A Sustainable House for the Southeastern United States

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Abstract

Under the auspices of the US Forest Service Forest Products Laboratory and the Coalition for Advanced Wood Structures (CAWS), a multidisciplinary team of wood scientists, architects, landscape architects, mechanical and civil engineers are designing a sustainable house for the Southeastern United States on the campus of Mississippi State University. The objectives for this demonstration 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 of the projects are to develop practical definitions for sustainability and durability for wood-constructed residences for hot-humid climates and to educate the public of how to design and construct a sustainable house and landscape that employs 75 percent less energy than the typical house presently built in the southeastern US, yet maintain a conventional aesthetic.

The paper presents a research in progress. It does not present results rather causes and influences as well as strategies and agendas to address the equally significant concerns of durability and energy conservation in wood residential design and construction. The paper is comprised of two primary sections. In the first, we discuss building decay associated with fungi and insects, which are the predominant causes for natural structural failure in wood structures and for whom countermeasures must be developed to produce durable buildings in the southeast US. Regarding fungi, the focus is on the most economically damaging of wooden structure, the brown-rot decay fungi group. Concerning insects, we address the devastating affect of the Formosan termite. In the second section, we will address the social and climatic influences on energy conservation for the southeastern US and present the research agendas and strategies for the sustainable house.

Introduction

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. If we don't establish working definitions for sustainable environments, then lay people will not recognize the value and antagonists will employ short-sided excuses, such as immediate economic benefits, to belay research and development.

Under the auspices of the US Forest Service Forest Products Laboratory and the Coalition for Advanced Wood Structures (CAWS), a multidisciplinary team of wood scientists, architects, landscape architects, mechanical and civil engineers are designing a sustainable house for the Southeastern United States on the campus of Mississippi State University. The objectives for this demonstration 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 of the projects are first, to develop practical definitions for sustainability and durability for wood-constructed residences for hot-humid climates and second, to educate the public of how to design and construct a sustainable house and landscape that employs at minimum of 75 percent less energy than the typical house presently built in the southeastern US, yet maintain a conventional aesthetic.

The paper is comprised of two primary sections. It does not present results rather causes and influences as well as strategies and agendas to address the equally significant concerns of durability and energy conservation in wood residential design and construction. In the first, we discuss building decay associated with fungi and insects, which are the predominant causes for natural structural failure in wood structures and for whom countermeasures must be developed to produce durable buildings in the southeast US. Regarding fungi, the focus is on the most economically damaging of wooden structure, the brown-rot decay fungi group. Concerning insects, we address the devastating affect of the Formosan termite. In the second section, we will address the social and climatic influences on energy conservation for the southeastern US and present the research agendas and strategies for the sustainable house.

Building Decay Associated with Fungi and Insects

Wood destroying organisms, such as fungi and insects, cause tremendous damage to our homes and offices. To control their infestation, we must understand them first on a biological level, then incorporate this knowledge into our designs and building products. In the southeastern United States these wood destroying organisms thrive because of high yearly rainfall totals and warm humid temperatures. (Fig. 1) To insure against them we must control moisture. The most common types of fungi found are white rots, brown rots and water conducting varieties. Termites are the most common type of insect that infest structures and they cause millions of dollars worth of damage yearly. It is critical that we address these issues from an applied biological viewpoint to better understand how to design, construct and maintain wood frame structures in the southern hot-humid climatic regions.

Figure 1. Wood decay hazard map

In North America 90% of our homes are made from wood and wood products and our forest have grown 20% in the last 30 years. An average acre of vigorously growing young trees in a commercial forest consumes 5.5 – 6.6 metric tons of carbon dioxide a year and gives off 4.4 metric tons of fresh oxygen, and produces 4.4 metric tons of new wood. It is our duty as researchers and conservationist to maximize the utilization of wood - our renewable building product and to keep the cycle of young forest vibrant and productive. When compared to other building products, wood product manufacturing is a relatively clean process and almost all wood residue is converted into building panels, pulp, paper and other products.

Increasing the durability of wood building components is a key factor in increasing the utilization of the raw material. Housing demands and costs continue to increase while introduced pest such as the Formosan termite combined with governmental restrictions on wood preservatives increase the probability that structures will decay or become colonized by termites. It has been estimated that decayed and termite-damaged wood costs U.S. homeowners over $500,000,000 U.S. dollars per year in wood replacement costs alone. It is very important, especially in southern climatic regions where the decay and termite attacks are a high hazard, that we use proper design techniques and use preservative treated wood. If we do not utilize wood preservatives, it has been estimated that an additional 266,000,000 trees would need to be harvested yearly in the United States to fill the current demand for wood products.

Causes of Wood Decay in Structures

The primary cause of decay in wood is allowing moisture to reach the wooden product. This is caused many times by faulty design techniques or landscape features that hold moisture near the structure. Water necessary for the growth of fungi may come from the following sources: 1) The original water in green wood; 2) Rainwater; 3) Ground water; 4) Condensation; and, 5) Plumbing leaks.
It cannot be assumed, however, that the design features or construction practices that have caused no

problems in one geographic region can be used successfully in another. The decay hazard to structures in any region is dependent on both temperatures and rainfall. Special precautions to avoid decay must be used in hot, humid regions such as the southeastern United States (Amburgey, 1986).

Wood Altering and Destroying Fungi

Many species of primitive plants, known as fungi, can inhabit wood. Some of these organisms use only the food that is stored in the wood (molds and sapstains), while others (wood-destroying fungi) attack the cellulose or lignin and cause the wood to decay. Three types of fungi inhabit wood: mold, sapstain, and wood decay fungi. These fungi are usually separated into two categories with the first two (mold and sapstain) together and wood decay fungi together. The molds and sapstains in general don't directly affect the strength of wood, but indirectly they can cause many problems both structurally and aesthetically. Molds and sapstains are often a very good indicator that there is a moisture problem present in a structure and by increasing the capacity for wood to absorb water they can actually increase the rate at which the wood is decayed by other fungi.

Wood decay fungi can be grouped into three classes based on type of decay that they cause: brown rots, white rots, and soft rots. The most economically devastating fungi in wooden structures is the brown-rot decay fungi group. From a structural standpoint, brown-rot fungi cause significant damage to wood frame structures due to the fact that they are associated with softwood species, which are the predominant species used in new home construction. This decay is associated with the Basidiomycetes fungi and primarily attacks the wall carbohydrates, leaving behind a network consisting of modified lignin, with small amounts of more resistant crystalline cellulose. On drying, the surface of the decayed wood checks in a characteristic cube-like pattern and the decayed wood collapses that decreases the wood size and shape. The strength of the wood decreases rapidly as the decay proceeds and is converted into a powdery mass of varying shades of brown (Lfungdahl and Eriksson, 1985). This is a very economically devastating organism and these particular fungi can withstand desiccation, and survive for years in dry wood.

Wood Destroying Insects

There are many different types of insects that destroy wood but for most economic significant group would be termites. Termites occur in virtually every state of the United States except Alaska and in all U.S. territories. Termites in general have extended their natural range to approximately the 50°F (10°C) annual mean isotherm north and south of the equator. Years ago, their damage was concentrated to the southern half of the United States but since the widespread installation of central heating units, the damage from termites is becoming common in the northern states (Haverty). The two most destructive types of termites are the native subterranean (*Reticulitermes* spp.) and the introduced Formosan subterranean (*Coptotermes formosanus* Shiraki).

The native subterranean species causes a tremendous amount of damage annually to wood frame structures but recently the majority of the focus in the southeastern United State has been on the control of their cousins the Formosan termite. Among the 2,400 known termite species, the Formosan termite is considered one of the most destructive and aggressive species of termites in the world. They have been given the nickname "Super Termite" and an active colony of Formosans has been known to eat 1,000 lbs. (454 kilograms) of wood per year compared to 7 lbs. (3 kilograms) per year by an active native colony. These termites are native to China and have been introduced into Japan, Guam, Sri Lanka, South Africa, Hawaii and the continental United States. They were first discovered in the United States in 1965 in a shipyard in Houston, Texas. After that discover, more colonies were found in New Orleans, Louisiana and Galveston, Texas in 1966 and Charleston, South Carolina in 1967. Since then well-established colonies have been found in most all southeastern states and it appears the colonies are moving north. It is believed that the colonies will stop at the 35°N Latitude line that coincides with the warmer temperatures. (Fig. 2)

The Formosan termite feeds on cellulose, which is the major component of wood and paper products; they have been known to attack (but not eat) non-cellulose material such as thin sheets of soft metal (lead or copper), asphalt, plaster, mortar, creosote, rubber, and plastic in search of food or moisture. The Formosan colonies can be ten times the size of a native subterranean colony with individual members numbering as many as 10 million and are more destructive that the natives because of sheer numbers and the fact that they feed on both the softer wood produced during the spring growth and the harder summer growth wood. The colonies can forage in areas up to 38,500 square feet (1/3 hectare) and have been know to attach more that 47 species of living plants. It has been estimated that the Formosan subterranean termite causes in excess of 300 million U.S. dollars in damage per year in the Greater New Orleans, Louisiana Metropolitan Area (McClain, 1999).

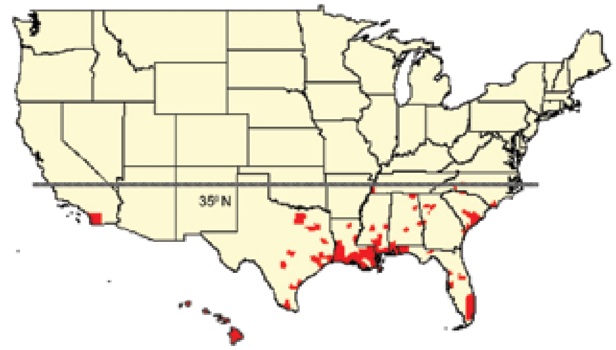

Figure 2: Formosan termite known infestations in the United States represented as dark areas. Could potentially affect 50 million people.

Description of the House

In the first section, we introduced biological forces that degrade structural integrity. In this second section, we will address the social and climatic influences on the form of the facility. In conjunction with these descriptions, we will discuss the strategy for energy conservation, an overview of the particular research agendas of the respective members, and will illustrate the design of the house.

Social and Climatic Influences

As has been so eloquently depicted in stage and theatre, the southeastern US, commonly called the "South," is known for its sultry climate. Yearly average temperature is approximately 62°F, with the summer months (May through mid October) averaging almost 80°F; however, extremes range from 105°F to 110°F. Accumulated rainfall is 56", which is relatively consistent throughout the year and results in a yearly average soil wetness of 60% saturated. These statistics alone speak volumes toward the causes for decay, rot, and mold as well as the necessity for proper foundations, extensive roof overhangs, and sufficient cross ventilation. However, any cursory investigation of home construction in US suburbs over the past forty years would illustrate that style, regardless of location, and increased size of houses are the primary social influences for home selection. According to the 2001 American Housing Survey, over one third of all housing units and all housing units constructed in the last fours years were in the southern US (HUD, 2002); therefore, any attention given to producing more durable and energy conserving houses would benefit an extensive percentage of the US population.

Strategy for Energy Conservation

We developed six social, historical, constructional, landscape, environmental, and formal strategies for achieving the proposed seventy-five percent reduction of energy objective. Culturally, 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 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 sustainable 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. This proportioning will save 30% of the projected energy use. Extensive overhangs, trellises, and screen porches designed to block the sun's rays during the summer months and allow them to penetrate during the winter months will save an additional 15% of the projected energy use. Our third strategy is to locate planting on the east and west sides to shade the building and to plant a wind ramp, which is planting that steps up in height, so to deflect our predominant northerly cold winter winds. The fourth strategy employs passive conservation techniques of high ceilings, which range from ten to seventeen feet in height (3 to 5m) and thermal interception systems in the walls. The fifth, and final passive strategy is the incorporation of thermal mass in the flooring. The thermal massing, in conjunction with the ventilation strategy, will absorb heat during the summer months that will be dissipated by cross ventilation before it enters the main portion of the house and during the winter months, when the sun is low in the sky, the thermal mass in the main portion of the house, will retain the heat. The last three strategies each will reduce the projected energy use by 10%, for a total of 75%. (Fig. 3 a-d)

The team employed three design intentions to govern the form, function, and energy sensibility of the house. The first is conventionality. Energy conserving homes in the 1960's in the US have a distinctive aesthetic that, in some respects calls attention to themselves. The forms suggest that the architecture responds to very particular energy conserving concerns, such as lifting the roof to allow additional sunlight in during the wintertime or placing all of the public areas along the south portion of the house. To live in an energy efficient house, people believe they must dramatically alter their lifestyle, which the majority of the US population is unwilling to do. In response, our objective is to design a house that

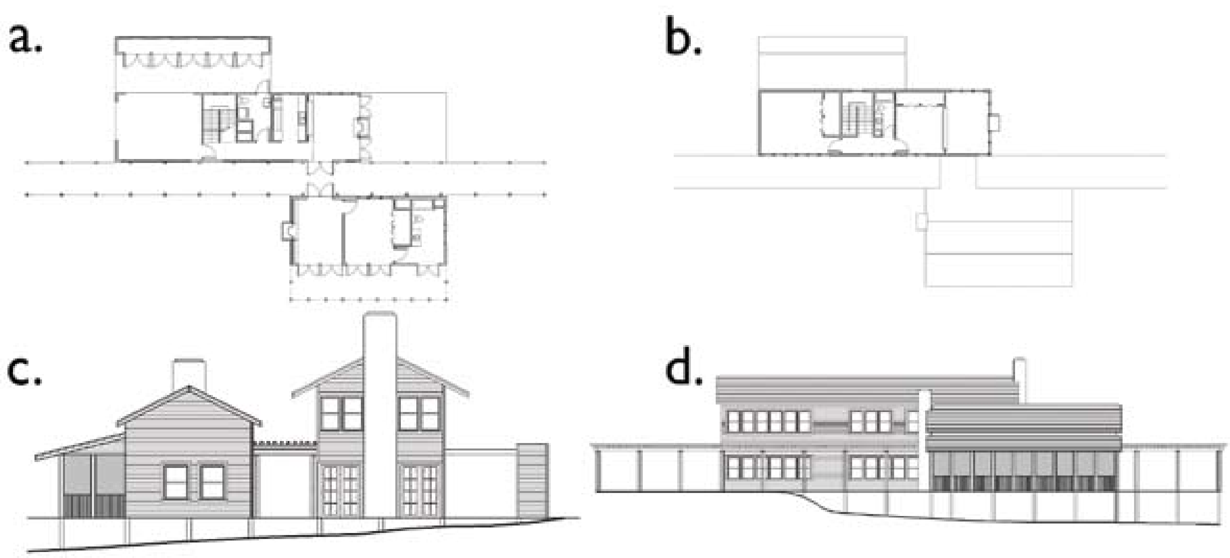

Figure 3: a) Ground floor; b) Second floor; c) East Elevation; d) South Elevation

appears conventional, yet provides a dramatic reduction in energy usage.

Besides aesthetics we addressed conventionality through the size of the house. In the US, the average sized house is approximately 1798 square feet (180 sq. m) [4], 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 (176 sq m). Our proposed house is 1800 square feet (180 sq. m). The social intent behind this conventional sizing is to illustrate that the size of a sustainable house does not need to be either abnormally small, which suggest that fewer square feet translates to less area to heat and cool or too large, which suggests additional rooms to accommodate the extra features. And from an economic perspective, the house would appear affordable to the broadest audience.

The third aspect of conventionality is lifestyle. Besides the public walkway that separates the two buildings, which if the house is to be a private residence would become an enclosed entry way, the house appears to be one out of a magazine. The arrangement, room sizes, and public and private area organization are not dramatically altered from the typical. Regarding the arrangement, we always conceived the buildings as a house 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 room sizes are fairly standard with bedroom ranging from twelve by twelve feet (3.6 m by 3.6 m) to sixteen by sixteen feet (5m by 5m). The living and dining rooms are both nominally twelve feet by sixteen feet (3.6m by 5m). Last, as with a typical house the public areas are the first ones that a visitor encounters with the more private ones situated out of the public arena.

I should note the extensive sun/screen porch located on the south side of the southern building. Screen porches, in particular, are quite common in the southern US. They are outdoor living rooms, especially welcome during the early spring and autumn months and late evenings during the summer, when you are able to sit outside. This room is enclosed with windows with screens that will allow its use all year around. The extensive amount of windows is an added expense to the typical house, however their use allows the house to grow in size without artificially conditioning the space.

The second design intention that influenced the buildings form is the demonstrational purpose. It is our intent 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. We plan to provide opportunities—displays, exhibits, variety of materials, and exposing portions of the buildings for people to inspect the workings and problems of the house.

The educational aspect extends beyond the buildings. The chosen site was intentionally difficult. It is quite common for the typical US house to resides 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 almost six feet (1.8m), which will require a combination of slab and raised floor. The raising above the ground will also create both problems with stability of the foundation because of the difficult drainage problems. Also regarding the site of the building, we will plant three acres of trees and vegetation to illustrate the required acreage to sequester the carbon dioxide for a typical house and note the area required for ours.

The third, and final, design intention is the research component. In conjunction with demonstrating sustainable and durable design issues, the facility will house multi-disciplinary research projects. They are:

1) Moisture control of windows, which is one of the most destructive, yet unknown causes for decay and failure in wooden structures;
2) Study of non-chemical control methods and treatments with very low if any mammalian toxicity, such as borates., to prevent decay and termite infestation
3) Natural herbicides to ward off Formosan termites;

4) Landscape as a significant factor in energy conservation and durability;
5) Tie-down systems for both foundations and roofs, so to counteract the high lateral wind loads;
6) Heat-interceptor systems, which have been erroneously called "radiant cooling"; to regulate interior temperatures
7) Study of hydroscopic materials to control moisture levels and humidity swings;
8) Low-velocity ventilation so to evaluate the location and size of windows in facades and the flow pattern of air; and,
9) Appropriate ceiling heights to control temperature and humidity.

Concluding Statements

When developing design and building techniques, termites especially the Formosan termite and wood decay fungi should be considered a major challenge in the southern US. They coexist interdependently and have (and will) cause devastating effects in all types of wooden structures in hot-humid climates. Their adverse affects suggest that durability is an equally significant consideration with energy conservation with respect to sustainability in the southeastern US. Sustainability is both a local and global concern that demands practical, grass root and microclimatic definitions on the one hand, while on the other acknowledging its social and cultural underpinnings so to convince people that it is not a marginal circumstance.

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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.