A Multidisciplinary Design Methodology for Southern Housing

David C. Lewis

SCH Report 4

2006

Abstract

Under the auspices of the US Forest Service Forest Products Laboratory and the Coalition for Advanced Wood Structures (CAWS), the Southern Climatic Housing Research Team -- a multidisciplinary group of wood scientists, architects, landscape architects, mechanical and civil engineers – is designing a research and demonstration house for the Southeastern United States on the campus of Mississippi State University. The objectives for this house are to solve climate-related housing construction problems endemic to hot-humid climates: high heat, humidity, decay fungi, mold, high wind, low velocity ventilation, and various insects, including the devastating infestation of the Formosan termite. An overview of the design strategy and research strategy that respectively underpinned the proposed design of a research and demonstration house and organized the multidisciplinary research agendas amongst the five members of the team is presented. The design strategy involves six social, historical, constructional, landscape, environmental, and formal strategies. The research strategy entailed three significant components, all of which are ambiguous in nature. The first is an ambiguity between design and scientific experimentation; the second is an ambiguity among the five disciplines, and the third is an ambiguity among three objectives. Because this is a work in progress, the conclusion will take the form of descriptions of a selection of particular research projects.

Introduction

According the 2001 American Housing Survey, over one third of all housing units and one half of all housing units constructed in the last four years were in the Southern US. [1] Over ninety percent of all houses constructed in the US use wood and wood products. Conversely, it has been estimated that decayed wood and termite-infested damage cost US homeowners approximately $500 million annually in replacement costs alone. Also, if the construction lumber is not properly treated, then additional 266 million trees must be harvested to meet present demands. [2] The development of design ideas and construction techniques that address durability and energy efficiency concerns particular to the southeastern US would have not only regional ramifications but have national benefits.

Under the auspices of the US Forest Service Forest Products Laboratory and the Coalition for Advanced Wood Structures (CAWS), the Southern Climatic Housing Research Team -- a multidisciplinary group of wood scientists, architects, landscape architects, mechanical and civil engineers – is designing a research and demonstration house for the Southeastern United States on the campus of Mississippi State University. The objectives for this house are to solve climate-related housing construction problems endemic to hot-humid climates: high heat, humidity, decay fungi, mold, high wind, low velocity ventilation, and various insects, including the devastating infestation of the Formosan termite. The goals for the research and demonstration facility are practically and educationally oriented. We intend to provide researchers, architects, and contractors with practical definitions for energy efficiency and durability for wood-constructed residences for hot-humid climates. We also want to educate the public on how to design and construct a moderately priced house that requires only twenty-five percent of the typical amount of consumable energy used today in a residence of comparable size, to insure that all wood remain durable during the life of the house, and to maintain a healthy indoor air quality, yet presents a conventional appearance.

In this paper, I will present an overview of the design and research strategies that respectively underpinned the proposed design of a research and demonstration house and organized the multidisciplinary research agendas amongst the five members of the team. In conjunction with the description of the research strategy, there will be a discussion of several proposed research projects.

Before presenting the design strategy, a brief description of the members is in order. The idea of the house and the coalition of different disciplines is the brainchild of Terry Amburgey, professor in the Department of Forest Products. He is a leading expert in microbiological concerns in wood products, in particular decay and termite infestations. During his thirty years of investigating these concerns in both the laboratory and in residences around the world, he has experienced a myriad of inappropriate construction techniques, to which he wishes to address in this proposed house. Concerning termites, his expertise includes the Formosan termite, which are rampantly infesting the city of New Orleans and which eventually will overrun areas as far north as the 35th parallel in the US. [2] A second member of the group is Pete Melby, Co-Director of the Center for Sustainable Design, a professor of Landscape Architecture, and author of Regenerative Design Techniques: Practical Applications in Landscape Design, which present strategies for sustainable design for both architecture and landscapes. Our third member, Louay Chamra, is a mechanical engineer, who is presently researching residential applications for cooling, heating and power systems, which are called MicroCHP. There are two civil engineers, Chris Eamon, who has also trained as an architect, and specializes in severe lateral loading, ones generated during severe storms and tornadoes and Ralph Sinno, who has research uplift problems in residential structures and who is presently working with other architecture faculty on this problem in manufactured housing. The last member is myself, who has over twenty years of architectural practice specializing in housing and energy efficiency.

Design Strategy

The design strategy, like the research strategy, entails ambiguous relationships among three concerns: first, to establish a facility that functions as a house, a research laboratory and a demonstration classroom; second, to produce a building whose overall form is energy efficient for hot-humid climates yet present a conventional aesthetic; and, third, to be capable of transforming spaces and construction so to comply with particular research projects.

As much as the first intent of designing a facility that must function equally as a house and as a research laboratory may appear contradictory, we employed two tactics that endeavored to conjoin the two aesthetics. Regarding the research aspect, the general principle of scientific research to use a control along with the test manifested itself into a split building. The building has two main components; a northern wing and a southern wing that are connected with an entry foyer. In general the northern wing will contain conventional features, such as typical construction, slab on grade, a standard HVAC unit and duct layout, while the southern building will contain the more passive-oriented systems, such as use of thermal mass and controlled direct lighting, along with the MicroCHP unit, a proposed heat interceptor wall, a ceiling plenum air distribution, and treated-pier foundation.

Complimenting the research dialectic of northern conventional and southern innovative, we planned the room layout to respect a conventional public to private distribution. The arrangement, room sizes, and public and private area organization are not dramatically altered from the typical. The "house" is intended for a typical family, two parents and two or three children, which translates for the typical US house as three bedrooms with two and one-half bathes. The distribution respects the conventional public to private areas transition, wherein the more public areas are adjacent to the front door, while the more private farther away. Concerning the demonstration aspect, we intend to educate a wide variety of people, from school-age children, to university students and faculty, to fellow researchers of sustainability and durability of wood products, and the public at large with the goal to inspire people to design their own energy efficient and durable houses. The educational aspect extends beyond the building. The chosen site was intentionally difficult. It is quite common for the typical US house to reside on a flat site, either one naturally defined or man-made. The reasons are strictly economical; a slab-on grade foundation is cheaper than a raised floor, yet the raised floor allows for cross ventilation. Our site slopes over six feet (2m) over the diagonal length of the house, which will require a combination of slab and raised floor. Raising the house above the ground creates stability problems for the foundation because of drainage issues. A particular educational component of the site is to illustrate carbon dioxide sequestering. The typical house in America requires three acres of trees and vegetation to sequester the carbon dioxide given off by the house. We will plant three acres of trees and vegetation to illustrate the required acreage and demarcate the area required for ours.

Regarding the juxtaposition of energy efficiency and conventionality, we defined six social, historical, constructional, landscape, environmental, and formal tactics. Socially, we recognize the design attributes of traditional southern houses as antecedents for this research and demonstration house. It is not our intent to romantically rekindle the aesthetic of the past with contemporary technology. The traditional houses were constructed prior to central heating and cooling; therefore, their geometry, their orientation, their proportions, their construction, their relationship to the ground, responded directly to providing comfort, which we ironically conceive as energy efficient design. The most significant energy savings derives from the strategy of correct buildings proportions and orientation. To abet cross ventilation, residences in hot-humid climates should have a minimum of a 1:2 proportion with the long axis oriented due east and west. The long faces receive the maximum amount of low angle of our winter sun during the four months of heating and, more significant, to reduce the solar heat gain on the east and west elevations during our six months of cooling. In conjunction with proportioning, other passive means, such as extensive overhangs, trellises, screen porches, thermal mass in the floors, high ceilings, which range up to seventeen feet in height (5.3 m) and thermal interception systems in the walls. However, to live in an energy efficient house, people typically believe they must dramatically alter their lifestyle, which the majority of the US population is unwilling to do. As with some suburban houses, the narrow side faces the street, the garage projects forward, and the front door is sometimes recessed. In the proposed house, the garage is situated on the northwest corner, which places it closes to the road and which will block northwest winter winds. The front door is located in the interstitial room that both distinguishes and connects the northern and southern wings.

Besides planning we addressed conventionality through the size of the house. In the US, the average sized house is approximately 1798 square feet (app. 180 sq. m) [1], while according to the Tennessee Valley authority, the primary electrical power source for the southeast region, in the southeastern US the average size is 1,761 square feet (app. 176 sq m). Our proposed house is 1776 square feet (app. 176 sq. m) of conditioned space. The social intent behind this conventional sizing is to illustrate that the size of an energy efficient house need not be either abnormally small, which suggest that fewer square feet translates to less area to heat and cool, nor abnormally large, which suggests additional rooms to accommodate the extra features. And from an economic perspective, the house should appear affordable to the broadest audience. The room sizes are also standard with bedrooms ranging from twelve by twelve feet (3.6 m by 3.6 m) to twelve by sixteen feet (3.6m by 5m). The living and dining rooms are both nominally twelve feet by sixteen feet (3.6m by 5m). However, all living areas, such as living and dining rooms as well as the bedrooms have an adjacent room or space that provides the impression of a larger living environment and allows the inhabitation to vary according to seasons. It is our intent to design a dynamic house. People can expand or contract their living space according to the seasons. Lastly, this issue of conventionality also influenced construction. The longest span of any room is 16 feet (5 m), which can be readily achieved using stock dimensional lumber. All of the house can be built with conventional materials, however not all walls are the same thickness. We will vary thickness according to orientation, which will make the house more efficient, yet not be readily apparent.

Research Strategy

The research strategy entailed three significant components, all of which are ambiguous in nature. The first is an ambiguity between design and scientific experimentation; the second is an ambiguity among the five disciplines, and the third is an ambiguity among three objectives.

It has been our intent to investigate architectural concerns, such as climatic, durability, and health issues within an architectural setting. To date US Forest Service demonstration houses are conventional appearing houses with a few monitors and sensors. We, however, intend to investigate a myriad of biological, architectural, climatic, and structural influences on the design of a house for hot-humid climates. The issue, therefore, is: should we produce a laboratory that looks like a house or are we producing a house that contains a myriad of laboratory experiments. In other words, what is the relative value of architectural design to scientific experimentation?

It was decided early on that the house should respect aspects of conventional architecture and incorporate transformative characteristics. The research and demonstration house must appear to be a house (versus a laboratory), but more significantly allow for typical inhabitation, which suggests a typical program, planning, and presume everyday lifestyles. We recognized that allowing people to live in a house, which is also a research laboratory, would result in a gamut of indoor climatic conditions, rather than precisely controlled ones. It may make the collection of data more difficult; however it may also make the data more applicable. As a result, we intend for the facility to be both a livable house and a research laboratory.

The second ambiguity of our research is the interdisciplinary ethos. It is readily apparent that five disciplines are represented in this research project: architecture, landscape architecture, civil and mechanical engineering, and wood science. Each discipline, or rather member, has his/ its own concerns regarding energy efficiency, durability, or indoor air quality. To diagram the relationship amongst the five disciplines by discipline would grossly misrepresent the actual relationships. To begin, each member has a particular expertise brought to the table; but, that expertise has not been considered more relevant than another's body of knowledge. Secondly, to suggest that correspondence between two disciplines is greater than another two disciplines would also misconstrue the ethos. For example, to suggest that the relationship between inhabitation and wood preservation issues has taken precedent over or is considered more pertinent to the overall objective than the relationship between the regenerative landscape design and indoor air quality is simply not the case.

The question, therefore, arises: how do you represent the interdisciplinary ethos of this research group? First, you must eliminate the titles and traditional boundaries of a discipline. Even though I am called, the "architect," and I am responsible for construction documents, I am the liaison amongst the members regarding the research projects and the house. However, and more critical than the naming of responsibilities, we organized our research according to the three primary objectives and relationships between objectives.

The three objectives are: 1) reducing energy consumption by at least 75% through a variety of means; 2) to insure durability of the building by maintaining a moisture content of at or under 20% (MC20) for all untreated wood and wood products; and, 3) to maintain a healthy indoor air quality by maintaining a relative humidity of 45 – 50%. Individually the objectives are easily achievable and would not be considered innovative. Zero energy homes are readily available in the US. Sufficient building products are already on the market to produce tightly protected structures. Mechanical systems can maintain RH of 45-50% at the flip of a digital switch. However, many vapor barriers used to deal our buildings trap moisture in the walls, which causes the moisture content in the lumber to rise above MC 20, which in turn transforms that lumber into the ideal environment for bacterial growth and food for termites. To depend solely on mechanical units, even though their efficiency has dramatically improved in recent years, does not question the paradigm of complete reliance on technology to provide comfort? In particular, and quite ironic, the ducts of forced-air systems are breeding grounds for bacteria because the relative humidity in them needs to be quite high. Also, the sultry RH of the southern climate does not lend itself to using passive cooling needs for much of the year. As a result, our methodology is comprised of research projects that address at least two objectives simultaneously.

Proposed Research Projects

In this final section, three proposed research projects will be introduced that particularly address the relationship between energy efficiency and indoor air quality.

Evaluation of the Traditional Theory that Taller Ceiling Heights Provide Cooler Spaces

Tradition has manifested a belief that taller ceiling heights produce cooler spaces. This cooling occurs because the warmer air molecules rise to the highest elevations, while cooler air molecules settle. Optimum ceiling heights are not known that insure appropriate stratification of air temperatures for inhabitation. Today, construction and cost factors control ceiling heights rather than air temperature. Also, mechanical air conditioning provides inhabitants with uniform temperatures throughout a residence, which results in uninhabited portions of rooms, eg. above head heights, being over-conditioned, and not allowing natural convection currents to regulate temperatures.

Using the federal guidelines, 78^0 F for cooling and 68^0 F for heating as standards, we will determine the appropriate ceiling heights that insure these temperatures for the inhabitation zone, floor level to six feet above finish floor. Various means of conditioning the air will be employed: passive means only, ceiling fans to stratify, and mechanical means to establish the guideline temperatures and determine the percentage increase in energy consumption, eg. compare an eight foot ceiling height with a twelve foot height and determine which required more energy to maintain the requisite temperature. Because the research and demonstration house contains room whose ceiling heights vary from eight feet to seventeen feet, it is possible to incorporate sensors in every room. Also, the dining room will have an operable ceiling that will be raised and lowered so to measure heights between those other rooms.

Evaluation of Radiant Heat through Roof Systems

Older homes contain ventilated attics that buffer the heat radiated through roofs. However, it is common for people today to inhabit their attics or construct cathedral ceilings. Both of these design situations require the rafters to contain sufficient insulation to buffer the radiant heat and conversely, do not ventilate heated air. My general question is: Does the traditional design feature of a well insulated and properly ventilated attic the most appropriate means for buffering radiant heat through a roof in a hot-humid climate? The proposed research will involve the evaluation of an alternative design proposal that allows the attic spaces to be inhabited. The north building will contain two roof systems. Above the dining room and hallway will be a conventional attic space: flat ceiling with blown insulation, rafters, sheathed and metal roof. The two bedrooms will contain raised ceilings with insulated 2" x 10" rafters, sheathed with reflective coated and treated OSB, 1" x 2" runners and a metal roof. Sensors will be place midway in the insulation and monitored on a weekly basis.

Ceiling Plenum

Forced-air ductwork system contains an inherent problem; the increased pressure in the duct increases the relative humidity (RH) of the conditioned air. Also, they tend to be noisy and localize the point of conditioned air. A recent alternative of using sealed crawl spaces as plenum eliminates the issues of noise and localization, but not completely insure against reduction in RH, which in turn increases the potential for bacterial problems. In the south building, a suspended ceiling, approximately one foot deep will be incorporated into the living room and master bedroom. This ceiling will consist of a wooden frame and screen inset panels. These panels will be made of Teflon-coated fabrics, initially supplied by the W. L Gore Corporation Architectural Fabrics Division. The porosity of the fabric will be evaluated with the intent of providing a uniform distribution of quiet, low RH conditioned air through out the rooms.

Conclusion

How should a designer develop a house that respects the land, its local climate, possibly local construction practices, durability issues as they apply to materials and maintenance, all the while acknowledging that the average home buyer can afford only a relatively small lot, a relatively small house, for Mississippi a monthly utility bill of $168 and who wishes to be like his/her neighbors? This question underpinned the design intentions of a proposed research and demonstration house located on the campus of Mississippi State University.

To define the average, the common ground, the typical in American housing is arguably an impossible task. Geographical distinctions, historical features, cultural differences as well as the more abstract concerns, such as convenience or taste, distinguish particular housing. However, we transgressed these aesthetic and cultural factors by incorporating into the design mix a scientific methodology that potentially could inherently transform the southern house.

Throughout this paper the terms sustainability and green have been conspicuously absent. It has been by intent that they were replaced by more measurable terms: energy efficiency, durability, and indoor air quality. Arguably one of the most used, but least understood terms by architects, engineers, or environmentalists is sustainability. It is an idea that when used as a noun, sustainability, it is not a thing but a goal: a circumstance, standard, or ethos to which we aspire, yet understand that it now is more closely akin to Thomas Moore's Utopia than any realistic objective. This idealistic state defies establishing significant boundaries for practical purposes. Our methodology, which is based on ambiguous relationships amongst the disciplines investigating the southern house and which will develop practical definitions for energy efficiency, durability, and indoor air quality for the southern house, will derive a precise understanding of sustainability for the southern house.

H.U.D. 2002. American Housing Survey for the US:2001. Office of Policy, Development, and Research. pp. 4, 11.

Lewis, D.C., Kitchens, S.C. 2006. A sustainable house for the Southeastern United States. Pages 117-26 in Design and Nature II. W.I.T. Press, Southampton, UK.

The MSU Southern Climatic Housing Research Team is a collaborative effort involving Architecture, Civil Engineering, Electrical Engineering, Forest Products, Landscape Architecture, and Mechanical Engineering. The MSU Southern Climatic Housing Research Team is affiliated with the Coalition for Advanced Wood Structures (CAWS) as a partnership with the USDA Forest Service, Forest Products Laboratory in Madison, Wisconsin. CAWS is a partnership between universities, industry and government to advance research for wood structures related to residential, non-residential and transportation uses.

southern • climatic Housing mississippi state university