SETTLING CELLULOSE SOURCE OF STRATIFICATION

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ABSTRACT

Green building encompasses more than installing the latest piece of machinery to recycle or reduce energy usage. In many cases it can be as simple as redesigning a wall assembly to mitigate thermal bridging allowing the systems already in place within the building's envelope to use less energy to achieve the same or even better levels of warmth.

Contractor Robert Bolman designed the wall assembly in his house in an attempt to reduce thermal dissipation due to thermal bridging across the wooden joints. Our experience of the interior space was thermally comfortable, even though the wood-burning stove – the main source of warmth, was not lit and the day was uncomfortably cold. Bolman wanted to know if the application technique of the cellulose insulation in the wall had settled causing the wall assembly to be less efficient. We wanted to know if the changes the designer introduced were responsible for the remarkably comfortable interior temperatures.

Through various tests we determined that the wall design was very efficient having only a few places, mainly the connections between ceiling, walls and floor where thermal bridging was evident.

1. INTRODUCTION

On a corner lot in southwestern Eugene, Oregon a tiny eco-village has sprung up. It began as a real estate investment in 1981 and soon turned into a landscape of experimental buildings. From the standard 1930's home that was originally on the lot to extremely experimental yurt-like structures made of cardboard and corrugated plastic election signs. The building we are focusing on looks, from the exterior, like typical multi-family housing: it is a U-shaped, gable roofed triplex with cedar shake siding. Inside the building, the walls were of plywood covered in plaster and paint, the ceiling was exposed log beams with wooden boards as decking. The floor was compressed sand, earth, and chopped straw, held together with linseed oil. The real difference, however, between this building and most contractor-built homes were the walls' built interiors.

In an attempt to reduce heat loss during winter months due to thermal bridging, the stud wall assembly was redesigned so that each vertical structural member consists of 2 2x3s separated at top and bottom by 2" wood gusset. The wall itself was then filled in with lightly compacted cellulose insulation. Our mission was to discover whether or not this method was successful in decreasing heat loss through the wood of the wall.

2. THE PROBLEM & HYPOTHESIS

In an effort to stay as close to the earth as possible in both building materials and energy consumption, a unique construction method and an alternative type of insulation were used in the wall assemblies. The construction method attempted to limit thermal bridging through the studs by allowing no single piece of wood to contact both the interior and the exterior of the wall. By using organic cellulose insulation, synthetics were avoided in the wall assembly. However, due to the powdery nature of the cellulose insulation, significant settling of the insulation is expected in these situations. This settling of the cellulose insulation led us to this hypothesis: the deep pack cellulose insulation settling within the wall assembly created a temperature stratification of 40 degrees.

3. METHODOLOGY & EQUIPMENT

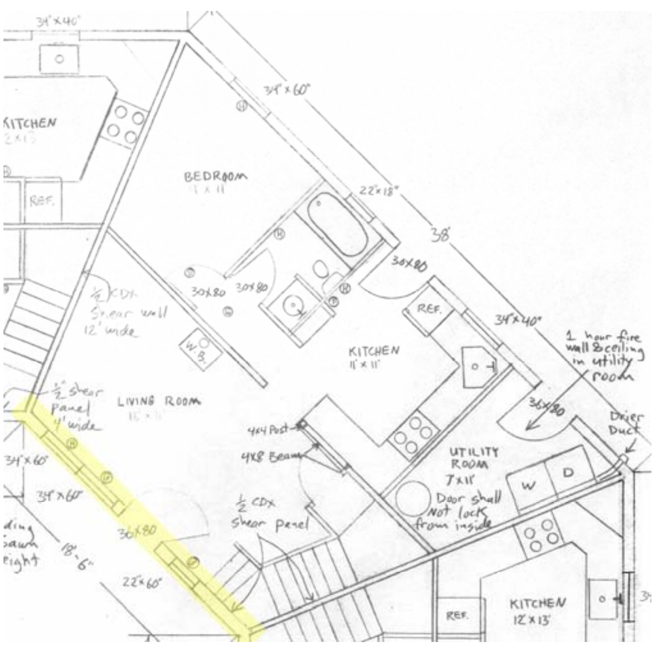
In order to test our hypothesis, it was be necessary to get an accurate image of the temperature conditions along the wall. To do this, we set up a regular grid system covering the area of the wall at regular intervals. Then, using a Raytek Non Contact Thermometer Gun ®, we tested the temperature at each point in the grid. This method was used at the same locations on both the interior and exterior of the building. We then repeated this procedure at the same place at a different time of the day. Using these data we found the mean of all the data collected at each point in the grid and used that as our temperature.

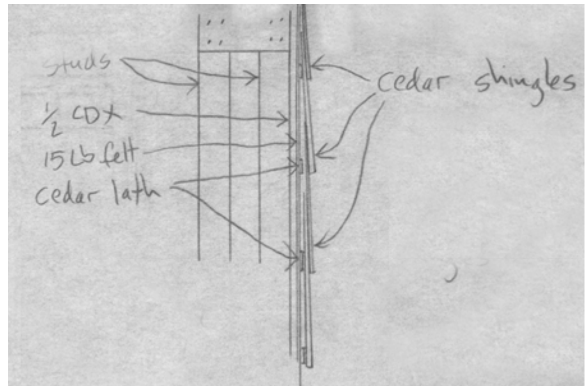
Finally, we verified our findings with a Fluke Ti R1 thermal imaging camera. (2)

4. RESULTS

The first image we have included is a contractor provided section of the wall assembly we studied in the complex. As can be seen from the section, the thermal bridging caused by a typical stud assembly has been interrupted by the 2" thermal gap between the two 2"x3" studs.

IMAGE 1: FLOOR PLAN (3)





IMAGES 2&3: WALL SECTION (3)

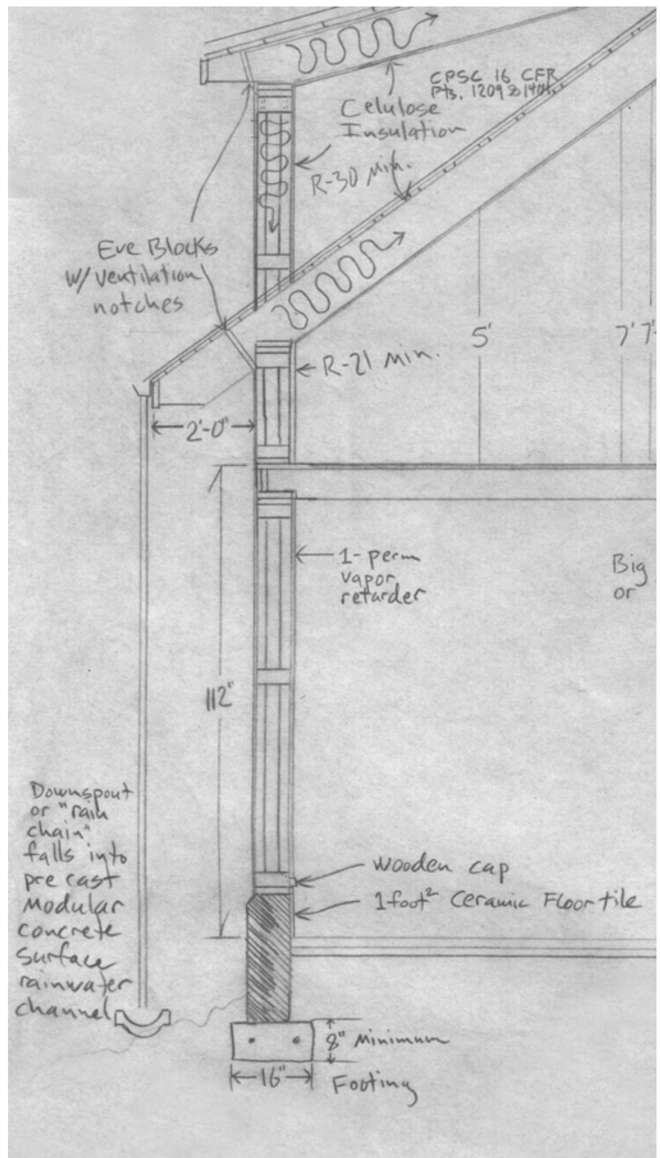


IMAGE 4: FEBRUARY 9, 2009. 10 AM

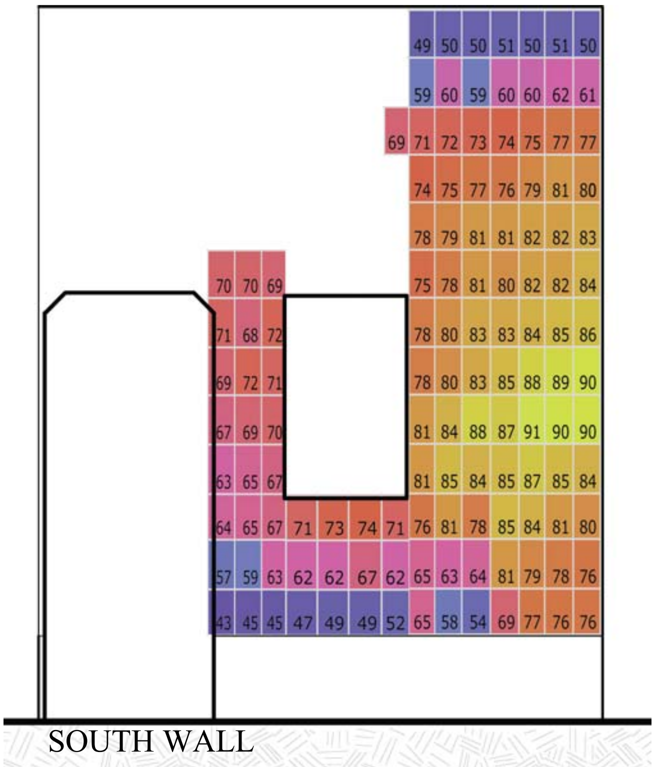
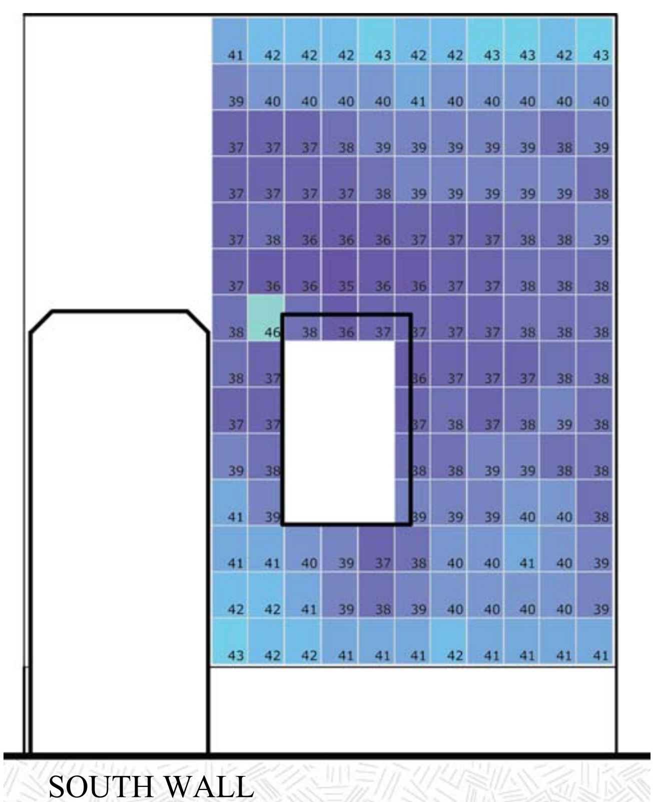


IMAGE 5: FEBRUARY 20, 2009. 8 PM



5. ANAYLYSIS & DISCUSSION

Results from Monday 9 February 2009 (10:00 am)

We set up a grid and took exterior surface temperature measurements with the Raytek Non Contact Thermometer Gun ® while the wall was receiving direct sun, but was still chilled from the previous night. In this way we hoped to find out how solar gain affected the wall. We believed that any thermal bridging on the exterior would show up as cooler zones. The results from this method of testing: cooler areas around the window, door, and the top and bottom plate of the wall - having solid wood members rather than the split studs utilized elsewhere - seemed to corroborate our beliefs. It should be noted the cool bands at top and bottom accrue less solar gain due to shading from a short eave and rosemary bushes respectively (see Image 3). This ensured nighttime temperature data gathered (see Image 5) showing elevated temperatures in these regions would not be the product of solar heat gain but would instead be evidence of heat loss from within the building.

Temperature Gradient Key

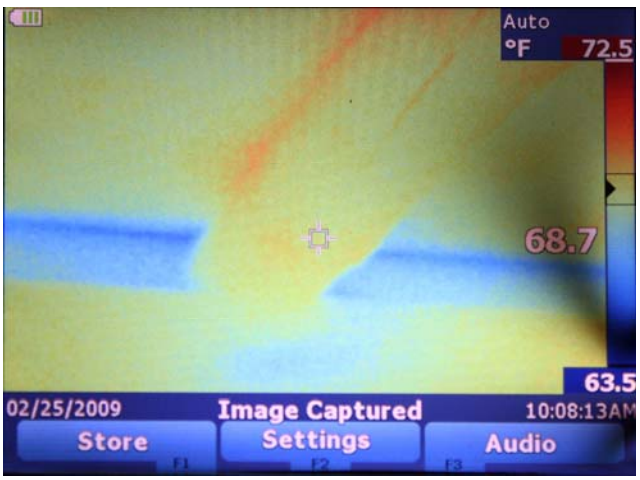
Results from Friday 20 February 2009 (8:00 p.m.)

The preliminary results seemed to show a higher average ΔT at the middle of the wall. Both the lowest and highest rows of data collected on the wall have the smallest difference in temperatures, making them the areas of interest for further analysis. Smaller differences in temperature could be either a thermal bridge or a proposed pocket in the insulation. The average temperature difference for the measured wall area is 7 degrees. The area that appears to have the largest ΔT, and thus the best performance, is directly over the window, with differences being around 10 degrees. The area performing the worst is the very top of the wall assembly, near the roof connection. This area typically has a continuous plate to support the trusses, possibly creating a thermal bridge, or the problem could be due to settling of the blown in cellulose insulation. The second area of interest lies at the bottom plate where the wood wall meets the rastra foundation. The data collected from the bottom of the wall, led us to conclude the likelihood of thermal bridging as opposed to insulation settlment as the cause of temperature stratification across the wall. This conclusion was substantiated by the thermal images obtained the following week (see images 6 & 7).

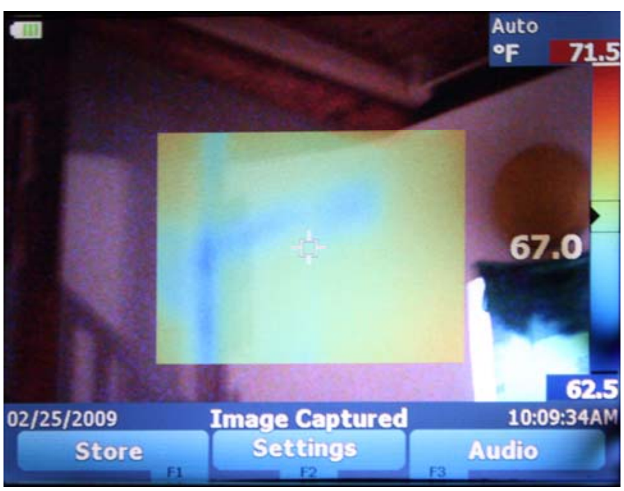
Results from Wednesday 25 February 2009 (9:00 am)

Sarah Helmers, an energy management specialist from EWEB's Residential Energy Management Department, came out to our case study site and took pictures of our case study wall using her thermal imaging camera. We found that the wall, as a whole, was doing very well. By and large there was no thermal bridging apparent within the wall itself, not even over the studs. The only thermal weaknesses found were at major connections such as the ceiling plate (see image 6) and corners where two walls meet (see image 7) which is unavoidable (2).

<u>IMAGE 6: ROOF PLATE AND LOG RAFTER</u>



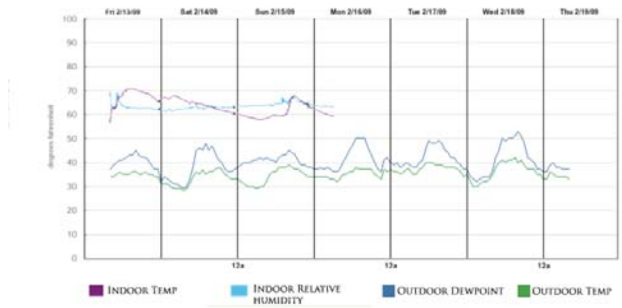
<u>IMAGE 7: SOUTH & EAST WALL CONNECTION</u>



Results from February 13–19 2009 (8:00 am installation)

This graph shows the indoor versus outdoor conditions. We only had the Air Advice Sensor for 3 days but have included the available outdoor data for the entire week in order to better establish baseline. The indoor relative humidity remains within a narrow band, interior temperature fluctuations though outside of ANSI/ASHRAE 55-2004 (6) were acceptable to the residents we interviewed (2) who were accustomed to these conditions.

<u>INDOOR VS OUTDOOR CONDITIONS</u>



6. CONCLUSIONS

Based on the results of our preliminary tests, it appeared that the center of the wall, especially the area surrounding the window was well insulated having the largest ΔT. We attributed this to settling of the insulation.

Further testing revealed that the largest temperature differences were occurring at the top and bottom of the wall. This led us to believe that thermal bridging, possibly in combination with the insulation settling, could be the cause of the temperature stratification.

Final testing via thermal imaging camera showed that the walls were actually very thermally sound with no bridging whatsoever - barring connection points. This led us to conclude that Bolman's 2x3 combination wall stud was successful in mitigating thermal bridging. Additionally it showed that his choice of deep pack, blown in cellulose insulation was highly effective in maintaining interior temperatures. This conclusion was further supported by the EWEB energy consumption graph for that residence which shows the extremely low electricity draw from the time Bolman took up residence there in October 2006 (4).

In the process of taking data, specifically that from the thermal imaging camera and the Air Advice Sensor, we learned that at least one weakness in the wall assembly was the rare settling of the cellular insulation (see image 8). Additionally the Air Advice Sensor showed us that the thermal living conditions inside were consistently at the low end of ANSI/ASHRAE 55-2004.

Interestingly, the graph provided by EWEB of the electrical energy use shows the occupants use less energy than a typical "thrifty" (2) user. This may be due to the minimalist lifestyle permeating Maitreya Eco-Village.

EWEB ENERGY CONSUMPTION GRAPH

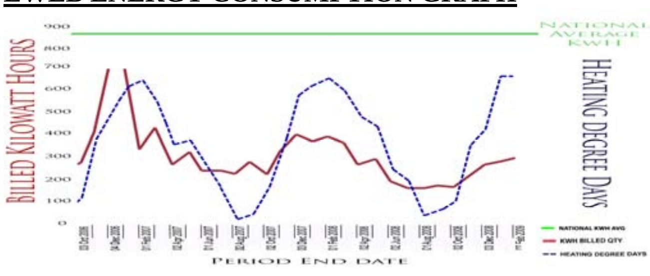
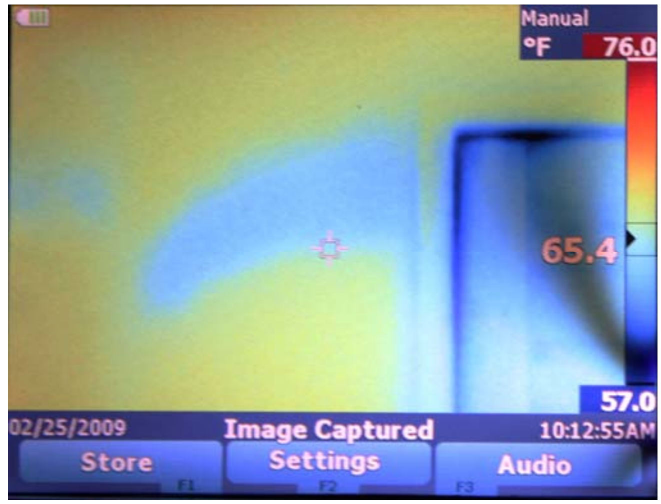


IMAGE 7: SOUTH & EAST WALL CONNECTION



7. ACKNOWLEDGMENTS

Robert Bolman of Maitreya EcoVillage. Thank you for lending us your home for study.

Sarah Helmers, Energy Management Specialist II, Residential, EWEB. Thank you for lending us your time, expertise and equipment.

8. REFERENCES

1. An Inconvenient Truth. Dir. Davis Guggenheim. Perf. Al Gore. Paramount Classics and Participant Productions, 2007.
2. Buckman, Aaron, Tristan Whitrock, and Sarada Thomas. Interviews with Professionals and Residents. Raw data. Rob Bolman's House, Eugene, Unpublished.
3. Bolman, Robert. "1631,1633,1635 W. Broadway Triplex." House Plans. Unpublished.
4. EWEB, Energy Consumption Chart
5. ConTrol Contractors. Air Advice Sensor. Raw data. 5000 SE 25th Ave, Portland, OR. 04 Mar. 2009.
6. "Publishes Thermal Comfort Standard." ASHRAE. 13 Mar.2009 <http://www.ashrae.org/pressroom/detail/13394>.