting the decking, stretched across the distance of the small room. Those 2 by 4's were connected to the wall of the rectangle room and the bondbeam over the outside wall of the triangle room. All of those pieces of wood were easily unscrewed and removed. The bond beam over the wall was easily lifted off, and the bales of the wall were removed in the same manner as the bales of the circular wall.

Here is a picture of the triangle room with only the decking removed:

Dismantling the Walls of Swarthmore's Straw Bale House

The next step was to remove the I-beams over the rectangle room, but first we had to quickly remove the small section of the roof left intact for access to the roof of the circular room.

The I-beams over the rectangle room proved to be a fairy tale compared to the problematic I-beams over the severely slanted circular room. They, too, were supported with facia, screws into the bond beams, and metal strips, but the straight walls (easier to walk on) and the minimal incline allowed for easy removal. Simple removal of all screws allowed us to lift the edges of the beams, walk along the bond beam, and toss the 35 feet long beams over the side of the roof.

The four bond beams on the walls of the rectangle room were simply secured by the weight of the roof, so they were easily pushed off the tops of the walls (see Figure 1). The bales were removed in the same manor in which the bales of the circular room were removed.

Figure 1: Seen here is the bond beam on top of the rectangle wall.

Reusing and Recycling All Materials in the Straw Bale House

Our goal was to reuse or recycle 100% of all materials in the house.

Material	Fate
asphalt roofing paper	
4'*8' decking	
25'/35' I-beams	
bent nails and screws	recycled at Swarthmore Recycling Center
reusable nails and screws	
straw bales	
loose straw	
small wood (2*4, 2*6, small sheets)	
angle irons	reused by Swarthmore College Engineering Dept.
wire lathe	
stucko	
broken door	
telephone poles	
large wood (2*6 or 2*8 greater than 10 feet long)	
windows	
concrete foundation	
metal sheets which supported I-beams	
steel rebar	
wooden stakes	
bamboo stakes	

Inhabitants of the Straw Bale House

The natural inhabitants of the straw bale house appeared to be those which liked the seclusion of it.

Figure 1: A carpet beetle, who doesn't eat straw but possibly feeds on mold or other insects.

Figure 2: Robin's eggs. Several bird's nests were found under the rafters at various places.

Figure 3: The mold fugus, with flower, that grew on some bales that had been lying outside the house for several years.