

## DESIGN OF A SUSTAINABLE HOUSE FOR RESIDENTS OF A *COLONIA* IN SOUTH TEXAS

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### ABSTRACT

This paper reviews the process of designing a site-specific sustainable home for a family in a *colonia* near Laredo, Texas. The home's design derives from discussions with the family, the constraints of the narrow site, and the incorporation of sustainable materials and building practices. Sustainable features include utilizing straw bale infill, exploiting natural lighting and ventilation, positioning the HVAC ductwork inside the conditioned space, and employing appropriately-sized overhangs. In addition, the selection of materials and construction methods encourages family and community participation. Three cisterns were integrated into the design to harvest scarce rainwater. Results from heliodon modeling were used to assure the appropriate amount of overhang shading on the south facade during hot summer months.

### DEFINING SUSTAINABLE DESIGN

Human interaction with the environment leads to change, even if one diligently works to avoid it. Regarding building construction, at issue are both short- and long-term results of this change, given the building's impact and function.

Attempts to lessen negative impacts benefit both the occupant and the environment as one can reduce a building's initial and monthly energy consumption while constructing with materials and principles widely deemed to be 'sustainable'. Proper design in a hot and humid climate using appropriate materials and construction techniques will reduce the electrical lighting requirements and the cooling capacity of HVAC systems, saving capital costs and reducing monthly energy charges. With buildings lasting two or three life-times and longer, choices made during design development greatly affect our future collective energy need, consumption and resulting production.

While some propose 'no growth' and say that any growth is harmful, our society continues to increase in population and in materialistic want. A more rational approach relies on directly influencing the

growth of the built environment by focusing on the long-term effects of our construction.

Defining 'sustainable' and 'green building principles' requires one to pick points along a long continuum. At one extreme, only site-derived, renewable materials usable in their found state fit the definition (such as wood or field stones collected manually on-site). At this point, one could even consider the source energy required to grow the food eaten by the builder. At the other end, a palatial retreat reveals the wealth of the owner. Exotic materials, imported from several thousand miles away, and highly crafted details vie for the attention of visitors at every turn. Ironically, 1.6 gallon toilets, low-flow faucets, triple-glazed low-E argon filled windows, a 15 SEER HVAC system, etc., might earn the 30,000 square foot 'home' a government-endorsed "energy efficient" rating.

In an attempt to bring a pragmatic, working meaning to these concepts, this paper will use a comparative definition of 'sustainable' and 'green building principles' when considering options to perform a function. To accomplish this, options were chosen which require less energy to produce or create less waste, are closer to the material's raw state, or benefit the environment. The author accepts that this definition leads to debate and welcomes the dialogue it produces.

### IS SUSTAINABLE DESIGN A WORTHY PURSUIT?

#### A Large Scale, Large Budget Success

Integrating 'green building principles' and 'sustainability' into our structures benefits our society, the environment and the owner/occupant. Through careful planning and design, construction or renovation can improve an existing man-made environment. Regardless of the scale, each decision we make counts.



Figure 1: Ford's 1100 acre River Rouge industrial complex has a history of environmental degradation.

For example, by Ford's own accounting, architect Bill McDonough will save Ford Motor Company \$35 million while renovating the huge Rouge River manufacturing plant in Dearborn, Michigan, through creative landscaping and porous paving. The savings are expected by analyzing Ford's liability under the federal Clean Water Act and designing green roofs (roofs topped with soil supporting vegetation) and covering parking lots with porous paving rather than asphalt. "The habitat roof is a third of what a normal drainage site might cost with gutters, down spouts and underground pipes," stated Tim O'Brien, vice-president of real estate for Ford Motor Land Development Corp. "Where it might cost \$50 million to put all that in, the habitat roof system is \$15 million" (The Detroit News, 2002). Instead of directing otherwise undesirable storm water from rainfall into concrete pipes and chemical treatment plants, McDonough's research found the savings by absorbing the rain in 454,000 square feet of green roof and collecting it in gravel beds below parking spaces. These gravel beds lead into constructed wetlands where it is filtered by water-loving plants. By doing this, the EPA's Clean Water Regulations are met during the three-day trip the water takes to reach the river via a natural filtration system, a system which adds to the local native habitat (New Texas Magazine, 2001). Sustainable design on a large scale can reap significant savings for companies while enhancing the environment. Cumulatively, projects on a small scale also affect our environment, and individual homes are often the showcase for such designs. Using sustainable building principles, how does one successfully provide a good, long-term home built for those within a low or very low income?

#### **SUSTAINABILITY ON A VERY LIMITED BUDGET**

In collaboration with the Center for Housing and Urban Development at the Texas A&M University,

College of Architecture, the author chose to work with a family in a Texas *colonia* as the case study for his Master of Architecture's final study project.

#### **The Typical State of a Texas *Colonia***

*Colonia* is a Spanish term for neighborhood or community. As used in this paper, a *colonia* also describes an unincorporated community located within 150 miles of the Texas-Mexico border, or a city or town within this defined region with a population of less than 10,000 according to the latest U.S. Census. Further, these *colonias* have a population primarily composed of individuals and families of low and very low income, who lack safe, sanitary and sound housing, and often "basic services such as potable water, adequate sewage systems, drainage, streets, and utilities". Often beginning with tents or makeshift structures of wood, cardboard, or other materials, residents strive to improve their homes as their budgets allow. "With living conditions often compared to Third World countries, the *colonias* represent one of the most critical housing needs in the State of Texas" (TDHCA, 2000).

Located approximately 5 miles east of Laredo, the case study site is in a relatively small *colonia* surrounded by cacti and mesquite trees. The *colonia* lacks services common in Texas communities: water, sewage and natural gas lines. Fortunately, electricity has been linked to these homes.

For the family chosen for the case study, drinking water is purchased in three- or five-gallon containers while other water is collected every other day from a community water well. Toilet facilities consisted of a single port-a-john, maintained weekly by a local business. Natural gas lines do not exist, thereby eliminating a cheap fuel source for cooking and heating.

Residents of the *colonias* want what other Americans want: practical, attractive, long-lasting, and comfortable housing. Conventional housing is out of reach for most residents in a *colonia* because of the need for relatively expensive building materials and skilled craftsmen. As is typical of *colonias*, some homes are built with discarded wood pallets, scavenged building components or other inexpensive, less permanent materials.

#### **Understanding the Client's Site and Housing Needs**

Interactions with the owners of the case study site lead to a design specific to her evolving requirements, the site and the site's climate.

The site on which she would build consisted of a narrow strip bordered by a neighbor's unbuilt plot to the south and her father's home, in which she and her children were living, to the north. While discussing the current use of the home's footprint, I learned that extended family gatherings for *barbacoas* (barbecues) happened on the south side of her father's house. The home design would respond to the gathering space between her father's house and her home. As is common in *colonias*, running water, sewer and natural gas connections do not exist on the site.

During our initial conversation, the client stipulated what she needed for herself, husband and two daughters: a three bedroom, one bath home with kitchen, dining, living, and utility spaces. She had given much thought to what she wanted in her new home. Though she had gone as far as developing a

schematic floor plan with the help of her brother-in-law, her view of the house consisted primarily of the floor plan and the experience she had living in her own home. Advertising, television and magazines played a major role in defining how she wanted her house to generally look. Unfortunately, her budget could not live up to what she wanted: a home in a nice suburban development, which would last forever without maintenance and be built with hard work but little or no money. Other than an acceptance of new building materials and construction techniques, she seemed unflinching in her vision.

Through an extended conversation about how she and her family would use her home, I learned that the family's use schedule was typical, with early morning starts around sunrise and bedtimes around 10:30 PM. Groups of family and friends would gather outside more often than inside the home,



Figure 2: The home's future location, looking east from the west boundary of the site. The family toilet, a port-a-john, is in the lower left-hand side.



Figure 3: The site, looking northwest, with the houses of client's father and brother in background.

which allowed smaller interior spaces for the immediate family. While family cooking regularly occurred inside, the scale was small; large events centered around outdoor *barbacoa* pits. Her daughters, age 10 and 16, would need study space, with space for cousins who occasionally stayed overnight in their rooms; her older daughter wanted a queen-sized bed. For her bedroom, the client requested a space for reading in a chair, plus space for a king-sized bed she had previously placed on lay-away. My comments concerning the extra space needed for larger than double-sized beds were discussed, with her original choices remaining her final choices. Although no hookups existed, fixtures for the bathroom and laundry room were to be installed as county connections were expected in the next two years.

### **Introducing Straw Bale and Outlining the Home's Construction**

After introducing images of straw bale homes, discussing the construction process, and reviewing the advantages and challenges of straw bale construction, the client seemed comfortable utilizing straw bales as a building material in a non-load bearing structure. During our conversation, I realized that my client would not accept a load-bearing 'Nebraska-style' home, though many exist and this low-cost housing solution has been proven to be durable.



Figure 4: Mix of load bearing and non-load bearing walls of straw bale.

The straw walls would be used as a plastering surface for interior and exterior walls and require only simple tools to place. No straw walls would contain water pipes. A common slab-on-grade foundation would require minimal site work. Conventional building skills for dimensional wood structures would directly transfer to the construction of the home's structure.

A durable 5-V tin roof would be beneficial for rainwater collection. Interior walls were proposed as load-bearing compressed soil blocks. Her husband would complete most of the interior cabinetry and wood trim. Her father would install an internally ducted heating/ventilation/air-conditioning unit. The home was designed to accommodate two stages of construction, if necessary: the bedrooms, bath and laundry room; and, the kitchen, living and dining rooms.



Figure 5: Straw bales lend themselves to unskilled labor and minimal tools.

'Barn raisings' have helped to create community cohesiveness across the United States, and this approach would be employed here, as hand-plastering straw bale walls is labor intensive. Her willingness to help build her house and her promise of help from extended family and friends allowed for the possibility of straw bale construction. As a typical home's walls are 10 – 20% of the total cost, I stressed that while straw bale walls benefit from 'free' communal labor, long-term savings derived from lower energy use would be far greater. We joked about the story of 'The Three Little Pigs' and I assured her that her house would be designed with a sound structure and would not be blown down by a wolf or a strong wind.

### **The Total Cost of Owning a Home**

An understanding of the total cost of a homeownership extends beyond a mortgage or even maintenance. Factors of monthly utility costs, human comfort and well-being, homeowner's pride, and community integration also may be considered to calculate the price or value of one's home. Wise selection of materials and construction methodology plus 'sweat equity' can yield substantial long-term savings. For my client on a low income with little

chance for career advancement, rising energy costs could become overbearing. In the event that mechanical cooling could not be afforded and following the sustainable tenet of creating buildings which inherently use less energy and optimize what energy it does use, passive cooling strategies for the extreme heat of the climate were used: proper orientation to the sun and cooling breezes; large, shading overhangs; living spaces with windows purposely aligned for cross ventilation; an insulated building envelope with a low infiltration rate.

**DESIGNING FOR THE LOCAL CLIMATE**  
**Laredo's Climate**

Variables important in Laredo's climate include the house's orientation to the sun and prevailing cooling breezes. Mitigating long, hot and dry summers is of paramount importance and drives most thoughtful designs in climates such as Laredo. Air temperature data for Laredo from the International Station Meteorological Climate Summary, Version 4.0, reveal that the average temperature rises above the human comfort zone (78°F) from May until mid-September, with the average high temperature between 90°F and 100°F. The normal number of

cooling degree days is 3915. Breezes flow from the south and southeast during months with high temperatures. Average precipitation is less than 20 inches per year. Monthly average humidity ranges from 55 to 65%. Laredo's elevation ranges from 372 to 899 feet above sea level and lies at latitude 27.5°N.

**FUNDAMENTAL CONCEPTS DRIVING THE DESIGN**

**Proper Solar and Wind Orientation**

The shape and organization of the case study house reduces its exposure to harsh western sun; the home is oriented along an east-west axis, with no west facing openings. A single-room-wide plan was chosen to allow for natural ventilation during the spring, summer and fall, capturing the cooling breezes flowing from the south and southeast with multiple windows. A loft space above the hallway provides interior bedrooms with additional space and better cross ventilation; south-facing windows capture the breeze and windows in the loft on the north side allow it to exit from the highest, hottest part of the house.

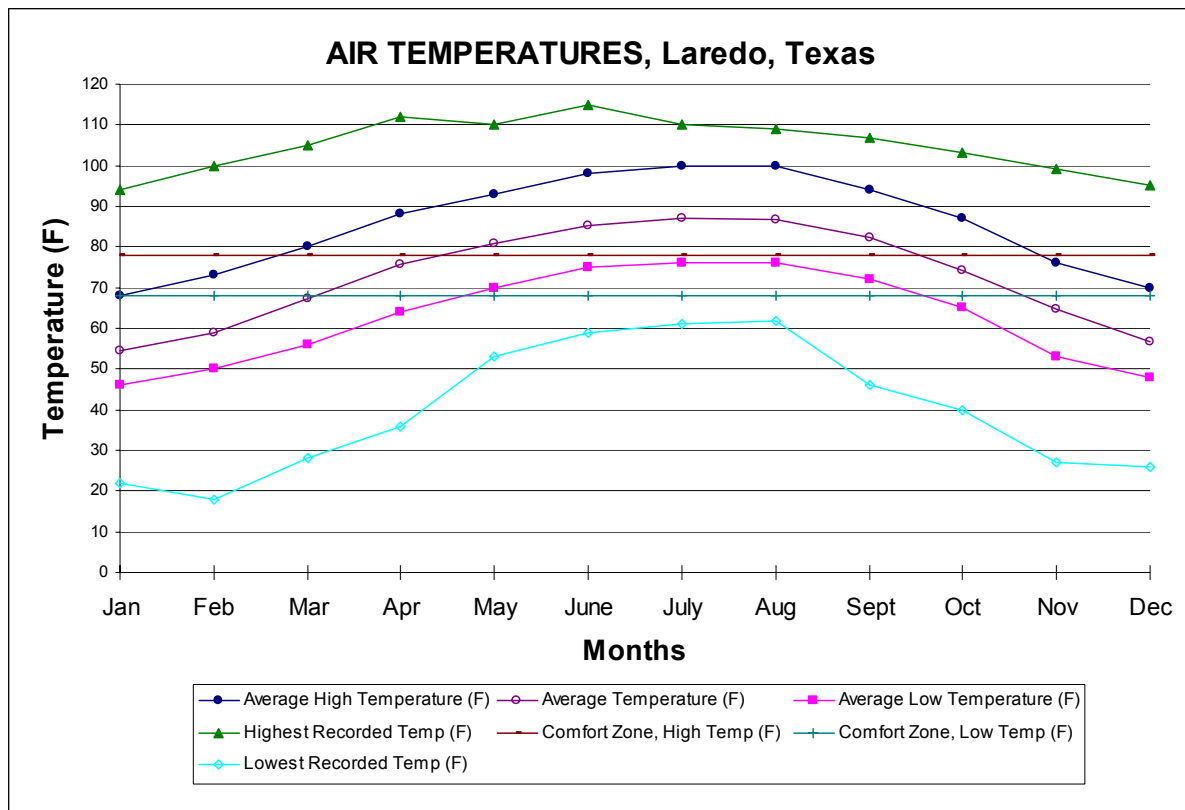


Figure 6: Air temperatures associated with Laredo, Texas, from International Station Meteorological Climate Summary, Version 4.0

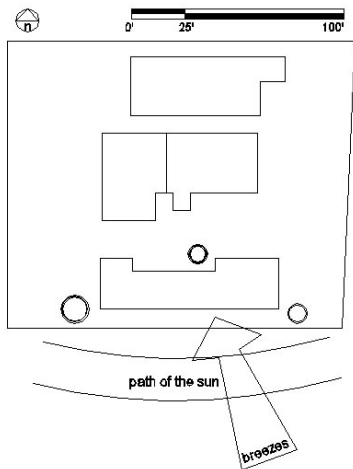


Figure 7: Sun path and general breeze direction.

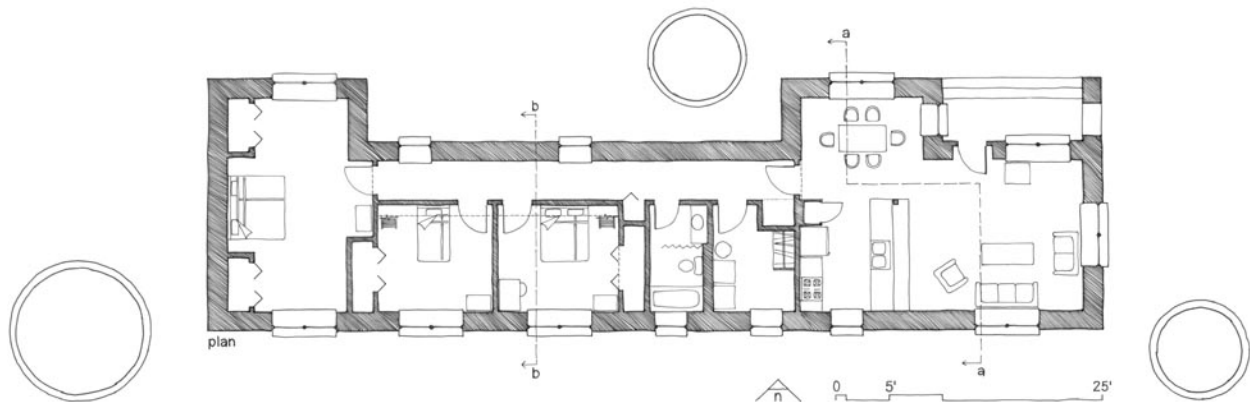


Figure 8: Final plan of home indicating long and narrow design solution.

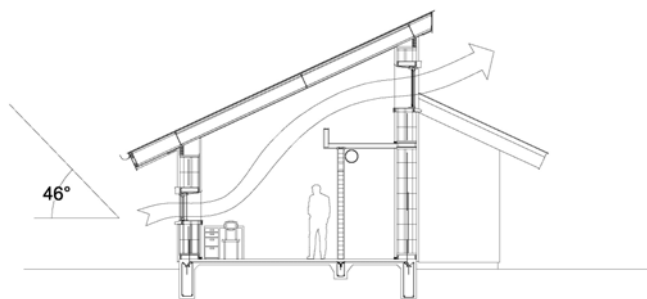


Figure 9: Section bb, through the middle bedrooms, illustrates overhangs and cross ventilation via southern breezes. Note round main HVAC duct positioned below loft floor.

### **Roof Overhangs**

The overhang on the southern elevation shade much of the wall and all of the low placed windows during the hottest and most intense solar months- from late February to late October- while allowing varying solar penetration during the winter months. Overhangs on the north were minimized to reduce material costs and facilitate natural lighting.

### **Natural Daylight**

With living spaces containing windows on at least two exterior walls, indirect daylight provides relatively high indoor lighting levels. This reduces the internal heat load from and reliance on electrical lighting. Natural light also possesses other aesthetic qualities which occupants prefer.

### **Optimum Positioning of the HVAC System**

All HVAC ductwork leaks. Therefore, when placing the heating/ventilation/air-conditioning system in the case study home, the unit was positioned centrally to reduce duct length, and the ducts were deliberately located within the conditioned space. The ductwork runs under the loft in the hallway to the rear of the house and forward through the dining space and kitchen to the living room. Potential efficiency-robbing air leaks and thermal losses normally associated with ducts are therefore kept within the conditioned space. Energy 'lost' in leaks remains inside to do its job. A US national survey reveals that home ductwork leaks 25 – 40% on average and can account for 10 – 30% of the total heating and cooling costs of a building (Sustainable Building Sourcebook, 2000).

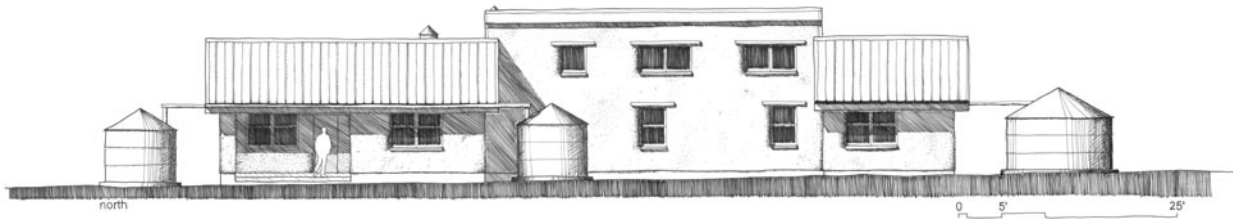


Figure 10: North elevation shows windows placed high for daylight penetration and ventilation; the three cisterns for rainwater harvesting are clearly visible.

### **Flexible and Simple Straw Bale In-Fill Walls**

Attention also has been given to properly insulating the case study home. Using a modified post-and-beam structure, straw bales allow a ready plastering surface, inside and out, plus offer double the insulative value found in typical home construction. Unskilled labor can quickly acquire the ability to stack and plaster straw bales. Minimal unpowered hand tools are needed; materials are non-toxic and forgiving to novices. Using straw bales means that surfaces on the interior and exterior are easily plastered and create a tightly sealed home with a low air infiltration rate. Mineral wool (from 'slag wool') was proposed for the roof and above the ceiling with a thickness of 9 inches offers an R-value of 30.

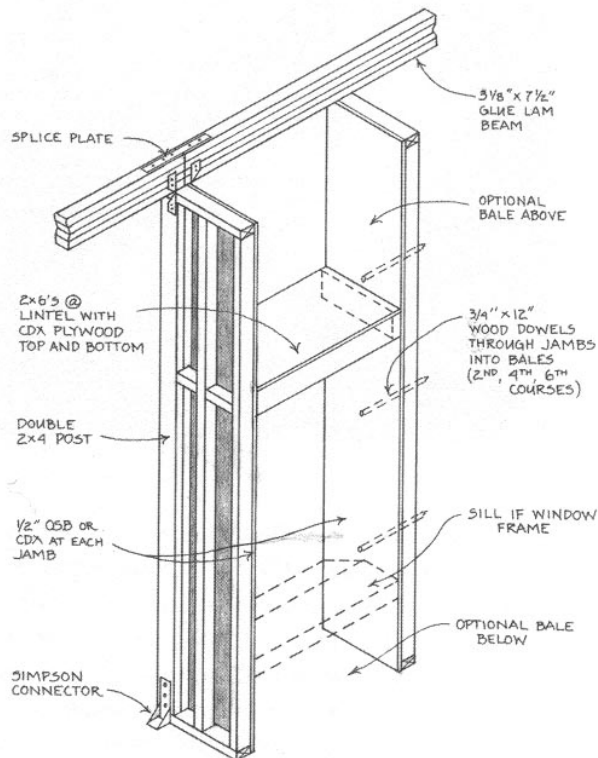


Figure 11: Diagram of modified post and beam structural system composed of 'box' supports.

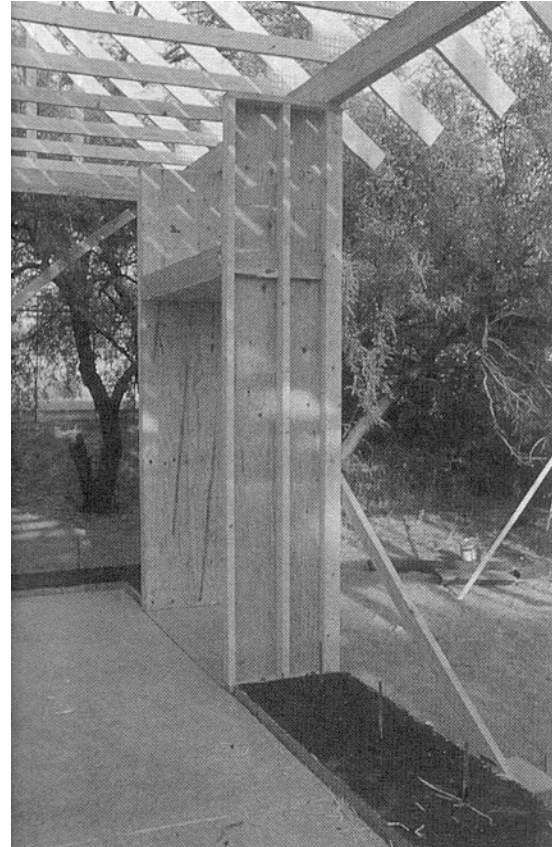


Figure 12: Image of modified post and beam structural system composed of 'box' supports.

### **Straw Bales and R-value**

The R-value of straw bales has been under discussion since the publication of measurements performed by Joseph McCabe at the University of Arizona in 1993 as part of his master's thesis. McCabe measured the flow of heat through a single bale that was 23 inches (580 mm) wide by 16.5 inches (420 mm) high using a "guarded-hot-plate" apparatus (procedure ASTM C-177-85). "He reported R-values of 48.8 (RSI-8.6) for [the] bale on edge and 54.8 (RSI-9.7) for the bale laid flat. Thus he concluded that the insulating value is R-2.68 per inch (0.054 W/m<sup>2</sup>C) when heat flow is perpendicular to the orientation of the straws (bales stacked on

edge) and R-2.38 per inch (0.061 W/m°C) when the heat flow is parallel to the straw orientation". (EBN 1998)

Since 1993, research on straw bale R-value has yielded widely divergent results. Complicating the R-value calculations are the varying properties of straw bales: conductivity, density and specific heat. In turn, these factors differ significantly depending on moisture content and type of straw, such as wheat, oats, rice, etc., and the soil composition where it is grown. The following is an excerpt from *Environmental Building News*, October 1998:

In 1994 a thermal probe was used by R. W. Acton at Sandia National Laboratory to deduce the R-value of a 16.5-inch wide (420 mm) bale as R-44 (RSI-7.7), which seemed to support McCabe's findings, but this is considered a fairly primitive testing procedure. In 1996, Oak Ridge National Laboratory (ORNL) constructed a bale wall that was stuccoed on the cold side and covered with gypsum drywall on the warm side. This test found the R-value to be only R-17 (RSI-3.0). On a per-thickness basis, this is just R-0.94 per inch (0.15 W/m°C). The explanation for this very low R-value, suggested researchers, was that an air gap resulted from the way the drywall was attached to the bale wall; this could have created convection currents in the wall, depressing the R-value.

In 1997, the California Energy Commission, (CEC) sponsored their own tests, working with Architectural Testing Inc. of Fresno, California. Two straw-bale walls were built and plastered on both sides: one had bales laid flat, producing a 23 inch-thick (580 mm) wall, and the other had the bales laid on edge, producing a 16 inch-thick (400 mm) wall. The walls were then tested in the company's new state-of-the-art guarded-hot-box (ASTM C-236-style) apparatus. With the bales

laid flat, the total R-value was R-26 (RSI-4.6) and, with the bales on edge, the R-value was R-33 (RSI-5.8). On a per-thickness basis, this is just R-1.13 to R-2.06 per inch (0.13 to 0.07 W/m°C). An explanation for these low R-values was provided by researchers Tav Commins and Nehemiah Stone in a paper presented at the ACEEE Summer Study. On disassembly of the walls following the measurements, the walls were found to be quite wet. Water had been sprayed on the stucco to prevent cracking, and the walls were tested after less than a week of drying. This water was found to have wicked as much as 6" (150 mm) into the wall along the edges of some of the bales. Also, during construction the walls were compressed with polypropylene strapping, which left a 3" (80 mm) gap at the top; this gap was filled with loose straw. Upon disassembly, it was found that there were voids at the top of the wall and very loose packing in places.

Finally, on May 15, 1998, researchers at ORNL completed a second test in their guarded-hot-box chamber. Several nationally known straw-bale home builders and Tav Commins of CEC oversaw construction of the walls and the testing in an effort to avoid problems experienced with the earlier ORNL and CEC tests. Bales were 19" (480 mm) wide and stacked flat. After being plastered on both sides, the wall was allowed to dry for almost two months (to 13% moisture content). The test chamber was operated with one side at 70°F (21°C) and the other at 0°F (-18°C), and two weeks were provided for the wall to reach steady-state heat flow conditions. Measurements then showed the wall to insulate to R-27.5 (RSI-



4.8). On a per-thickness basis, this is R-1.45 per inch (0.099 W/m°C), just over half of the value most commonly reported.

In the paper, by Commins and Stone at the 1988 ACEEE Summer Study, the authors suggest that this is the most accurate measure of the R-value of straw bale walls to date. Achieving a wall R-value of 28 (RSI-4.9) for a straw bale building is nothing to sneeze at, but it is significantly lower than the R-50 to R-60 (RSI-8.8 to RSI-10.6) that has been suggested in the past. The wide variation in tested R-values that may result from gaps or moisture intrusion also indicates how important proper installation is with straw-bale construction.

With the specified 18-inch wide bales for the case study home, at a theoretical R-value of 1.45 per inch, the straw bales possess an approximate R-value of 26. One would expect the actual R-value straw walls created by non-expert builders to be lower. This is not to say that conventional stick-built construction is without flaw. Poor installation of insulation can be found with other forms of insulation as well.

#### **Straw Bales, Not Hay Bales**

Straw bales differ substantially from the more common hay bales. Hay is grass or another nutritious crop collected from a meadow or field for later use as an animal feed. Straw is the cellulose stem of grain crops, such as wheat, oats or rice. While fungi and mites can live in wet straw, straw will not rot if kept dry and sealed with plaster. Homes built using straw bales continue to successfully survive for decades, as interior and exterior walls are sealed by moisture vapor permeable plaster, and they can be elegant and formal as with the Burritt mansion.

#### **Fostering community cohesion**

By pooling the 'free' labor of family, friends and neighbors, a straw bale home allows the labor required in the construction process a natural method for strengthening one's ties to family and community. Reminiscent of 'barn raisings', the process can instill

a sense of local pride and empowerment. By witnessing the results and low-tech methods of construction, workers may be inspired to initiate their own straw bale home.



Figure 13: Interior of Burritt mansion/museum, a two-story home built in 1938 in Huntsville, Alabama.



Figure 14: Exterior of Burritt mansion/museum, a two-story home built in 1938 in Huntsville, Alabama.



Figure 15: Community construction of the Canelo Project in Mexico.

### **Rainwater harvesting**

Laredo typically receives less than 20 inches of rain per year. The home's pitched roof has 1,560 square feet of horizontal surface area. In a normal year, it would collect about 18,000 gallons of rainwater. Three above ground cisterns hold roughly 10,100 gallons combined for non-potable uses, such as flushing toilets or bathing. With the rain spread relatively evenly throughout the year, the cisterns provide a ready water source.

### **HELIODON STUDY SUPPORTS LARGE OVERHANG DESIGN**



Figure 16: Representative heliodon, which allows table top movement below a fixed light source to simulate changes in latitude, time of year and time of day; building model would be placed on table top.

To test the theory behind the length of the overhangs designed for the home, a 1/4-inch scale model was placed on the heliodon in the Langford Architecture Center, Texas A&M University. The goal centered on shading the south-facing windows from April to September, the months when insolation greatly affects indoor comfort in Laredo. The design's 22-inch thick straw walls allow the windows to be set back from the exterior wall, allowing the wall to shade the window's glazing during very early morning and late evening hours. The south-facing windows are shaded during April and September, so shading occurs in the hottest summer months, too.

The east-facing wall has windows placed for aesthetics and to allow the client views of the road in front of her house; the west-facing wall has no windows as stopping the western sun is of paramount importance. Laredo's latitude is 27.5°N.

### **Overhangs Allow Protective Shading**

In April, from 9AM to 4PM, the south-facing wall remains essentially completely shaded.

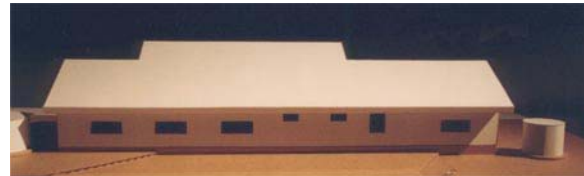


Figure 17: Heliodon Shading Study, 9AM, 1 April.



Figure 18: Heliodon Shading Study, noon, 1 April.



Figure 19: Heliodon Shading Study, 4PM, 1 April.

During the day with the longest day light hours, 21 June, the average high temperature is near 100°F, and the south-facing wall remains in shade all day.

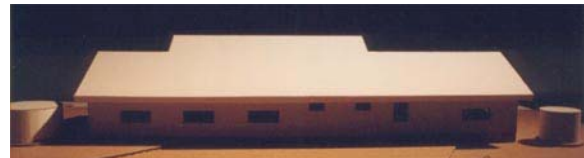


Figure 20: Heliodon Shading Study, 9AM, 21 June.

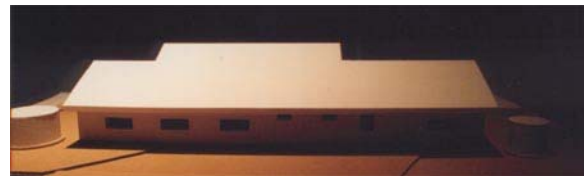


Figure 21: Heliodon Shading Study, noon, 21 June.



Figure 22: Heliodon Shading Study, 4PM, 21 June.

As expected, the overhang completely shades the south-facing windows and essentially shades the entire wall throughout September. The sun's altitude becomes lower as winter approaches. This means that sunlight reaches further up the wall and penetrates the windows. Compare the images of September and December.

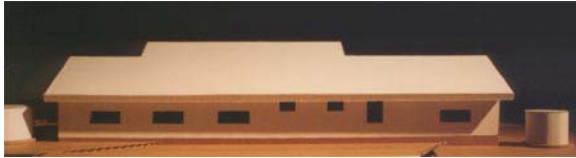


Figure 23: Heliodon Shading Study, 9AM, 30 September.



Figure 24: Heliodon Shading Study, noon, 30 September.



Figure 25: Heliodon Shading Study, 4PM, 30 September.

Proper consideration of the benefits of shading result in a design solution appropriate to a hot climate. The extensive southern overhangs also shield the walls from rain, an added benefit for any type of construction or building material.

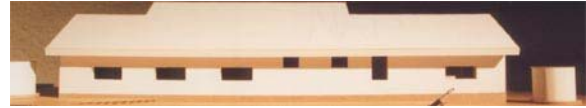


Figure 27: Heliodon Shading Study, 9AM, 21 December.



Figure 28: Heliodon Shading Study, noon, 21 December.



Figure 29: Heliodon Shading Study, 4PM, 21 December.

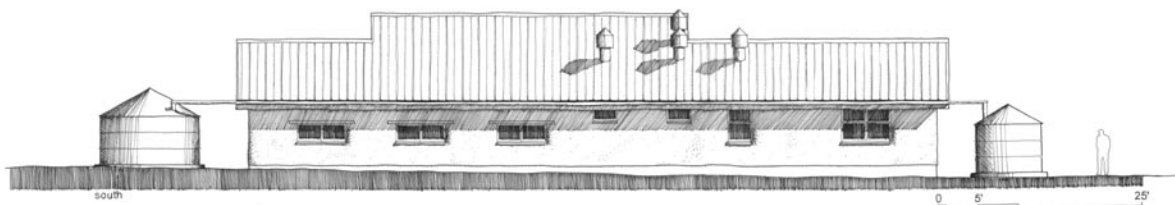


Figure 26: South elevation, morning in the winter; overhang works with sun's lower altitude to allow warming insolation to enter the home.

## CONCLUSIONS

Because the client bowed out near the end, the work remains as only a final study project. The author acknowledges that certain design elements of the home do not align well to families on a low or very low income. Certain choices were made to include more expensive elements in the design to enhance the learning experience and development process. For truly low cost housing, fair compromises must be made. Therefore, it is recommended that the following strategies could be easily incorporated to substantially reduce the cost of the home without unreasonably diluting the value and comfort one expects.

### Further Strategies for Lowering Combined Capital and Monthly Expenses

- Load-bearing straw bale walls, known as 'Nebraska-style' construction.

- Perimeter beam, or possibly gabion, foundation under structural walls.
- A stabilized earthen floor in place of concrete or wood.
- Use of reclaimed materials and elements, such as lumber, windows, doors, roofing, etc.
- A collection of joined rooms built as one's budget allows.

In conclusion, it seems that certain sustainable building practices are applicable to divergent scales of buildings. A thoughtful review of possible solutions allows for the integration of sustainable choices. And the long-term beneficial effects of a building's impact on the environment can coincide with financial rewards to the owner/occupant.

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Figure 1

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Figures 2, 3, 7 – 10, 17 - 29

Trent J. Schoenemann

Figures 4, 5, 11 - 14

Steen, Athena Swentzell; Steen, Bill; Bainbridge, David. *The Straw Bale House*. Chelsea Green Publishing Company, White River Junction, Vermont, 1994.

Figure 6

Based on data from the International Station Meteorological Climate Summary, Version 4.0

Figure 15

<http://www2.strawbalecentral.com/sb/canelo/project.html>, The Canelo Project Athena and Bill Steen

Figure 16

Website of Sam C M Hui, Department of Architecture, The University of Hong Kong, Hong Kong  
<http://courses.arch.hku.hk/IntgBuildTech/bs2/heliodon/helio10.jpg>