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I am submitting herewith a thesis written by Mary Elizabeth French entitled "Increasing the Structural Engineer's Influence Over Sustainability by Using Integrated Design Teams." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Civil Engineering.

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Vice Provost and Dean of the Graduate School

# **Increasing the Structural Engineer's Influence Over Sustainability By Using Integrated Design Teams**

A Thesis  
Presented for the  
Master of Science  
Degree  
The University of Tennessee, Knoxville

Mary Elizabeth French  
August 2010

## **Acknowledgements**

First of all, I would like to thank my family for their constant support and encouragement throughout my college career, and further to thank my father, Professor Robert C. French for instilling in me a love for buildings and architecture and an appreciation and respect for all the disciplines involved in the design process. I am also very thankful to Dr. Ma for taking a chance and allowing and encouraging me to step slightly outside the field of engineering in order to integrate architecture with engineering as a more complete design team. I would also like to thank Professor Tricia Stuth for helping and encouraging me, for her persistence on the New Norris House, and spending the time to organize an integrated design team class. And, Dr. Bennett for always being supportive of my college career, both undergraduate and graduate, and for serving on my committee. I would also like to thank the local professional community for responding to my surveys and Frances Yang, P.E. and Patrick McCafferty of ARUP and Phineas Marshall and John Quale of the University of Virginia for answering questions and providing me with case study information. The research reported in this thesis is part of sustainable structures initiative, (PI: Dr. John Ma), sponsored by the Institute for a Secure and Sustainable Environment, (ISSE), at the University of Tennessee, Knoxville.

## **Abstract**

Sustainability is quickly becoming a “buzz word” in today’s environmentally conscious world from political leaders to building professionals to design experts to consumers as they rethink their impact on current healthy, efficient indoor/outdoor environments as well as long term benefits to future generations.

This thesis seeks to investigate ways to increase the structural engineer’s influence over the sustainability of the building industry by using integrated design teams. It explores current practices within the building industry, in particular the housing industry and the ways in which the integrated design team differs from most current practices. It strives to promote the positive impact an integrated design team with structural engineers on board from the onset has on the design process as far as time, cost, and environmental concerns are considered. This thesis continues by establishing methods for measuring the success of an integrated design team, its effects on sustainability, and how the structural engineer was involved.

The focus of this thesis is the New Norris House class project: its background and the integrated design team’s process as it differs from the traditional design concept. The results of the project including the LEED and HERS rating and material efficiency and the impact of the structural engineer’s inputs from the onset will be discussed. The thesis ends with a discussion of the differences between the educational and professional community and how integrated design teams are an efficient and cost effective way to achieve high levels of sustainability.

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## **Chapter 1. Introduction**

Our world population today has surged to an overwhelming number of 6.3 billion people from 2.5 billion in the 1950s (Anonymous 2009), and in the past several decades the world has experienced noticeable detrimental changes to the environment such as depleting natural resources, species extinction, air and water pollution, ozone depletion, and soil degradation, to name a few. Environmental stresses are often the result of the growing demand on scarce resources and the increased pollution generated from the increase in living standards. These changes lead to a concern as to whether the world can sustain the current population and still be able to provide a consistent or better standard of living for future generations, thereby renewing the idea of sustainability. Sustainability is ensuring that the needs of the present are met without compromising the ability of future generations to meet their needs (World Commission on Environment and Development 1987).

Whether directly or indirectly, buildings and their construction make up 39% of the United State's energy consumption (Ward 2010), 45% of the world's total energy use, 50% of all materials and resources (Anonymous September 14, 2004), 39% of the world's CO<sub>2</sub> emissions (Ward 2010), 80% potable water use, 25% of freshwater withdrawal, 40% of municipal solid waste destined for landfills, and 50% of the ozone-depleting CFCs still in use (Anonymous September 14, 2004). These statistics make the progression of sustainable building practices a crucial responsibility to the building community, and although sustainability is important to all industries, the application to

the building industry could have a large impact on the sustainability of the world's environment.

The aim of this study is to explore the increase of the structural engineer's influence over the sustainability of a structure through the use of integrated design teams. This study will focus on the New Norris House limiting the scope of the investigation to the influence within the residential building industry; nonetheless, the implications of the study should be universal within the entire building industry.

Sustainability is defined in Chapter 2, which also includes a look at the components that contribute to a structure's sustainability. Once an understanding of the sustainability of a structure has been established, Chapter 3 explores the current practices in the residential building industry and the current structural engineer's view on sustainability. Other successful sustainable projects are discussed in Chapter 4 in order to examine the design processes, identify the obstacles encountered and how the obstacles might apply to the New Norris House, and to establish methods of measuring success. This leads into the background of the New Norris House project and the description of the integrated design team used in the study discussed in Chapter 5. Chapter 5 not only describes the integrated design team, but it also describes the design process used by the integrated design team and how it differs from a traditional design process with no integrated design team.

Chapters 6, 7, and 8 reveal the results of the project and the structural engineer's impact on those results in the form of the expected LEED (Leadership in Energy and Environmental Design) rating, the expected HERS (Home Energy Rating System) rating, and the material efficiency. The conclusions in Chapter 9 discuss the results and

their implications and how the results might be applied to the building industry outside of residential, ending with areas of research that could be explored further.

## **Chapter 2. Definition of Sustainability**

As the statistics in Chapter 1 show, the building industry has a large negative impact on the environment. It would be advantageous to investigate ways to reduce this impact. In order to lessen the building industry's impact on the environment, the challenge to the design community is to progress beyond designing simply "green" buildings and begin designing sustainable, high-performing buildings (Subasic 2009).

This chapter investigates the influence the building industry has on the environment. This thesis focuses on the residential portion of the building industry which constitutes 51.5% (U.S. Census Bureau 2009) of the industry, making the sustainability of residential structures an important part of the total building industry. The chapter also defines what a sustainable, high-performance building is; it explains factors that influence a structure's sustainability and how those factors could relate to structural engineering.

A sustainable structure is one for which the site, design, construction, occupancy, operation and maintenance, and deconstruction are considered in order to promote energy, water, and material efficiencies while providing not only a comfortable, healthy indoor environment but also long-term benefits to the owner, occupants and society (Sustainable Buildings Industry Council 2008). In order to achieve a sustainable structure, some of the principles that should be considered are as follows:

commissioning and decommissioning, high performance lighting, daylighting, visual, acoustic, and thermal comfort, environmentally responsive site planning, water efficiency, energy use analysis, renewable energy, energy efficient building envelopes, high performance HVAC systems, passive energy systems, indoor environmental

quality, safety and security, life cycle cost analysis, and environmentally-preferable building materials (Subasic 2009).

The commissioning and decommissioning relates to the adaptability or flexibility of the structure. Currently, the United States generates about 136 million tons of construction and demolition debris each year compared to the 210 million tons of municipal solid waste generated the same year. Increasing the adaptability, flexibility, and deconstruction ease of structures can decrease the building industry's waste's impact on landfills by prolonging the life of the building and allowing for salvage opportunities at the end-of-life. Designers should consider issues like the structure's possible reuse for other purposes when determining live loads, future additions, and/or allowances for disassembly by clearly marking electrical circuits for easy identification and removal, designing systems separate from one another, and choosing materials and connections that can also be disassembled (Barr and McCafferty 2009).

Environmentally responsive site planning mainly includes storm water control and the impact the structure has on the surrounding area and community, such as the community's water supply. Storm water control can be achieved by minimizing impervious surfaces and exchanging them for pervious parking lots or vegetative roofs (Subasic 2009).

Water efficiency is generally associated with the use of highly efficient water fixtures, but it can also be achieved by means of water reclamation. Rainwater collection systems can be incorporated with impervious roofs and used to irrigate, or be treated and used for other domestic purposes. The gray water the occupants produce can be used for irrigation as well with or without treatment.

Knowledge and use of passive energy systems help to influence the indoor comfort, daylighting, and energy efficiency of the structure. The main components of these systems include sun orientation, thermal mass, shading, ventilation, and insulation. Structures oriented in the north-south direction with minimal east and west windows and shaded southern windows in the summer maximizes the sunlight in the winter allowing for optimal natural lighting without increasing the interior temperatures during the warmer seasons. The thermal comfort can be increased even more by allowing the winter sunlight to fall on an interior wall with high thermal mass. High thermal mass materials such as concrete, concrete masonry units (CMU), or clay brick will store heat from the sun. Operable windows are important to provide natural ventilation during times of enjoyable outdoor temperatures. These components not only magnify the indoor environmental comfort and quality, but they also allow the occupant to use less energy for artificial lighting and HVAC systems. Also, north-south orientation is the optimal orientation for photovoltaic panels allowing the structure to incorporate renewable energy which also increases energy efficiency (Barr and McCafferty 2009). The impact these systems have on the energy efficiency of the structure can be confirmed by energy analysis programs.

The safety and security of a structure applies to the durability of the structure, therefore increasing its longevity. The structure can be designed beyond life safety (what the building codes call for) and be designed to withstand more strenuous loads in order to protect possible expensive “green” systems and products contained within the structure (Subasic 2009).

When choosing building materials, efficiency, including waste management and environmentally-preferable products, should be considered. Designing for the chosen loads increases material efficiency; however, material efficiency can be further influenced through the construction phase. Providing detailed drawing sheets with each material and appropriate length will reduce waste due to mistakes. Also, carefully planning the construction process can keep materials from sitting stagnant at a job site where they are susceptible to weather damage and theft. Environmentally-preferable materials can be different for each project and location; the embodied energy of the material choices should be investigated in order to determine the best option for a specific project, conditions, and situation. Embodied energy is the energy consumed to extract, assemble, transport, install, remodel, and maintain a given material. Contributions to a material's embodied energy include extracting, harvesting, producing, and manufacturing of the product, material transportation to and from the site, construction related activities, such as water use while installing, maintenance repair and replacement, and demolishing and disposal to name a few (Barr and McCafferty 2009). Other influences over the environmental preferability of a material might include abundance and regional availability of a material, recycled content, reduced or eliminated toxic substances, responsible storm water management, use of renewable energy or alternate sources of fuel or water efficiency, and/or reuse in the harvesting, production, or manufacturing process.

All the previously stated factors can contribute to the life cycle cost analysis, which not only includes the initial economic cost of the building but also includes determining the life span of the building materials used and the required operation and

maintenance costs. Consideration may also include end of life costs such as demolition and recycling costs (Subasic 2009).

When first glancing over the factors that influence a structure's sustainability introduced in earlier, it may seem that a structural engineer would only be able to affect a few of those categories. However, after investigating each of these elements, it becomes evident of the potential for structural engineer involvement and influence.

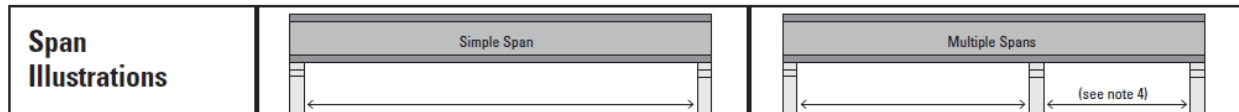
## **Chapter 3. The Current Residential Building Industry**

With an understanding of the factors that affect a structure's sustainability, but before attempting to try and develop a process for increasing the structural engineer's influence, the current residential building industry processes and practices should be investigated.

The following two sections will explain the design through construction phases of each type of home, and at what point the structural engineer might become involved. Section 3.1 focuses on the Type A home which is the typical contractor-built home with little to no professional design or architectural involvement. Section 3.2 focuses on the Type B home which is the custom-built home or higher-end home with professional design involvement. Section 3.3 will reveal survey results from structural engineers and how they relate and support the statements in the first two sections.

### **3.1 The Type A Home**

The Type A home is a contractor-built, speculative home. Sometimes the contractor serves as the developer and builds a neighborhood based on a few home designs that have already been approved; or, the contractor is given a set of already approved plans by a homeowner, often purchased online, as from Southern Living House Plans (<http://www.slhouseplans.com/>). In both cases, the structural framing is frequently chosen by prescriptive methods from load or span tables in product manuals or in the International Building Code, IBC (International Code Council 2006). An example of a product manual span table that a contractor might use to determine floor joists is shown in Figure 1.



#### 40 PSF Live Load + 10 PSF Dead Load

#### Improved Performance (L/480)

| Joist Series | Joist Depth | Spacing (Simple Span) |          |            |          | Spacing (Multiple Span) |          |            |          |
|--------------|-------------|-----------------------|----------|------------|----------|-------------------------|----------|------------|----------|
|              |             | 12" o.c.              | 16" o.c. | 19.2" o.c. | 24" o.c. | 12" o.c.                | 16" o.c. | 19.2" o.c. | 24" o.c. |
| GPI 20       | 9½"         | 17'-01"               | 15'-07"  | 14'-09"    | 13'-10"  | 18'-07"                 | 17'-00"  | 16'-01"    | 15'-00"  |
|              | 11⅞"        | 20'-05"               | 18'-08"  | 17'-08"    | 16'-06"  | 22'-03"                 | 20'-04"  | 19'-02"    | 17'-05"  |
|              | 14"         | 23'-03"               | 21'-03"  | 20'-01"    | 18'-09"  | 25'-04"                 | 23'-02"  | 21'-04"    | 18'-06"  |
| GPI 40       | 9½"         | 18'-00"               | 16'-06"  | 15'-07"    | 14'-07"  | 19'-08"                 | 17'-11"  | 16'-11"    | 15'-06"  |
|              | 11⅞"        | 21'-06"               | 19'-08"  | 18'-07"    | 17'-04"  | 23'-05"                 | 21'-05"  | 19'-09"    | 17'-08"  |
|              | 14"         | 24'-04"               | 22'-03"  | 21'-01"    | 19'-05"  | 26'-07"                 | 23'-09"  | 21'-08"    | 19'-04"  |
| GPI 65       | 11⅞"        | 23'-03"               | 21'-03"  | 20'-00"    | 18'-08"  | 25'-04"                 | 23'-01"  | 21'-09"    | 20'-04"  |
|              | 14"         | 26'-05"               | 24'-02"  | 22'-09"    | 21'-03"  | 28'-10"                 | 26'-03"  | 24'-09"    | 20'-08"  |
|              | 16"         | 29'-04"               | 26'-09"  | 25'-03"    | 23'-07"  | 32'-00"                 | 29'-02"  | 25'-11"    | 20'-08"  |
| GPI 90       | 11⅞"        | 26'-04"               | 24'-00"  | 22'-07"    | 21'-00"  | 28'-08"                 | 26'-01"  | 24'-07"    | 22'-10"  |
|              | 14"         | 29'-11"               | 27'-02"  | 25'-07"    | 23'-10"  | 32'-07"                 | 29'-07"  | 27'-10"    | 25'-11"  |
|              | 16"         | 33'-01"               | 30'-01"  | 28'-04"    | 26'-04"  | 36'-01"                 | 32'-09"  | 30'-10"    | 26'-07"  |
| WI 40        | 9½"         | 18'-00"               | 16'-05"  | 15'-06"    | 14'-06"  | 19'-07"                 | 17'-11"  | 16'-04"    | 14'-07"  |
|              | 11⅞"        | 21'-05"               | 19'-07"  | 18'-06"    | 16'-08"  | 23'-05"                 | 20'-05"  | 18'-07"    | 16'-07"  |
|              | 14"         | 24'-04"               | 22'-03"  | 20'-06"    | 18'-04"  | 25'-11"                 | 22'-05"  | 20'-05"    | 18'-03"  |
| WI 60        | 11⅞"        | 22'-07"               | 20'-08"  | 19'-06"    | 18'-02"  | 24'-08"                 | 22'-06"  | 21'-02"    | 19'-07"  |
|              | 14"         | 25'-09"               | 23'-06"  | 22'-02"    | 20'-08"  | 28'-00"                 | 25'-07"  | 24'-01"    | 19'-09"  |
|              | 16"         | 28'-06"               | 26'-00"  | 24'-07"    | 22'-10"  | 31'-01"                 | 28'-04"  | 24'-09"    | 19'-09"  |
| WI 80        | 11⅞"        | 24'-11"               | 22'-08"  | 21'-04"    | 19'-10"  | 27'-01"                 | 24'-08"  | 23'-03"    | 21'-07"  |
|              | 14"         | 28'-03"               | 25'-09"  | 24'-03"    | 22'-07"  | 30'-10"                 | 28'-00"  | 26'-05"    | 23'-11"  |
|              | 16"         | 31'-04"               | 28'-06"  | 26'-10"    | 25'-00"  | 34'-02"                 | 31'-01"  | 29'-03"    | 23'-11"  |

#### 40 PSF Live Load + 20 PSF Dead Load

#### Improved Performance (L/480)

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|              |             | 12" o.c.              | 16" o.c. | 19.2" o.c. | 24" o.c. | 12" o.c.                | 16" o.c. | 19.2" o.c. | 24" o.c. |
| GPI 20       | 9½"         | 17'-01"               | 15'-07"  | 14'-09"    | 13'-10"  | 18'-07"                 | 17'-00"  | 15'-07"    | 13'-11"  |
|              | 11⅞"        | 20'-05"               | 18'-08"  | 17'-08"    | 15'-11"  | 22'-03"                 | 19'-05"  | 17'-09"    | 15'-05"  |
|              | 14"         | 23'-03"               | 21'-03"  | 19'-06"    | 17'-05"  | 24'-08"                 | 21'-04"  | 19'-03"    | 15'-05"  |
| GPI 40       | 9½"         | 18'-00"               | 16'-06"  | 15'-07"    | 14'-02"  | 19'-08"                 | 17'-04"  | 15'-10"    | 14'-02"  |
|              | 11⅞"        | 21'-06"               | 19'-08"  | 18'-01"    | 16'-02"  | 22'-10"                 | 19'-09"  | 18'-00"    | 16'-01"  |
|              | 14"         | 24'-04"               | 21'-09"  | 19'-10"    | 17'-09"  | 25'-01"                 | 21'-08"  | 19'-09"    | 17'-01"  |
| GPI 65       | 11⅞"        | 23'-03"               | 21'-03"  | 20'-00"    | 18'-08"  | 25'-04"                 | 23'-01"  | 21'-06"    | 17'-02"  |
|              | 14"         | 26'-05"               | 24'-02"  | 22'-09"    | 21'-03"  | 28'-10"                 | 25'-11"  | 21'-06"    | 17'-02"  |
|              | 16"         | 29'-04"               | 26'-09"  | 25'-03"    | 22'-03"  | 32'-00"                 | 25'-11"  | 21'-06"    | 17'-02"  |
| GPI 90       | 11⅞"        | 26'-04"               | 24'-00"  | 22'-07"    | 21'-00"  | 28'-08"                 | 26'-01"  | 24'-07"    | 22'-02"  |
|              | 14"         | 29'-11"               | 27'-02"  | 25'-07"    | 23'-02"  | 32'-07"                 | 29'-07"  | 27'-09"    | 22'-02"  |
|              | 16"         | 33'-01"               | 30'-01"  | 28'-04"    | 23'-02"  | 36'-01"                 | 32'-09"  | 27'-09"    | 22'-02"  |
| WI 40        | 9½"         | 18'-00"               | 16'-05"  | 14'-11"    | 13'-04"  | 18'-11"                 | 16'-04"  | 14'-11"    | 13'-03"  |
|              | 11⅞"        | 21'-05"               | 18'-08"  | 17'-01"    | 15'-03"  | 21'-06"                 | 18'-07"  | 17'-00"    | 15'-02"  |
|              | 14"         | 23'-09"               | 20'-06"  | 18'-09"    | 16'-09"  | 23'-08"                 | 20'-05"  | 18'-08"    | 16'-05"  |
| WI 60        | 11⅞"        | 22'-07"               | 20'-08"  | 19'-06"    | 17'-11"  | 24'-08"                 | 21'-11"  | 20'-00"    | 16'-05"  |
|              | 14"         | 25'-09"               | 23'-06"  | 22'-00"    | 19'-08"  | 27'-10"                 | 24'-01"  | 20'-07"    | 16'-05"  |
|              | 16"         | 28'-06"               | 26'-00"  | 23'-09"    | 19'-10"  | 30'-00"                 | 24'-09"  | 20'-07"    | 16'-05"  |
| WI 80        | 11⅞"        | 24'-11"               | 22'-08"  | 21'-04"    | 19'-10"  | 27'-01"                 | 24'-08"  | 22'-09"    | 18'-02"  |
|              | 14"         | 28'-03"               | 25'-09"  | 24'-03"    | 21'-02"  | 30'-10"                 | 28'-00"  | 24'-11"    | 19'-11"  |
|              | 16"         | 31'-04"               | 28'-06"  | 26'-06"    | 21'-02"  | 34'-02"                 | 30'-00"  | 24'-11"    | 19'-11"  |

Figure 1. Wood I-Beam Joist Span Table (Georgia-Pacific Wood Products 2008).

If the contractor and/or the homeowner decide to make sustainability a priority, the contractor can follow the prescriptive methods explained in the National Green Building Standard supported by the National Association of Home Builders National Green Building Program (National Association of Home Builders and International Code Council 2008). That book explains sustainable methods for site preparation and building, and the contractor can choose how few or how many sustainable methods they would like to employ. The Green Scoring Tool allows the contractor to track his or her success (National Association of Home Builders 2008).

With this approach, the Type A home can be built (sustainable or not) without required contribution from the structural engineer. The structural engineer's involvement might become necessary if problems arise. Problems that might require the attention of a structural engineer include:

1. The contractor or homeowner wishes to make changes to the set of approved plans, such as adding square footage or removing parts of load-bearing walls,
2. The local building inspector requires approval for some aspect of the foundation or framing, or
3. The specific site requiring unexpected foundation or retaining wall design.

For problem 1, the structural engineer's effect on sustainability would be limited to durability and/or recommending the selection of environmentally-preferable materials. At this point in the project, the structural materials have already been chosen, but the structural engineer could recommend the use of the more environmentally friendly option of this material, such as local lumber or recycled steel. Also, he or she could increase the durability of his or her design by considering the possibility of future

additions and the loads that might accrue, salvaging possibilities by designing connections that can be easily detached, or by designing the members to endure for a longer time. However, the increase in durability would be limited to the selected portion of the house that the structural engineer would be addressing.

At the time of involvement for problem 2, construction would have already begun making problem 2 a limited area for influence. If inspection reveals that changes need to be made, then the structural engineer could influence the sustainability of those changes through durability and/or environmentally-preferable projects such as problem 1.

For problem 3, the structural engineer's influence over sustainability could be greater than the previous problems depending on the amount of foundation and/or retaining walls are required. The structural engineer could also have an impact over the structure's durability and what environmentally-preferable products are chosen as shown in problem 1 and 2. If the materials have not yet been chosen, then the structural engineer can investigate all environmentally-preferable options and choose the most appropriate for that particular site and application, therefore having a larger impact.

### **3.2 The Type B Home**

The Type B home is a custom or higher-end home designed by an architect. With this type of home, the architect is typically hired by the homeowner and together they will make decisions on whether or not to pursue sustainable approaches and to what degree. The structural engineer typically becomes involved in the project once the

full design or design concept is complete. Depending on the complexity of the structure, the responsibilities of the structural engineer could be as much as a full set of structural framing plans with foundations, or as little as sizing a few beams and columns or verifying foundation design. Architects have varied structural knowledge, and they can also use load and span tables to size typical framing members.

With a Type B home, the structural engineer is possibly involved earlier in the project than they might be with a Type A home, allowing the opportunity to have a greater impact on the structure's sustainability. However, the structural engineer's influence would be limited to the areas of the home that the structural engineer is asked to design. At this point in the design process, with the design practically complete, the building materials have been chosen. Thus, the areas of sustainability that the structural engineer can influence would include adaptability, durability, and environmentally-preferable materials similar to the Type A home described above.

If the structural engineer is designing a majority of the structural framing, then he or she could have a noticeable effect over the material efficiency as well. Any member designed by a structural engineer should be an efficient use of material designed to withstand the assumed loads; the more structural members that are engineered, the more influence the structural engineer has over the home's material efficiency.

### **3.3 Survey of Structural Engineers**

The information provided in the previous two sections is supported by the data obtained in a survey I conducted of local structural engineers, (practicing in Tennessee, mostly east Tennessee). The survey was distributed to Tennessee structural engineers

through the chapters of the American Society of Civil Engineers, (ASCE), and the Structural Engineers Association, (SEA).

The survey was aimed at discovering the current industry practices by determining when the structural engineer might become involved in the design process of a residential home and what would they be asked to do; I also wanted insight into how structural engineers believed that they could influence the sustainability of residential structures. The survey included three questions:

1. What would your design responsibilities and process be for a residential home?
2. At what point would you become involved in the project, and what information are you given in order to begin the project?
3. If, in the same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability?

Twenty-four civil/structural engineers responded to the survey. Thirty percent, (30%), of the survey answers indicated responsibilities in a Type A or Type B home with involvement occurring at the completion of the design or design concept and as problems arose. Sixty-one percent, (61%), of the survey answers indicated involvement in a strictly Type B home following the architect's completion of the design or design concept. Responses on sustainability influence varied from no influence to influence over environmentally-preferable materials, material efficiency, and durability. Twenty-six percent, (26%), of the survey-takers felt they could have no influence over the sustainability of a residential home; however, of that 26%, one survey-taker indicated that there could be more influence if the structural engineer was more involved in the project. Forty-three percent, (43%), of the survey answers indicated that the

sustainability of the materials could be influenced by either choosing environmentally-preferable options of the materials already selected and/or use the materials efficiently. Only 8.7% of the surveys indicated that the durability of the home could be influenced and only 13% said that the thermal efficiency or envelope of the home could be impacted. There were a few responses that mentioned other categories of influence that were not expected, such as storm water control through rain collection or controlling pervious surfaces, and the implementation of passive systems. The survey answers are summarized in Table 1 and some typical survey answers can be found in Table 2.

As shown in Sections 3.1 and 3.2 and supported by the responses from local structural engineers, it seems that current residential building industry methods allow for the structural engineer to influence none to a minimal amount of the sustainability of the structure. If the structural engineer is involved earlier in the project, then he or she could directly or indirectly influence many facets of the home's sustainable criteria. Two survey-takers indicated a preference for an integrated design team approach to residential design allowing all stakeholders to be involved in the project from the very beginning. Because of experience with integrated design team approach, those survey-takers listed many other ways that the structural engineer could influence sustainability, such as: employing integrated design principles, protecting and conserving water, and enhancing indoor environmental quality, along with increasing material efficiency, thermal efficiency, and durability. The integrated design team and the structural engineer's role as a team member merits further investigation and could optimize the sustainability of structures.

*Table 1. Summary of Survey Answers From Local Professionals*

| <b>Categories of Sustainability Influence</b>        | <b>Percentage of Survey-Takers Who Felt They Could Influence This Category</b> |
|------------------------------------------------------|--------------------------------------------------------------------------------|
| Materials: efficiency and environmentally-preferable | 43%                                                                            |
| Durability                                           | 8.7%                                                                           |
| Thermal efficiency or envelope                       | 13%                                                                            |
| <b>NO INFLUENCE</b>                                  | <b>26%</b>                                                                     |

Table 2. Sample of Survey Answers Indicating Different Categories of Sustainability Influence

| Questions                                                                                                                                                                                                            | Typical Answers Indicating Influence Over:                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                                                                      | Materials                                                                                                                                                                                                                                                                                             | Durability                                                                                                                                                                                                                                                                                                                                                                                                   | Thermal Efficiency                                                                                                                                                                                                                                                                 | No Influence                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| What would your design responsibilities and process be for a residential home (even if your responsibilities would be minimal to none because structural engineers aren't generally required for residential homes)? | In residential projects we, as structural engineers, get called upon typically in higher end homes where the intricate floor plans make for complicated load paths. Our responsibility is limited to helping the architect realize the architectural goal, using materials selected by the architect. | Structural engineers would get involved when there are non-prescriptive design requirements. Normally for larger homes and/or cut up framing plans. Example would be a large/long opening that is in a load-bearing wall. Also, if the home is designed with light gauge steel studs a structural engineer might be involved. The State of TN requires a structural engineer for homes larger than 5,000 SF. | Foundation (footer and wall), floor, porches and stairwell, and roof design.                                                                                                                                                                                                       | Designing member that are beyond the capability of the lumber supplier, such as steel beams and columns for long spans                                                                                                                                                                                                                                                                                                                                                                                |
| At what point would you become involved in the project? And, what information are you given in order to begin the project?                                                                                           | We get involved once the architect has reached substantial completion of the project. Structural engineers typically <u>have</u> to make the concept work.                                                                                                                                            | Funny you should ask. Should be involved in the design process, but normally called in after the fact when there are problems during construction or after it is completely built.                                                                                                                                                                                                                           | Following conceptual design approval by owner. Provided with regional locations, unique location code requirements, site conditions and structure's general geometry, i.e., foundation depth and soil conditions, specific structural feature and unique building materials, etc.. | I work with several high end custom home builders that build homes for 1-6 million in value. The builder will start with a set of plans from say Southern Living and then modify these plans using a drafting service to meet the clients needs. He will then turn the plans over to his lumber supplier who will generate a set of plans showing TJI framing with microlam beams. At this point he will review the plans with me to design members outside of the design capability of the supplier. |

Table 2. Continued

| Questions                                                                                                                                              | Typical Answers Indicating Influence Over:                                                                                                                                                                                   |                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |              |
|--------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|
|                                                                                                                                                        | Materials                                                                                                                                                                                                                    | Durability                                                                                                                                                                                                                    | Thermal Efficiency                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | No Influence |
| If, in the same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability? | Residential structures are typically built with wood or light gage metals (recycled), both of which, I believe, are regarded as sustainable. Additional contribution to sustainability by the structural engineer is limited | Light gauge steel increased the life of a structure plus eliminates termite contracts. Using metal roofs in lieu of asphalt shingles would be a big green item. Painted Kynar finishes on metal give recognized green values. | The architect's owner approved conceptual design would dictate the major features I would prepare my design within. In addition to those included in #2 (above), and within the approved conceptual design, I would focus on improvements to the building's structural envelope utilizing and/or supporting the following:<br><ul style="list-style-type: none"> <li>•local materials suitable to the regional and specific structure's locations</li> <li>•thermally resistant structural materials</li> <li>•accommodating incorporation of high-performance (super efficient Energy Star and Green Building rated systems and equipment) and/or natural systems <ul style="list-style-type: none"> <li>• high-performance heating, ventilation, humidity control and air conditioning (HVAC) systems</li> <li>• lighting system</li> <li>• water system, i.e., conservation and efficiency measures</li> </ul> </li> </ul> | None.        |

## **Chapter 4. Successful Sustainable Projects**

Chapter 3 explores the typical practices and sustainability within the residential building industry and how the structural engineer is involved. Although integrated design teams are currently a minority within the design community, there are some projects that employ them.

This chapter focuses on ecoMOD1, a successful sustainable project that was designed with an integrated design team in a university setting and the California Academy of Sciences designed with an integrated team members from ARUP. It investigates how integrated design teams were used, what obstacles were encountered when attempting to design a sustainable structure with an integrated design team, and how the success of the project was measured.

EcoMOD is a research and design / build / evaluate project at the University of Virginia School of Architecture that strives to create ecological, modular and affordable house prototypes. The project works in partnership with the UVA School of Engineering and Applied Science, and the goals are to demonstrate the environmental and economic potential of prefabrication, and to challenge the modular and manufactured housing industry in the U.S. to explore this potential. The program utilizes students from the disciplines of architecture, engineering, landscape architecture, historic preservation, business, economics, environmental science, planning, nursing and medicine, all participating in the design, construction and evaluation phases of the project. The program aims to challenge the idea that sustainable residential design is a luxury only reserved for the wealthy, because "...it is individuals at low and moderately low income levels who can truly benefit from the reduced energy, water and

maintenance costs associated with environmentally responsive homes. The ecoMOD project is committed to bringing sustainability to affordable housing by re-imagining the idea of 'home' through thoughtful, efficient and ecological design (ecoMOD 2008)."

The ecoMOD1 design is the first two-unit condominium in the city of Charlottesville, VA, sold with down-payment assistance and subsidized financing by Piedmont Housing Alliance. "The primary design strategy of ecoMOD1: the OUTin house, is to make the entire site habitable and useable. Rather than a rectangular box without functional outdoor spaces, the OUTin house is placed to merge outside and inside places. Sunlight, breezes, vegetation, the earth and the surrounding context are brought into the house through passive design strategies and shifted modules that define outdoor / indoor spaces. OUTin's design strategies are grounded philosophically and formally in our ecological mission, making ecology legible for the inhabitant (ecoMOD 2009)."

The integrated design team was organized as follows: students from varying disciplines enroll in either the engineering seminar or the architecture studio class. The professors start off by organizing the students in teams based on areas of interest. There is a clear set of objectives and steps required to achieve those objectives, and the students submit progress reports throughout the semester. Each team meets with the professors and the teams meet and coordinate with one another. The architecture studio and the engineering seminar generally meet at the same time so that students can mesh together as much as possible. The meshing allows for a more singular effort rather than two different teams designing the project (Marshall 2009).

According to Professor Marshall, the most notable challenge within the integrated design team has been the culture differences between architecture and engineering. Engineers are characteristically left brain thinkers while architects are characteristically right brain thinkers. The different ways of thinking mean the engineers approach problem solving logically and mathematically while architects may consider the logic of the problems, they also approach problem solving philosophically. The results render black and white solutions from engineers and solutions sometimes falling in the gray areas from the architects. These differences make it difficult for the students to understand and appreciate one another; so, communicating and working together is problematic. However, Professor Marshall is convinced of the importance of integrative design teams and interdisciplinary cooperation.

The projects encounter other obstacles. According to Professor John Quale, some of the obstacles they face include clients and other interested parties involved that do not support or understand the intentions of the project, and the additional costs of some sustainable technologies, which can represent a larger percentage of the budget for affordable housing as compared to the budget for commercial structures or market rate housing. They have succeeded in their efforts by working closely with the local affordable housing organizations such as the Piedmont Housing Alliance and Habitat for Humanity. Although they are pushing the organizations' green designs farther than they normally would, they have proved receptive and understand and care about the same issues such as taking care of indoor and outdoor environments, and affordable housing. When dealing with added expenses, they work to stay within the client's budget for the

baseline building (including “low-tech” sustainable approaches) and they raise separate money for the high tech devices and appliances (Quale 2009).

The team continues to monitor their projects after completion to verify expected outcomes, learn from their efforts, and then apply them to subsequent projects.

ecoMOD1: the OUTin house reports about a 50% reduction in energy consumption compared to a home of similar size and occupancy. Figures 2 and 3 show a breakdown of the ecoMOD1’s energy consumption over two years and an energy consumption comparison between ecoMOD1 and an average 1000-1500 square foot U.S. home (Marshall 2009).

Another exceptional example of a successful sustainable project is the California Academy of Sciences, designed using an integrated design team including engineers, designers, and consultants from ARUP. Some of the important structural features on the building included the green roof and the rocking walls, both of which are non-traditional elements that are beyond what is generally addressed in the building codes. Rocking shear walls as opposed to conventional fixed shear walls are paired with non-load bearing, non-linear supplemental damping systems for energy dissipation to improve seismic performance. Rocking walls can save money because they can minimize or eliminate the need for ground anchors and other materials associated with deep foundations. The engineers involved with the project felt that the obstacles associated with green roofs -- its effects on other various systems, including energy performance, seismic behavior, plumbing, drainage, and landscaping--required collaboration with other disciplines. The use of rocking walls is a new concept, which required proof of its validation to the local codes officials in order to receive approval.

Convincing the codes officials was accomplished by advanced analysis through the expertise of ARUP's advanced technology group and in-house structural analysis software. The engineers involved felt that the obstacles to the green roof and the rocking walls would have proven very difficult had they not had the advantage of working in an integrated design team enabling constant communication, demonstration, and perseverance (Yang 2009).

The Platinum LEED rating received by the California Academy of Sciences is one of the ways that the integrated design team measures the success of their project. The structural engineers involved also measure the success of the project through the life-cycle energy and water savings analyses, the cost savings, the resource savings, the lessened impact on the surrounding environment, and the increased seismic safety to the community (Yang 2009).

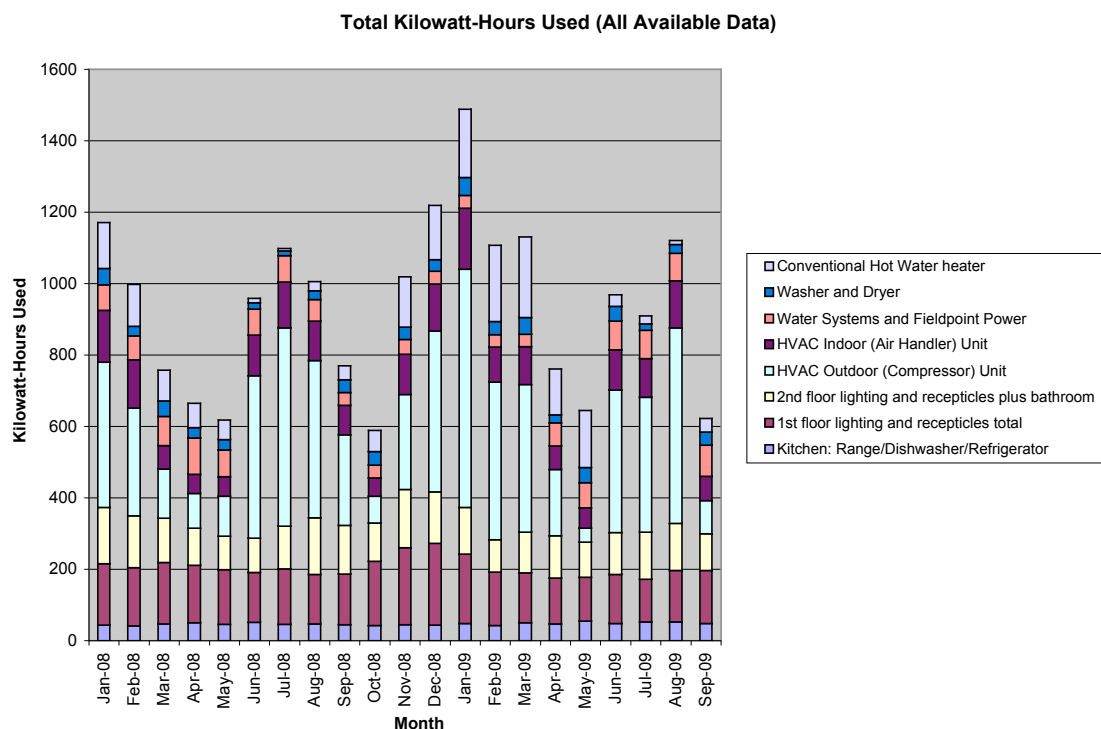


Figure 2. Breakdown of ecoMOD1 Energy Consumption for 2008 and 2009

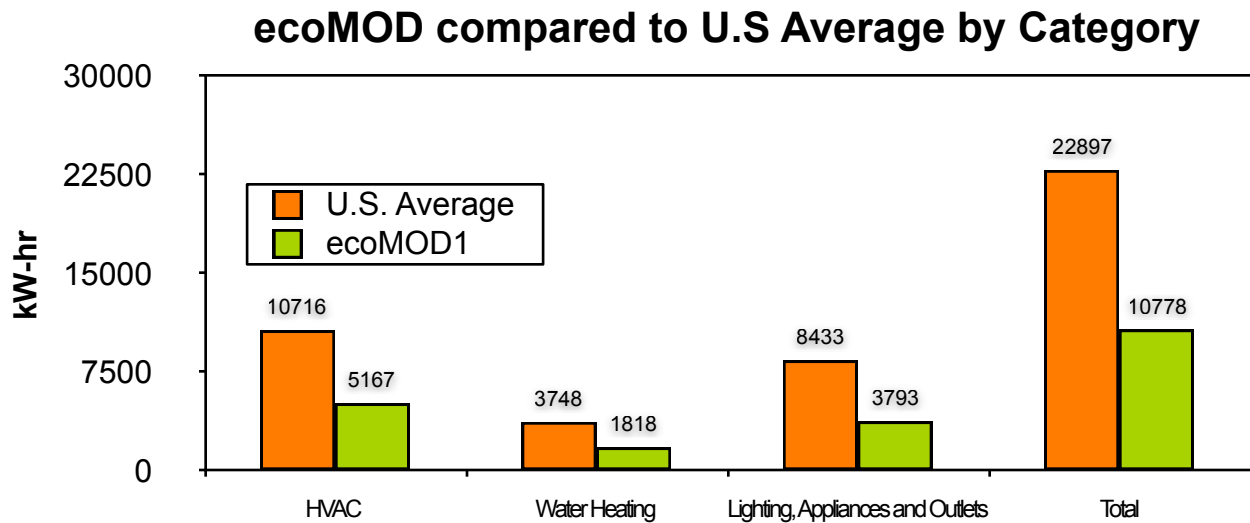


Figure 3. *ecoMOD1 Compared to Average 1000-1500 square foot U.S. Home*

The ecoMOD program and the California Academy of Sciences show that achieving sustainability in the building industry is possible and that integrated design teams are a way to obtain high sustainable goals, but not without some obstacles. We can expect that communication and meshing challenges within the integrated team as seen by ecoMOD and our project, the New Norris House, could also be met with budgetary roadblocks and misunderstandings from involved parties. The obstacles experienced by the integrated design team involved with the California Academy of Sciences indicate that the New Norris House could also be met with permit issues from the local code officials when trying to design outside the scope of what is addressed in the building codes.

## **Chapter 5. The New Norris House**

Chapter 3 describes the current state of the residential building industry which seems to indicate minimal contribution from the structural engineer on the sustainability of the home. It is my belief that the structural engineer could have a larger influence if his or her involvement in the design process began at the onset of the project. This type of involvement would mean employing the methods of an integrated design team where all stakeholders are involved in the project from the beginning. As proven by ecoMOD's energy performance and the LEED platinum rating of the California Academy of Sciences, an integrated design approach can produce a successful sustainable project. By being involved in the integrated design team charged with designing the New Norris House, it is my intent to show how much more influence the structural engineer as part of an integrated design team can have on the home's sustainability as opposed to the traditional design settings described in Chapter 3.

This chapter will begin by giving the background of the New Norris House project. With an understanding of the project background, the chapter will then describe the integrated design team and the people involved. The design process will be explained and how it differs from the processes described in Chapter 3.

### **5.1 Project Background**

The New Norris House is one of six national winners of the 2009 Environmental Protection Agency's People Prosperity and the Planet (P3) Competition. The idea for the project is centered around the ideals on which the town of Norris, Tennessee was built. In 1933, the Tennessee Valley Authority constructed an innovative community as part of

the Norris Dam construction project. The town of Norris was one of the nation's first planned communities. A key feature of this New Deal village was the Norris Cottages, homes built as models for modern and efficient living. In light of the seventy-fifth anniversary of the town of Norris, students sought to reinterpret the Norris paradigm to create a New Norris House - a sustainable home for the twenty-first century. As a result, the idea for UPLOAD was developed for the New Norris House and the P3 competition. "UPLOAD explores the potential for a future where the mechanics of globalization function synergistically with local economies. As the pendulum swings from a history of predominantly localized economy to a predominantly globalized economy and the effects therein, UPLOAD sees a middle ground where a new type of strengthened local economy becomes possible precisely because of the products, technologies and networks of communication resulting from the previously flattening and homogenizing forces of globalization. The idea of UPLOAD finds its basis and grounding in our understanding of the history and specificity of the town of Norris; we recognize that the concepts for UPLOAD were already latent to the town and had only been dormant. It is from this basis that the conceptual framework developed and expanded to take on a universal or multilateral dimension, to reach all places and times (Hooten, Luster et al. 2009)."

As a result of the project's success at the competition, the New Norris House received funding to both finish the design development through the construction documents and to build the home. A deed restriction prevented use of the originally intended lot, which led to the gift of another Norris lot. At the start of the Fall 2009

semester, an integrated team of students began applying the original design principles to the new site.

## **5.2 Integrated Design Team Description**

An integrated design team seeks to utilize all interested parties, such as clients, architects, engineers, and contractors, in the entire design process from beginning design through completed construction. Our design team included students from the University of Tennessee's College of Architecture and Design, College of Engineering, and Environmental Studies. The team members are as follows: architecture - Arklie Levi Hooten (Levi), Daniel Luster, Steven Nicholas Richardson (Nick), and Andrew Ruff (Andy), engineering - Matthew Snyder (Matt), Hanya Senno, Anupont Thaicharoenporn (Benz), and Mary French, and environmental studies - Ryan Edwards. I surveyed all the team members to determine their responsibilities, design process, and how they felt each differed from a traditional design setting, which can be found in Appendix C. Also, all students felt that integrated design teams were crucial to efficient sustainable design because so many sustainable components traversed many disciplines. I will describe the results from each student in the following paragraphs.

Hanya Senno was a senior in the Fall of 2009 in civil engineering with a concentration in environmental engineering. Her responsibilities for the project included researching waste water pretreatment options and design plan, help with the design of the rainwater collection system, and outline a plan for an irrigation system using the gray water discharge from the house. To achieve the project goals, her design process began with background research on waste water pretreatment and gray water

discharge. At that point, LEED criteria and site constraints were considered. The pretreatment for the waste water was never developed beyond the conceptual level as it did not seem feasible for a small scale project and would be better suited at the macro level. Finally with the assistance of the engineering faculty, a gray water discharge system was designed and load calculations were used to verify the design parameters. During the design process, the project required constant communication, input and updating with the other disciplines and teams; Hanya felt this constant communication would not have been realized in a traditional design setting because different team members/disciplines are involved at different times during the design process in a traditional setting.

During the Fall 2009 Andy Ruff was a senior in architecture and his responsibilities included research, architecture details, organizing all the product specifications in a manual, and staying in constant communication with the pertinent permitting office. Based on the literature and project research, we anticipated resistance from the building code officials and the community. Andy was responsible for keeping community and building officials involved in our design process in an effort to avoid resistance during construction. According to Andy, his design process included the application of significant amounts of research that could allow the house to progress in a practical manner and on a culturally relevant scale. Although he was given a precise role allowing him to focus on a few specific topics, responsibilities overlapped and the collaborative process enabled all team members to integrate themselves into the final solution.

Levi Hooten is a senior in the school of architecture and was part of the original design team that took part in the P3 competition. Levi's responsibilities included the schematic design, design development, energy analysis (including the sunlight modeling), the CAD drawings, and presentation. During the semester, Levi sought to integrate our project into a very vernacular and strong community. Levi felt our design process differed from what he was used to because he was constantly communicating his decisions to the other team members to confirm their practicality.

Daniel Luster is a senior in the school of architecture and was also a part of the original design team with Levi. His responsibilities included designing, coordinating with other disciplines and developing architectural and framing CAD drawings. His design process involved working with the other architecture students on a daily basis and meeting and working with the environmental science and engineering students two to three times a week. Despite the give-and-take and back-and-forth on drawings and project issues during design sessions with various team members, Daniel felt that the sessions created a smoother design process preventing extensive backtracking that occurs in many traditional design settings.

Matt Snyder is a junior in civil engineering whose responsibilities included site planning and surveying, researching and designing a water reuse and treatment system, and working on obtaining the water systems permit. His process involved researching codes pertaining to the water system, trying to work within those constraints, and keeping the governing bodies apprised of our design. He also visited other sites for examples on what could be done and then began developing the design, synthesizing it with the rest of the project and evolving the design to the final product by

working with input from other disciplines. He was also instrumental in our project obtaining an experimental water system permit so that we can employ our rainwater collection, treatment, and gray water dispersal system.

Nick Richardson is a graduate student in architecture and his responsibility was to effectively implement the LEED for homes criteria into our project. It was his responsibility to ensure that the sustainable features developed by the team were in compliance with the LEED strategies. He devised a LEED plan that would earn the project as many LEED points as possible so that we could achieve a Platinum rating (the highest LEED rating). He assigned each team member LEED categories to investigate to make sure that their design could and would earn those particular LEED points. According to Nick, the integrated team and regular meetings allowed the team to stay focused on the common goal of an efficient, sustainable home thus resulting in a more innovative project than might have been realized in a traditional design setting.

Benz is a Ph.D. student in civil engineering with a structural concentration. He was responsible for material research and foundation research and design. He began the semester researching material recycling opportunities in the dilapidated home on our site and helping in the research of green material options for our particular region and project. He also researched foundation options, worked closely with the architectural team to choose the best foundation type for our project, designed the foundation, and served as a liaison to the company providing the foundation material.

Ryan Edwards is a junior in environmental studies. He was responsible for working with Nick on navigating the LEED for Homes manual. He investigated all possible credits the project could earn and then worked with each team to ensure the

proper implementation of the strategies described in the LEED for Homes manual in order to obtain those credits. Ryan feels that he would unlikely be asked to become involved in traditional building projects; although, he does feel it would be difficult for a project to apply LEED strategies and become certified without a LEED coordinator focusing solely on organizing LEED strategies. He said integrated design teams are the best way to achieve high levels of sustainability without backtracking or a number of setbacks. Working together allows systems to become integrated which Ryan feels is necessary for energy and water efficiency.

I am a graduate student in civil engineering with a structural concentration. My responsibilities included material research, determining dead and live loads, designing the framing and connections, sketching framing plans and details, and marking-up the structural and architectural drawings for corrections. I began the semester by researching the structure of the original Norris cottages and determining if they could meet current structural code requirements (which some framing could not). I also assisted in researching material recycling options in the existing structure on our site. I investigated whether the components of the 2x4 wood trusses could be reused as wall studs and conversed with a masonry specialist on how to determine if the CMU block which comprised all the walls could be reused. I worked closely with the architects to help them achieve their goals of floor plan openness and material efficiency. During design meetings with the architects, the design went through several iterations before a final design concept and respective framing plan was chosen (calculations can be found in Appendix B). Also, throughout the process, I tried to be mindful of the construction process, whether it would be panelized or modular. Beams and posts were generally

sized in even numbers options so that they could be split apart; for example the floor girder was chosen as a quadruple 2x10 and among the ridge beam possibilities, a double 1  $\frac{3}{4}$ " x 14" LVL was chosen. A ridge beam was chosen to maximize the volume of the structure and eliminate the need for collar ties or ceiling joists that would create a sometimes minimally used attic. The exterior walls were chosen to be 2x6 studs in order to increase the R-value (the thermal resistance or the inverse of the thermal conductivity) of the wall and optimum value engineering, (OVE), techniques were employed, which requires case-specific analyses, to maximize insulation and minimize material waste. Framing using the methods of optimum value engineering is not as common as traditional framing methods because it requires engineering analysis of some of its components that for traditional framing can usually be found in load and span tables. Also, since OVE is not as common of a building practice, some of its techniques can be more difficult to install and require more hardware than traditional framing such as splice plates, header hangers, or two stud corners with drywall clips or scrap lumber (we found that drywall clips were difficult to find in the East Tennessee area). Optimum value engineering techniques include:

1. Spacing studs, floor joists, and roof joists at .61m (24") on center,
2. Stacking roof joists, floor joists, and wall studs to eliminate double top plates,
3. Designing homes on .61m (2') modules to help minimize sheathing waste,
4. Aligning the window and door openings with the .61m (24") stud framing where possible to eliminate excess studs (the needed king studs),
5. Sizing some windows for the .61m (24") opening that require no headers at all when possible,

6. Using two stud corners with scrap lumber instead of three or four stud corners minimizing lumber and maximizing insulation,
7. Doing away with headers in interior or non-load bearing walls,
8. Sizing headers correctly in load bearing walls,
9. Insulating headers with rigid foam instead of using plywood spacers,
10. Installing headers with hangers instead of using jack studs,
11. Using flat blocking or a single 2x6 backing nailer at the intersecting or partition walls instead of four or five studs, and
12. Using foam sheathing instead of OSB or plywood where possible.

I felt our constant collaboration allowed for a streamlined design process resulting in an efficient use of space and materials making our project unique as the architects had constant framing input while still establishing their design concept. In my experience in traditional design settings, trying to achieve a similar outcome would have been difficult and quite possibly could have resulted in partial or full redesigns since the structural engineer would not be giving framing input until after the design concept was complete.

### **5.3 Design Process**

The general design process of an integrated design team is shown in the following step-by-step procedure as it was utilized for our project starting in the fall semester of 2009 (August 2009).

1. Establish the project team (August 2009)
  - 1.1. Developer/Clients: with our project we acted as the developer and clients, and we also acknowledged the town of Norris as the clients as well

- 1.2. Design Team: we sought to generate interest with other disciplines by presenting our project to the student chapter and local professional chapter of the American Society of Civil Engineers and by sending letters to the University of Tennessee College of Engineering
  - 1.2.1. Civil/structural engineer: we obtained students who were supported by the faculty and professional community
  - 1.2.2. Civil/environmental/water resource engineering: we acquired students with the support of the faculty and professional community
  - 1.2.3. Environmental Studies: we obtained a student
  - 1.2.4. LEED Coordinator: we acquired an architectural student who was also a certified LEED AP
  - 1.2.5. Mechanical, electrical, plumbing (MEP) professional: we did not manage to enlist a student from this discipline, but a school of architecture faculty member specializing in such agreed to assist us in our design
  - 1.2.6. Contractor: we originally worked under the assumption that the students would be building the project under the guidance of a contractor, but later in the semester, enlisted the help of Clayton Homes (which will be explained later)
2. Define project goals and concepts (September 2009)
  - 2.1. Goals: achieving sustainability and working within a budget
  - 2.2. Concepts: working within the design concepts laid out in the original project sent to the P3 competition

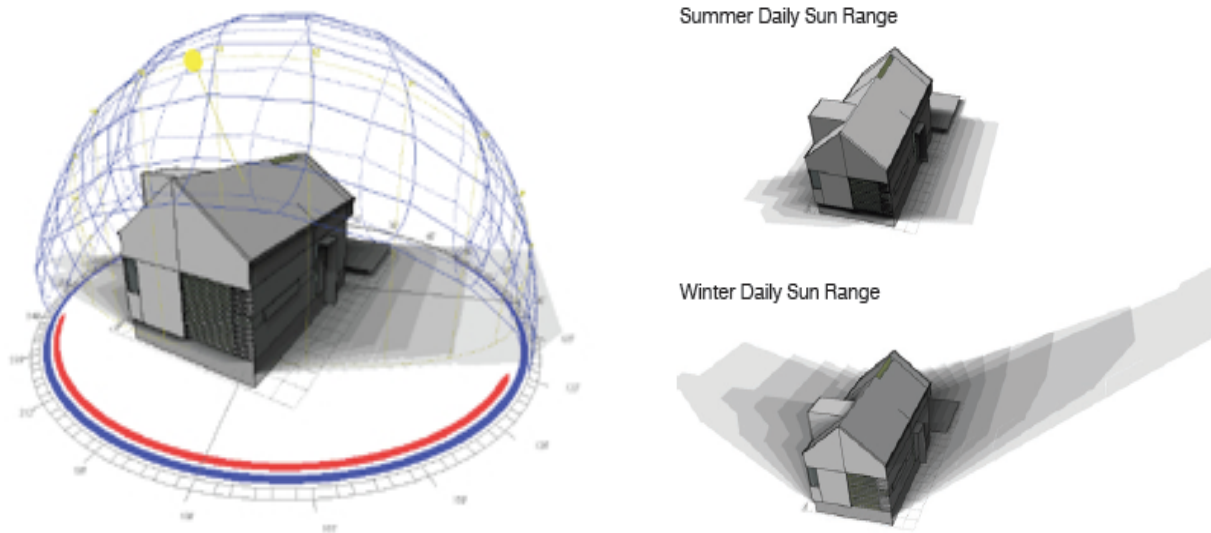
During this time, architecture students Daniel and Levi explained the philosophical goals to the team that the project was meant to accomplish within the community and what features of the project were architecturally important. This proved somewhat frustrating for the architects, because much of the team had no experience with the architectural process; therefore, it became imperative to clarify what was vital to their profession.

The remainder of the team began background research on the project, the community, the existing homes, and infrastructure, as well as additional research into sustainability and innovations in their field pertaining to sustainability. The structural team performed a structural analysis of the existing original Norris Cottages. Although most of the original homes are in good, livable condition, they did not completely meet today's 2006 IBC code requirements. The span of the first floor girders exceeded the maximum allowable span which is most likely why some of the cottages we visited had added girder supports not shown in the original plans. Also, the second floor framing did not meet the allowable live load requirements for habitable attic space according to the 2006 IBC but the framing was not off by much and not exhibiting noticeable signs of failure. Communication and working together proved arduous due to different backgrounds and experiences and lack of understanding of each other's design responsibilities; however, the research helped to provide an understanding of the project and sharing the research process with each other helped team members acquire general understandings of each other's disciplines.

3. Schematic design: This phase of the design process is where the integration truly takes shape and collaboration between all teams becomes crucial to achieve the goals set forth in step 2. Also, as all teams began working through their designs,

they were conscious of the assigned LEED categories, making sure that their design components were accomplishing the applicable LEED credits. Communication between teams of various disciplines was new to most of us and seemed unnatural in the beginning. For example, the architectural students think and learn visually and focus on the form of the structure as well as its function. However, the engineering teams think technically and are not accustomed to considering the form of their design, generally only taking into account its function. By October, as each team began to identify with each other's goals, priorities, and design processes, effective communication became evident and the project began making significant progress. We were all working toward a mid-October meeting with Clayton Homes to spark interest and hopefully procure involvement.

During this phase, the structural team met extensively with the architectural team to secure a design. The common goals included maximizing the volume since the footprint was only 6.1 m x 9.1 m (20' x 30'), maximizing the thermal efficiency of the whole house, determining an efficient use of windows and skylights to maximize natural light, ventilation, and solar heat gain in during colder seasons based on the daylight modeling performed in Ecotect (in Figure 4), and maximizing material efficiency and environmental friendliness.



*Figure 4. Daylight Modeling From Ecotect*

As the structural engineering team, we investigated the material options and discussed with the architects the pros and cons of the choices. In most areas of the U.S., timber products are readily available and are harvested and milled within a 500 mile radius, which is part of the reason for timber's low embodied energy. Also, timber is considered renewable and if the wood is harvested and is not allowed to decay, it will continue to store all the CO<sub>2</sub>, carbon dioxide, that the tree absorbs during photosynthesis (Ward 2010). In the East Tennessee area, southern yellow pine, SYP, is readily available and we were able to find SYP that was harvested and milled within the 500 mile radius. Considering the small size of the project, it was decided that timber products offered the most appropriate option with the lowest embodied energy, about 1.2 MJ/kg (Barr and McCafferty 2009). Although timber is the most sustainable choice for our project, it may not be the best option for all projects. Timber is not strong enough to be used to build skyscrapers, for example; it does not have the same

strength as concrete or steel. Once that was determined, we had to decide whether we wanted to use traditional timber framing or structurally insulated panels (SIPS).

Although the SIPS could provide larger R-values, we chose timber framing based on local availability and cost. In order to achieve similar R-values as in SIPS, the structural engineering team suggested using optimum value engineering methods (listed earlier) which included spacing all framing members at .61 m (24"). Knowing this information before being too far along in the design process and drawings kept the architects from having to redesign plans. After these decisions were made, we calculated the minimum framing sizes needed by determining the required live loads and estimating the dead loads (since all the finish materials had not been chosen), all in accordance with the 2006 International Building Code, IBC, (all calculations can be found in Appendix B).

Due to the roof slope, the roof live load could be reduced from 0.96 kPa to 0.81 kPa (20 psf to 17 psf) and the dead load was assumed to be 0.96 kPa (20 psf) since the final roofing materials had not been decided (roof joist calculations can be seen in Figure 5 and all calculations can be found in Appendix B). The floor live load was 1.92 kPa (40 psf) and the dead load was more accurately calculated since we knew most of the materials being used. The dead load used for the first floor was 0.48 kPa (10 psf) and the dead load for the loft was 0.72 kPa (15 psf). The loads for the walls studs included vertical loads induced by the roof and the loft where applicable and horizontal loads of around 0.86 kPa (18 psf) from the wind. Once the minimum allowable sizes of framing members were calculated, we worked with the architects to decide whether to use the minimum allowable sizes or increase the sizes to increase R-values. We increased the sizes of the wall studs from 2x4s to 2x6s and the roof framing from 2x8s to 2x12s. We

efficiently sized window headers as double members so that insulation could be placed in between the framing members. When designing the roof, the architects chose a roof slope to match the existing homes in the area and wanted to eliminate an attic or collar ties so that the space was more open and there could be a loft in part of the house. This could be accomplished by using a ridge beam or a middle load-bearing wall. Keeping in mind the possibility of future alterations, the structural engineering team encouraged the use of a ridge beam and gave the architects several spanning and material options. This allows for a more flexible and adaptable structure. The structural team consistently campaigned for flexibility so that the home could be added on to or adapted as needed if an owner chose. Although the architectural team did not always consider that their design may change someday, the structural team remained diligent that the allowing for future flexibility if the situation ever arose would make for a more sustainable home. When working on the foundations, instead of having floor insulation and a ventilated crawl space, it was decided to use a conditioned crawl space. This meant the structural engineers would design an insulated foundation. Benz determined that Superior Walls insulated precast foundation walls were the most environmentally friendly option that provided an R-value of 12.

Although there were no MEP students in the course, some students were researching our options and working with the faculty on the design. As the structural engineering team, we helped in the development of the solar hot water heater. The architects had to ensure that the dormer, where the water heater solar panels were going to be placed, had correct sun exposure and the structural engineering team had

to ensure that the added loading of the panels would not exceed the capacity of the roof joists.

The structural engineering team worked with the water resources team on the rainwater collection and treatment system. The roof slope made rainwater collection easy and kept collection off the roof so that we did not have to account for those loads. However, the cistern required to house the collected rainwater would have a 1,364 liter (300 gal) capacity; therefore we had to design a foundation to carry the weight if the cistern were to reach capacity. Also, the cistern housing was placed at the back of the house with a partial enclosure which meant designing the ridge beam so that it could cantilever out past its last house support and catch the cistern roofing.

Our meeting with Clayton Homes was successful and they became involved in the New Norris House as the contractors leading the project into step 4. Some of the presentation renderings for Clayton Homes that resulted from the schematic design phase can be seen in Figure 6 through Figure 8.

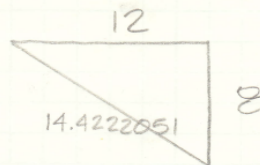
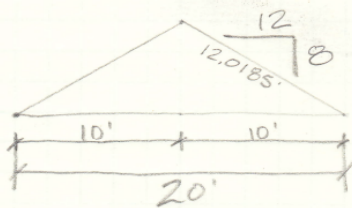
## NEW NORRIS HOUSE

### • PRELIMINARY SIZING CALCULATIONS (Benefit for Architecture during design process)

#### ROOF:

DEAD LOAD (ASSUMED) = 20 psf

- somewhat high assumption considering our plans for efficient framing
- once all materials/cladding, etc. are decided, more accurate loads will be used for headers, etc.



#### LIVE LOAD:

$$L_r = 20 \text{ psf} (R_1)(R_2)$$

$$R_1 = 1.2 - 0.001 A_T \quad (R_1)_{\min} = 0.6 \quad A_T = \text{tributary area}$$

$$R_2 = 1.2 - 0.05 F \quad (R_2)_{\min} = 0.6 \quad F = F:12 \text{ slope ratio}$$

- Roof Joists: Spacing = 24 in

$$L_r = (20)(1)(1.2 - 0.05 \cdot 8) = 16 \text{ psf}$$

$$TL = (36 \text{ psf})(2') = 72 \text{ plf}$$

$$M = \frac{(72 \text{ plf})(10')(12.0185')}{8} = 1081.665 \text{ lb} \cdot \text{ft} = 12979.98 \text{ lb} \cdot \text{in}$$

$$\text{Try } 2 \times 10\text{'s} \quad S_{\text{req'd}} = \frac{12979.98}{\left( \frac{1.15 \cdot 1050}{L_{C_r} L_{F_b}} \right)} = 10.749 \text{ in}^3 < 21.39 \text{ in}^3$$

$$\text{Try } 2 \times 8\text{'s} \quad S_{\text{req'd}} = \frac{12979.98}{(1.15 \cdot 1200)} = 9.406 \text{ in}^3 < 13.14 \text{ in}^3$$

∴ OKAY

Figure 5. Roof Joist Calculations

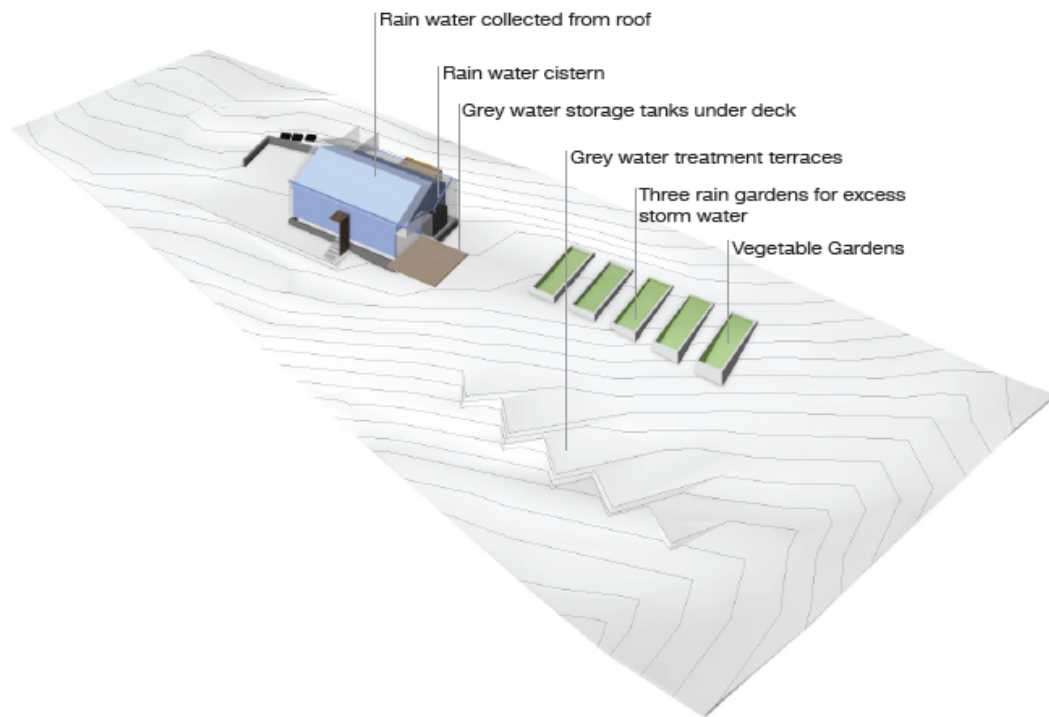
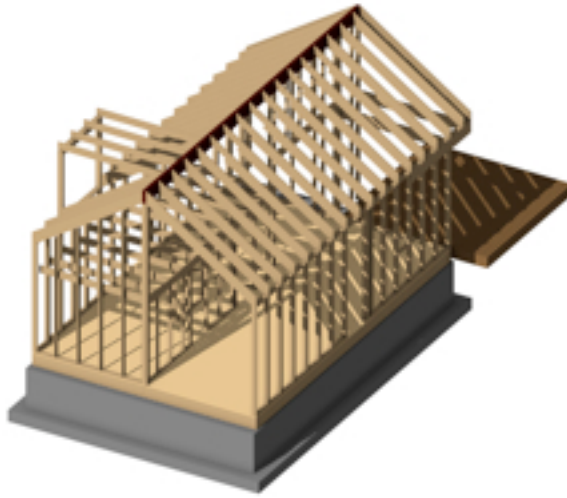


Figure 6. New Norris House Site Plan



Figure 7. New Norris House Rendering



*Figure 8. New Norris House Framing Axon*

4. Design Development: During this stage of a project, the team is working on finishing the design details, drawings, and specifications including all material choices. Upon completion of this stage, the construction documents (CDs) will be completed including cost estimates. Also, if attempting LEED certification, a LEED charrette should be assembled during this phase to ensure that the project is on track with its LEED goals.

Since we were approaching the end of the semester, we finished as much of the construction documents and details as possible. Although the structural team had been keeping the possibility of modularity in mind, we had to meet with Clayton Homes to discuss ways to split the house for transportation. Due to the height, transportation of the house with the roof attached became an issue as well; so, we discussed creating a

steeper pitch to allow for a scissor truss that could be transported separately or creating a hinge in the roof joists that would be extended once the house was in place. Splitting down the ridge and hinging the roof were the final decisions.

During the break, due to the existing 3.7 m (12') jig setup at the Clayton Homes manufacturing plant, the house dimensions were changed from 6.1 m x 9.1 m (20' x 30') to 7.3 m x 9.8 m (24' x 32'). Also, it was revealed that a crane could not fit on the site and place the home modules on the Superior Walls foundation; the modules would have to be backed onto the site, placed on temporary supports, the foundation built, and then the house lowered onto the foundation.

So, at the start of the Spring 2010 semester, the team of students (some new and some returning), had to address the dimension changes and the foundation issues, work on finishing all the small details and specifications, and determine all the cost estimations. The structural engineering team which included me and a new addition, a graduate student in civil engineering with a structural concentration, Beth Chapman, had to make sure that the framing members could span the new dimensions and address the foundation issues. Since cranes would be inaccessible on the site, Superior Walls would not be an option, so we decided to use traditional .2 m (8") CMU foundation walls with interior CMU piers supporting the middle girder. To obtain a similar R-value as seen by the Superior Walls, we chose to reinforce the CMU block wall only where needed and fill the remainder of the cells with an environmentally friendly insulation. We will achieve an R-value of 11.1 with this option. The remainder of the class began focussing on the small details and specifications. Our job as the structural engineers was to be available to all the team members to assist in details

such as steel canopies over the windows, guardrails on the decks, or deck connections to the house. The steel canopies provide shade during the warmer months to minimize heat gain during the wrong times, and the structural engineering team was charged with determining the required thickness of the steel and attachments to the house. During the start of the semester, we also scheduled and met for the LEED charrette with the Green Rater, Bruce Glanville and the results of our proposed LEED points and corresponding certification is discussed in the following chapter.

There are many design options and iterations during the process that are not addressed in this chapter, but as shown with all interested parties involved from the onset of the project, the structural engineer is very involved in many different aspects of the design and was able to achieve a greater influence. As expected, we did experience obstacles such as communication problems and misunderstandings, but we all managed to endure the initial hardships in order to create a successful sustainable home.

## **Chapter 6. LEED Rating Results**

The LEED rating system is an effective method for judging the sustainability of a structure and our project sought to become one of only four homes in Tennessee to receive a LEED Platinum rating, the highest rating. Throughout the design process, the team, led by Nick, our LEED coordinator, remained conscious of the LEED categories and corresponding points.

The following chapter will explain LEED and the LEED for Homes rating system and reveal the project's expected rating. The chapter will also examine each LEED for Homes category where we should receive points and how the structural engineer contributed to those categories. This contribution will be compared to an expected contribution in a Type A or B design process.

### **6.1 Description of LEED for Homes**

LEED is a nationally-recognized rating system designed to promote the design and construction of high-performance, energy-efficient, and healthy structures (to both the occupants and the environment) and encourages the building industry to adopt sustainable practices. LEED for Homes is one part of the LEED Green Building Rating Systems administered by the USGBC (U.S. Green Building Council) that specifically addresses the residential building industry (U.S. Green Building Council 2008).

LEED for Homes is composed of eight main categories. The categories and their corresponding maximum points are as follows: innovation and design 11; location and linkages, 10; sustainable sites, 22; water efficiency, 15; energy and atmosphere, 38; materials and resources, 16; indoor environmental quality, 21; and awareness and

education, 3. The total points that are secured by a project can place the home in one of four certified ratings, certified, silver, gold, or platinum with platinum being the highest achievement. In order to achieve one of these certifications, the point breakdown thresholds are as follows: certified = 45 - 59, silver = 60 - 74, gold = 75 - 79, and platinum = 90 - 136. However, there is a home size adjustment factor that applies to the previously mentioned thresholds. There is a square footage size for each home depending on the number of bedrooms that is considered the neutral size and the points thresholds are as above-mentioned. If the house is smaller or larger than the neutral size then points may be subtracted or added to the thresholds making them easier or harder to obtain, respectively. The maximum adjustment is a ten point addition or subtraction (U.S. Green Building Council 2008).

The innovation and design process category encourages design to go beyond what is normally addressed by the LEED rating system since green building and technology is constantly evolving. Points could be obtained by employing new technologies or incorporating an innovative design new to the building industry. Credit is also given to designs or regional practices shown to produce quantifiable benefits to environmental and human health or by achieving exemplary performances in one or more of the other main categories (U.S. Green Building Council 2008).

The location and linkages and the sustainable sites categories both pertain to the location of the home. The location and linkages category is used to promote site selection that is environmentally responsible through its land use and neighborhood development (U.S. Green Building Council 2008), which could mean city infill instead of clear-cutting a forest or destroying wetlands for a new neighborhood. The sustainable

sites category encourages the use of sustainable practices within the site once it is chosen (U.S. Green Building Council 2008). This could mean practices such as: building into a site's topography instead of extensive cut and fill efforts, reducing impermeable surfaces on the site, or landscaping with drought resistant and/or indigenous plants.

The category for water efficiency is divided into the subcategories of water reuse, irrigation systems, and indoor water use. Maximizing water efficiency helps decrease the effect on the nation's fresh water and decreases the demand on a region's usually aged water and waste water infrastructure systems (U.S. Green Building Council 2008). This can be accomplished with water efficient appliances and/or recycling rainwater.

The energy and atmosphere category is designed to create more energy efficient homes that decrease the demand on energy created from fossil fuels and thereby decreasing CO<sub>2</sub> emissions (U.S. Green Building Council 2008). This can be achieved through well-insulated homes with energy efficient appliances, the use of renewable energy sources such as photovoltaic panels, natural lighting, or solar heat gain during cold months.

The materials and resources category has three main components: material-efficient framing, environmentally-preferable products, and construction waste management. Construction and demolition waste make up about 40% of the U.S.'s solid waste (USGBC 2008). Material and waste efficiency can be accomplished through utilizing embodied energy information on materials, employing a structural engineer to design efficient framing, and drawing framing plans and details.

The indoor environmental quality is used to ensure the health and safety of the occupants by reducing indoor air pollutants (U.S. Green Building Council 2008). The choices of interior finishes, allowing outside air ventilation, and/or controlling the home's humidity can directly impact the indoor air quality.

The awareness and education category is used to hopefully ensure the continued growth of green building practices by educating the homebuyers and public on the components (not generally seen in a traditional home) of the green home and how to operate the new technologies that might be integrated into the house. The category also encourages monitoring the performance of the home (U.S. Green Building Council 2008). Demonstration projects and competitions aimed at sustainability are often used to accomplish the previously stated goals.

The New Norris House is expected to be one of only four homes in Tennessee to receive a LEED platinum rating and our expected rating is 96.5. Since our house will be a 71.3 square meters (768 sq. ft.), two bedroom home, we will receive the maximum threshold reduction of ten points; so, we only need 80 points to receive LEED platinum.

## **6.2 Categories Influenced by Structural Engineer**

We expect to receive six points in the Innovation and Design category and the structural engineer influenced two of the six points. The Innovation and Design category has three subcategories: integrated project planning, durability management process, and innovative or regional design. The fact that we are an integrated design team gave us two points in this category that would not be expected in a traditional

design setting where all the members including the structural engineers are not part of the team from project onset.

Although we anticipate receiving 8 points in the Location and Linkages categories and since our particular site was donated to us, none of the team members had influence over earning points in this category. If the structural engineer is part of an integrated design team that begins a project by choosing a site, then all team members can participate in ensuring that the proposed site meets the LEED criteria in the Location and Linkages category.

The Sustainable Sites category has six subcategories and our expected points in each subcategory are as follows: site stewardship, 1; landscaping, 7; local heat island effects, 1; surface water management, 7; nontoxic pest control, 1; and compact development, 0. Of the total 17 points we expect to earn, the structural engineer contributed to 7 of those points, 6 in the surface water management subcategory, and 1 in the nontoxic pest control sub category. During the design process we worked with the water resources group and the architects to decide on a driveway and parking area that is permeable. The team chose a slightly elevated steel grate system supported by footings; so, the structural engineers have to design the span of the steel grates and the footings. Due to budgetary issues, we also designed a less expensive, but not as permeable, option reusing concrete pavers from the existing on-site structure. The structural engineering team and the water resources team also worked together to control run-off from the roof. We considered a green roof, but decided the project would gain more from collecting the rainwater from the roof, treating it, and using the treated water to supply the house. The structural engineers contributed to the nontoxic pest

control sub category by working with the architects to ensure that all wood used on the house is a minimum of 0.3 meters (12 inches) above the surrounding soil.

In the Water Efficiency category, the structural engineers worked with the water resources team on the rainwater harvesting system. Once the decision was made to collect the rainwater from the roof, the structural engineer was responsible for designing the support and foundation for the cistern that collects the roof rainwater. Therefore, the structural engineers contributed to two of the expected eleven points in this category.

The project expects to earn 21.5 points in the Energy and Atmosphere category and 17.5 of those points are earned based on our calculated HERS rating. Since the HERS rating is determined by the expected energy efficiency of the house, the structural engineers played an integral part in the expected efficiency by designing a tight, well insulated envelope. The structural engineers employed the optimum value engineering methods described previously which maximizes insulation and worked with the architects to maximize natural lighting and ventilation, which lessens energy usage for lighting and HVAC systems. The influence over the HERS rating is explained in further detail in the next chapter.

The structural engineers were able to influence all the expected 15 points in the Materials and Resources category. There are three subcategories in the Materials and Resources category, material-efficient framing, environmentally-preferable products, and waste management. Points in the material-efficient framing subcategory are first earned by reducing material orders to a maximum of 10% over what is required and then the remaining points are achieved by either offsite fabrication or by providing detailed framing documents, cut lists and lumber orders, and by employing efficient

framing. During the project design, we designed efficient framing members, supplied framing documents, and were prepared to provide detailed framing orders and cut lists, but with the involvement of Clayton Homes we are able to receive points in this subcategory by the house being built through offsite fabrication. In order to receive points in the environmentally-preferable products subcategory, all team members including the structural engineers researched and tried to specify local, recycled, or other types of environmentally-preferable products. All the team members contributed to the waste management subcategory by first trying to determine ways to recycle materials from the existing structure on the site and then divert materials we could not reuse from the landfill. The team has also remained conscious of controlling the construction waste for the house and plans to be present during the construction process to keep as much waste out of the landfills as possible.

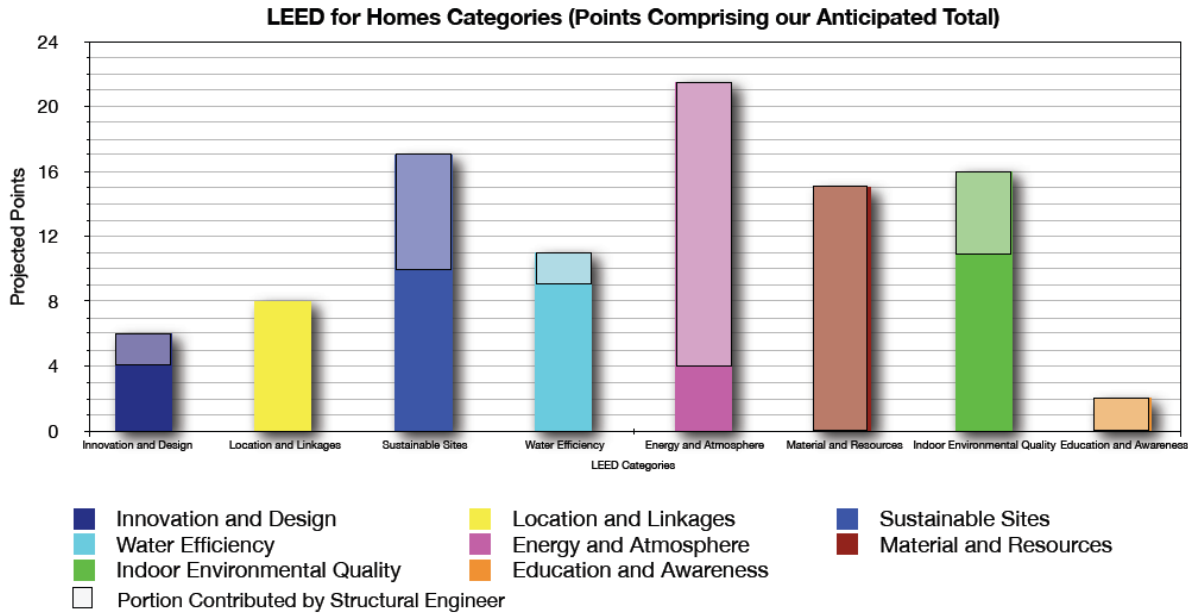
The structural engineers also played a role in obtaining five of the expected 16 points in the Indoor Environmental Quality category. We helped the architects achieve the desired windows to maximize the outdoor air ventilation contributing to two of the three points in the outdoor air ventilation subcategory. Although the structural engineers did not design the mini-split system, the HVAC system the project plans to use, we consulted with the team members working on the mechanical systems to make the decisions on HVAC systems. We discussed framing members that would allow for the passage of duct work if we chose a system with duct work, but if trying to maximize the volume of the house, we did not have the needed depth to use such framing members and ductwork. This among other factors made the highly efficient, multiple-zone, ductless, mini-split system the best option for the New Norris House.

Each team member played a role in obtaining the expected two points in the Awareness and Education category. Each of us worked with people in the professional community to help bring public awareness to the project. Also, the project will serve as a demonstration project so that the public and potential tenants will be well-educated on all the features of the home. Each team member was responsible for contributing to an owners manual that illustrates all the key sustainable features of the home.

The summary of the LEED points that the project is anticipated to receive, and the portions of each category's points that the structural engineer was able to influence can be seen in Table 3 and Figure 9.

*Table 3. LEED Rating Summary Chart*

| New Norris House<br>LEED for Homes Rating System                                         |                  | Totals                                   |
|------------------------------------------------------------------------------------------|------------------|------------------------------------------|
| Credit Category                                                                          | Projected Points | Points Influenced by Structural Engineer |
| 1. Innovation and Design<br>Maximum Points: 11                                           | 6                | 2                                        |
| 2. Location and Linkages<br>Maximum Points: 10                                           | 8                | 0                                        |
| 3. Sustainable Sites<br>Maximum Points: 22                                               | 17               | 7                                        |
| 4. Water Efficiency<br>Maximum Points: 15                                                | 11               | 2                                        |
| 5. Energy and Atmosphere<br>Maximum Points: 38                                           | 21.5             | 17.5                                     |
| 6. Material and Resources<br>Maximum Points: 16                                          | 15               | 15                                       |
| 7. Indoor Environmental Quality<br>Maximum Points: 21                                    | 16               | 5                                        |
| 8. Education and Awareness<br>Maximum Points: 3                                          | 2                | 2                                        |
| <b>Total Anticipated Points</b>                                                          | <b>96.5</b>      |                                          |
| <b>Percentage of Anticipated Points Influenced by Structural Engineer</b>                |                  | <b>52.33%</b>                            |
| <b>LEED Point Thresholds</b> (reflect 10 point deduction due to square footage of house) |                  |                                          |
| <b>Certified</b>                                                                         | 35 - 49          |                                          |
| <b>Silver</b>                                                                            | 50 - 64          |                                          |
| <b>Gold</b>                                                                              | 65 - 79          |                                          |
| <b>Platinum</b>                                                                          | 80 - 136         |                                          |



*Figure 9. Projected LEED Points and Portions Influenced by Structural Engineer*

As shown in Figure 9 and in Table 3, an integrated design team allowed the structural engineer to influence 52% of the LEED points. Based on the survey results from the structural engineers described in chapter 3, 43% of the structural engineers said that they could influence the materials of the project which would relate to the material-efficient framing and environmentally-preferable products subcategories of the Materials and Resources LEED category. Thirteen, (13%), claimed that they could influence the energy efficiency of the home which would relate to the HERS rating in the Energy and Atmosphere category. If the New Norris House was designed using a traditional design team and was still expected to receive 96.5 points, the structural engineers would only influence 29.5 of those points, (based on the survey results), which is only 31% of the total LEED points compared to the aforementioned 52%

## **Chapter 7. HERS Rating Results**

The expected HERS rating contributes to the LEED rating of the home, and is an excellent indicator of the home's expected energy performance. An energy efficient home is thermally comfortable, costs less to operate, and less of a burden on the town's usually aged infrastructure.

This chapter will explain the HERS rating system and the program used to obtain the expected results. It will also compare the rating of the New Norris House with the rating of a similar house with traditional framing and minimum code approved systems. Within the two rating differences, I will show in what ways the structural engineer contributed to the rating of the New Norris House.

### **7.1 Description of HERS and Rem/Rate**

A HERS rating is an analysis of a home's building plans using energy efficiency software. The result of the analysis is a HERS Index which is used during pre-construction to project a home's energy efficiency. The HERS Index scoring system was established by the Residential Energy Services Network in which a home built to the specifications of the HERS Reference Home will yield a HERS Index score of 100. Each one-point reduction in the HERS Index corresponds to a 1% reduction in energy consumed by the home as compared to the HERS Reference Home. Therefore, the lower the HERS Index score, the less energy the home will consume (U.S. Environmental Protection Agency and U.S. Department of Energy 2008).

The HERS rating is performed by a Home Energy Rater. Our Home Energy Rater is Bruce Glanville who performed the analysis using a software program

produced by Architectural Energy Corporation called Rem/Rate. The program uses the following inputs and local climate data to calculate heating, cooling, hot water, lighting, and appliance energy loads, consumptions, and costs. The inputs for the program are: the insulation used in the ceiling with attic, vaulted ceiling, above grade walls (insulation and components such as sheathing, exterior cladding and veneers), all of which corresponds to the spacing of the framing, conditioned foundation walls, unconditioned foundation walls, frame floors, slab floors, around the ducts, the types of windows and doors being used, the expected air infiltration and duct work air leakage, the mechanical ventilation (such as an energy recovery ventilator, ERV), the HVAC unit, the water heater being used, the lights and appliances, and whether interior thermal mass, a programmable thermostat, active solar systems, photovoltaics, or a sunspace is being utilized (Integrated Engineered Solutions 2007). The results of the analysis on the New Norris House projected a HERS Index rating of 61 which means it should consume almost 40% less energy than the HERS Reference Home.

## **7.2 Traditional Versus the New Norris House**

Mr. Glanville created another home for analysis in order to compare what our integrated design team accomplished with what might have been expected had the New Norris House been designed in a traditional design setting using the 2006 IBC. He used the building footprint of the New Norris House and changed the inputs to be consistent with what could be expected on a traditional code-compliant home. The analysis of the “Traditional, Code-Compliant New Norris House” revealed a HERS Index rating of 114. The difference in the HERS ratings indicated that the New Norris House we designed

using an integrated design team should use about 50% less energy than the same house designed using predominantly code specified minimums. The different program inputs that Mr. Glanville used for the two different New Norris Houses can be seen in Table 4. The analyses estimate a cost reduction close to 40%; the 50% less energy used by the integrated design team Norris House does not decrease the energy costs by 50% due to universal service fees and charges. The energy cost breakdowns of the two Norris Houses can be seen in Figure 10 and Figure 11.

The structural engineer was directly responsible for the design of the envelope and the foundation which determined the insulation input for the ceilings, above grade walls, foundation walls, and frame floor. Also, by using the optimum value engineering methods, Mr. Glanville expected an air-tightness to exceed the average home, therefore leading him to select an infiltration input lower than the average home. Although the structural engineer also collaborated on the HVAC system (affecting the duct insulation and leakage category) and the water heater as explained in Chapter 6, the categories directly impacted by the structural engineer account for half of the energy consumption reduction.

*Table 4. Summary of Input Differences Used for the HERS Rating Analysis*

| <b>Energy Features</b> | <b>Integrated Design Team<br/>New Norris House</b>                                                                                                                        | <b>Traditional Code-Compliant<br/>New Norris House</b>                                                                | <b>Affect on Energy Consumption<br/>(MMBtu/yr)</b>                                                                                                         |
|------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ceiling                | Better than code insulation, R-50                                                                                                                                         | Minimum required insulation, R-38                                                                                     | Decrease 0.29                                                                                                                                              |
| Above Grade Walls      | Methods of our case-by-case analysis minimizes lumber and thermal bridging and maximizes insulation and allows for continuous insulation (rim joist and headers included) | Code framing with studs at .41 meters on center (16") and no insulated headers or rim joists or continuous insulation | Decrease 3.8                                                                                                                                               |
| Foundation Walls       | Conditioned crawl space with insulation                                                                                                                                   | Unconditioned crawl space with no insulation (traditional ventilated crawl space)                                     | Increase 1.3. Using a conditioned crawl space means the foundation walls are insulated instead of the frame floors.                                        |
| Windows                | High quality double insulated with low emissivity, better than energy star                                                                                                | Slightly better than required by code, barely energy star rated                                                       | Decrease 1.3                                                                                                                                               |
| Frame Floors           | No insulation since we have a conditioned crawl space                                                                                                                     | Code insulation of R-19                                                                                               | Decrease 2.0. Ventilating crawl space means that the floors are insulated; so, combined with the affects of the foundation walls, a total decrease of 0.7. |
| Infiltration           | Low expected infiltration based on Mr. Glanville's experience                                                                                                             | Average expected infiltration of code-compliant homes based on Mr. Glanville's experience                             | Decrease 1.5                                                                                                                                               |
| Mechanical Ventilation | Energy recovery ventilator                                                                                                                                                | No energy recovery ventilator                                                                                         | Increase 0.6. Having a ERV uses energy, but the benefits are part of the reason for the decrease in other categories.                                      |
| HVAC                   | Mini-split system (allows for different rooms to be controlled separately)                                                                                                | Minimum code required of 14 SEER                                                                                      | Having a more efficient HVAC (the mini-split system) contributes to the reasons for the decreases in other categories.                                     |
| Water Heater           | Instant solar water heater                                                                                                                                                | Conventional electric water heater (91% efficiency)                                                                   | Decrease 2.3                                                                                                                                               |
| Duct Insulation        | No ducts in a mini-split system, so no insulation needed                                                                                                                  | Code compliant, R-8 insulation in ventilated crawl space                                                              | Combined with the affects of the duct leakage; see below.                                                                                                  |
| Duct Leakage           | No ducts, so no air leakage                                                                                                                                               | Average expected air leakage based on Mr. Glanville's experience                                                      | Total decrease 3.3                                                                                                                                         |
| Active Solar           | Solar hot water heater                                                                                                                                                    | No active solar systems                                                                                               | Contributor to the decrease in the water heater's energy consumption                                                                                       |

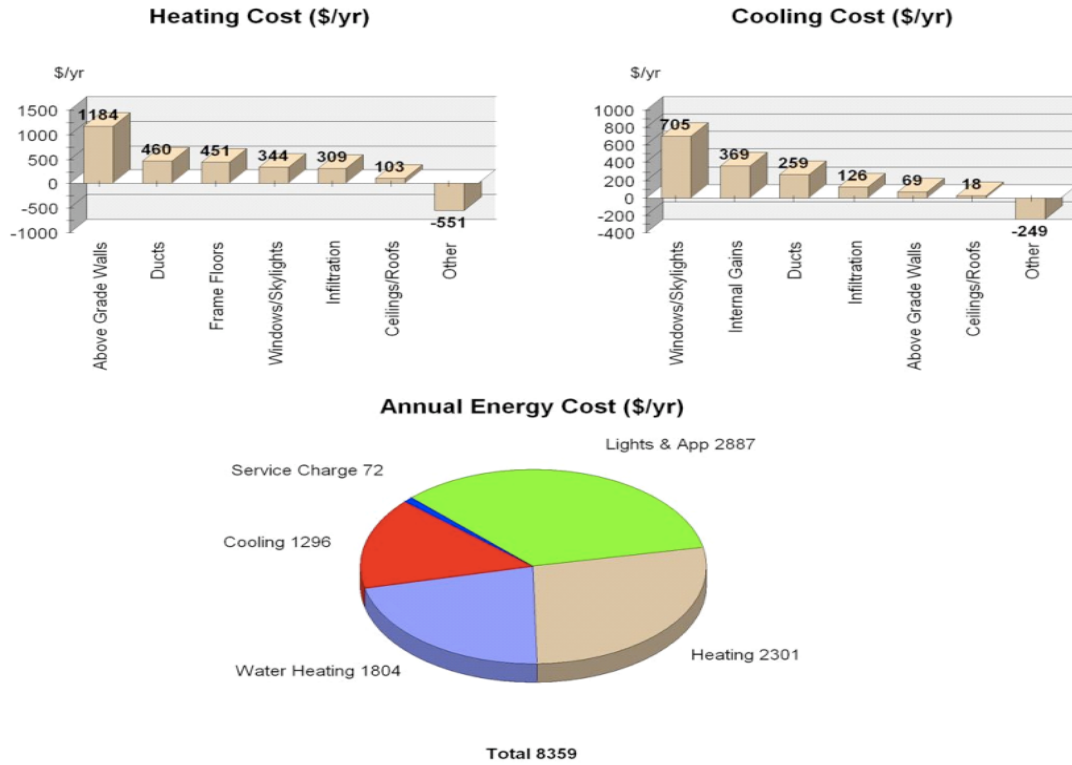


Figure 10. Energy Costs of “Traditional, Code-Compliant New Norris House”

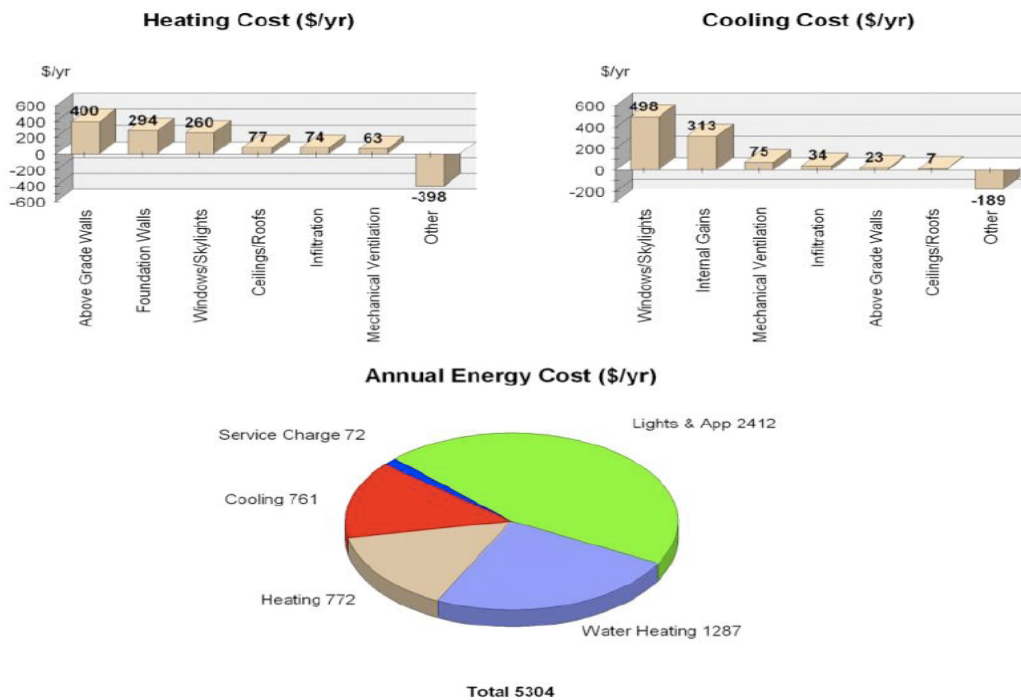


Figure 11. Energy Costs of the Integrated Design Team New Norris House

## **Chapter 8. Material Efficiency**

As seen in chapter 7, the optimum value engineering methods has a positive impact over the energy performance of a house, and contributes to the material efficiency. Although a structural engineer will practice material efficiency in any portion of a residential home in which he or she may be involved in and thereby affect the material efficiency category of the LEED for Homes, his or her involvement from the beginning as in an integrated design team allows for greater influence.

The following chapter will reveal the volume of lumber saved by employing the methods of optimum value engineering as compared to traditional framing. It will also show how the lumber volumes were calculated and explain the differences between the two models.

Architecture student John Sasse, enrolled in the New Norris House class in the Spring 2010 semester, created two different framing models of the New Norris House in 2010 Revit. The models illustrate the house framed using optimum value engineering methods, as the house was designed and will be constructed, as well as framed using traditional methods. The traditionally framed house followed the specifications in Chapter 23 of the 2006 IBC to size some of the framing members and all framing was placed at .41 meters on center (16" o.c.). The main differences between the two models are seen in Table 5.

Table 5. Differences in Traditional and Optimum Value Engineering Models

| Traditional Framing                                                                                                                      | Optimum Value Engineering                                                                               |
|------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
| 2x4 studs at 0.41m (16") on center                                                                                                       | 2x6 studs at 0.61m (24") on center                                                                      |
| Double 2x4 top plate                                                                                                                     | Single 2x6 top plate                                                                                    |
| All double headers have a 12.7 mm (0.5") plywood spacer (the double 2x header sizes are consistent with optimum value engineering sizes) | All double headers have no plywood spacers, but instead use 63.5 mm (2.5") of insulation between boards |
| 2x8 floor joists at 0.41m (16") on center (Table 2308.8(2) (International Code Council 2006))                                            | 2x8 floor joists at 0.61m (24") on center                                                               |
| 4-2x12 floor girder (Table 2308.9.6 (International Code Council 2006))                                                                   | 4-2x10 floor girder                                                                                     |
| 2x12 roof joists at 0.41m (16") on center (for insulation)                                                                               | 2x12 roof joists at 0.61m (24") on center (for insulation)                                              |
| 2x4 jack studs at all window and door openings                                                                                           | No jack studs used                                                                                      |
| 3-2x4 wall studs at all wall intersections                                                                                               | 1-2x4 at wall intersection with 2x6 backing (see Figure 12)                                             |
| 4-2x4 wall studs at all corners                                                                                                          | 2-2x6 walls studs at all corners with scrap lumber backing (see Figure 12)                              |

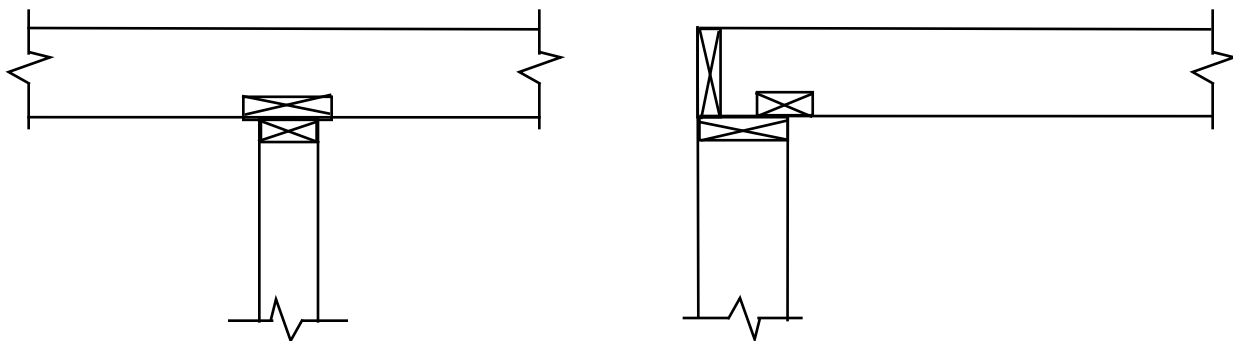


Figure 12. Optimum Value Engineering Wall Intersection and Wall Corner

Once the framing models were completed in Revit, (which can be seen in Figure 13 for the traditional framing and Figure 14 for the optimum value engineering framing), Revit can be used to calculate the volume of framing used. This is accomplished by viewing schedules, selecting schedules/quantities, and then picking structural framing. When this window appears, under the fields tab, select volume and add. This lists each member and gives its corresponding volume. The members and volumes can be exported to a spreadsheet to sum the volumes by exporting reports and then selecting schedules. This process was performed for each model and the corresponding volumes are as follows: the framing in the traditional model requires 9.8 cubic meters (346 cubic feet) of lumber and the required lumber for the optimum value engineering model is 8.1 cubic meters (286 cubic feet). This is a 17.4% reduction in lumber and the 1.7 cubic meters (60 cubic feet) difference in lumber is being replaced by insulation. Also, not only is that amount of insulation being added, but additional insulation is being utilized since the exterior stud walls are being increased from 2x4 walls to 2x6 walls, therefore, increasing the overall R-value of the walls from an average of 18.5 to an average of 24.4 as seen in Table 6.

Being involved from the beginning of the project allowed the structural engineers to explore different framing options before the house plans and framing plans were created, and the outcome resulted in less lumber and more insulation and higher thermal efficiency. When the structural engineers become involved at a later date as might be expected in a traditional design setting, it becomes more difficult to change framing plans and could decrease the influence over material and thermal efficiency.

Table 6. Calculation of R-Value of 2x4 and 2x6 Exterior Walls

|         |         | Wall Composition --> (Interior to Exterior) |                        |                   |           |               |                |                |         |           | Clear Wall Total |            |             |                 |            |             |
|---------|---------|---------------------------------------------|------------------------|-------------------|-----------|---------------|----------------|----------------|---------|-----------|------------------|------------|-------------|-----------------|------------|-------------|
|         |         | Gypsum                                      | Studs                  | Cavity Insulation | Sheathing | Vapor Barrier | Ext Insulation | Furring Strips | Air Gap | Siding    | Summer           |            |             | Winter          |            |             |
|         |         |                                             |                        |                   |           |               |                |                |         |           | Thru Insulation  | Thru Studs | Composition | Thru Insulation | Thru Studs | Composition |
| Wall #1 | Detail  | 1/2"                                        | 2 x 4 studs @ 16" o.c. | R-13              | 5/8" OSB  | Tyvex         | 1" R-4 Rigid   | 2 x 2          | 1"      | 3/4" Wood | 20.09            | 13.35      | 19.3486     | 18.39           | 11.65      | 17.6486     |
|         | R-value | 0.45                                        | 4.38                   | 13                | 0.77      | 0.17          | 4              | 1.88           | 0.9     | 0.8       |                  |            |             |                 |            |             |
| Wall #2 | Detail  | 1/2"                                        | 2 x 6 studs @ 24" o.c. | R-19              | 5/8" OSB  | Tyvex         | 1" R-4 Rigid   | 2 x 2          | 1"      | 3/4" Wood |                  |            |             |                 |            |             |
|         | R-value | 0.45                                        | 6.88                   | 19                | 0.77      | 0.17          | 4              | 1.88           | 0.9     | 0.8       | 26.09            | 15.85      | 25.2708     | 24.39           | 14.15      | 23.5708     |
|         |         |                                             |                        |                   |           |               |                |                |         |           |                  |            |             |                 |            |             |
|         |         |                                             |                        |                   |           |               |                |                |         |           | Improvement %    |            |             | 31%             |            |             |
|         |         |                                             |                        |                   |           |               |                |                |         |           |                  |            |             | 34%             |            |             |

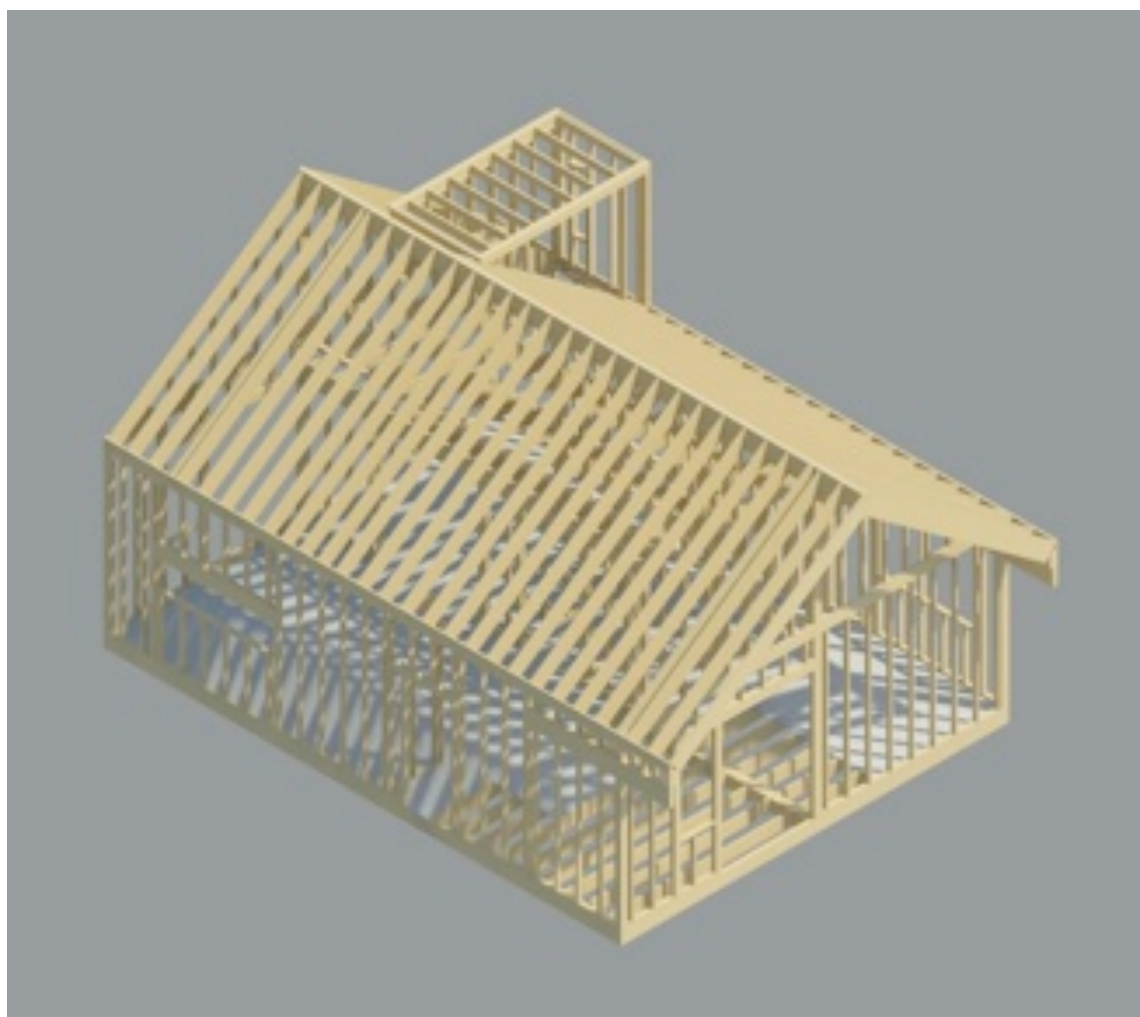
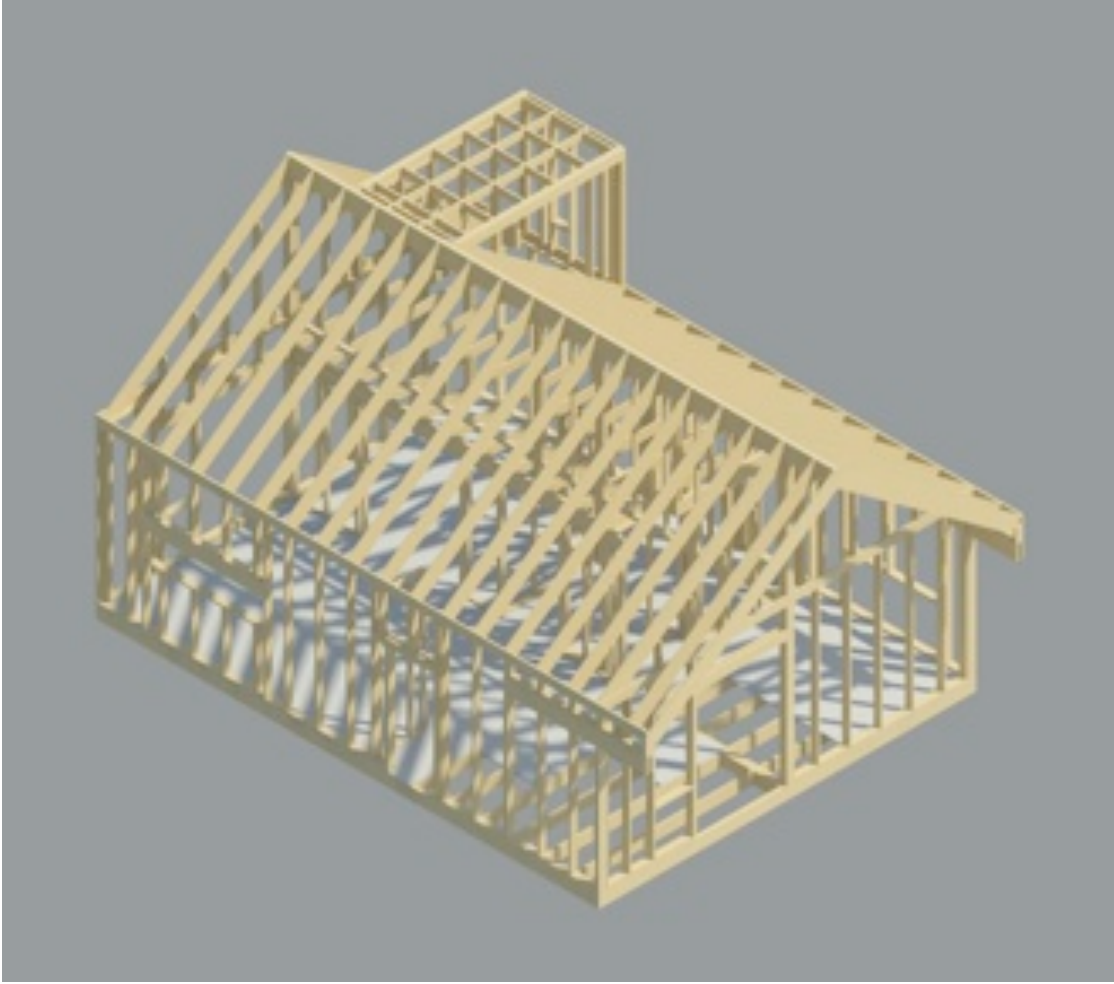


Figure 13. Traditional Framing Model



*Figure 14. Optimum Value Engineering Model*

## Chapter 9. Conclusions

Although the LEED rating, HERS rating, and material efficiency demonstrate the increased influence the structural engineer has over sustainability, it is important to consider the project's example on a macro level as well. If all new construction could boast a 50% reduction in energy consumption, a 17% reduction in framing materials, and water consumption that is not dependent on the municipal system, buildings could drastically reduce their impact on the environment. Those reductions can have a drastic influence on the percentages buildings and their construction tax the United State's energy consumption, materials and resources, and potable water use (seen in the introduction). Reducing the building industry's impact on the environment also reduces the building industry's impact on a city's infrastructure which decreases the amount of money needed for infrastructure expansion.

I have learned many other lessons from the New Norris House and the integrated design team as well. Currently there is a large disconnect between the professional practitioners and the solely academic community, and integrated design teams are an effective method for achieving high levels of sustainability while remaining time and cost competitive.

I discovered two ways in which the professional practitioners and the academic community differed, which gives credence to this type of research: the use of integrated design teams and the focus on sustainability. Integrated design teams are rarely attempted at universities, yet they are increasing in popularity in the professional design community. Even if the professional community is not working in integrated design teams, they will work together at some point during the design process. If working

together and communication with other disciplines is expected in our professional careers, then it should be addressed in our educational careers. As we discovered with the New Norris House, communication was not natural in the beginning and even I was surprised at the difficulties I experienced. Having grown up with an architect for a father, I expected to understand the architect's priorities better than I did. Engineers with no experience working with other disciplines could find communication even more difficult. Successful projects that flow fluidly through the design process is crucial to remain competitive in the industry making successful communication imperative and a lesson that should be approached sooner rather than later.

Given the gravity of environmental concerns, I was astounded at how many survey takers felt they have no impact over sustainability. The civil engineering code of ethics was revised in 1996 to include sustainability, and classes addressing sustainability are becoming more popular. As the academic community increases its focus and research into sustainability, it is important that the professional community evolves as well in order to remain competitive.

Since achieving sustainability in the building industry is generally more expensive than building traditionally, I believe that using integrated design teams are a way to make sustainability more cost competitive. Although costs of sustainability can be recouped over the life of the structure through energy and water efficiency, it can sometimes be difficult to persuade owners to invest the higher initial costs. The cost of the New Norris House is close to twice as much as the average square foot cost of a Type A home but well within the wide range of square footage costs of a Type B home. The high levels of sustainability we achieved in the New Norris House may be atypical

in the residential industry since the average homeowner may only stay in their home for five years which may not be enough time to recoup the costs of sustainability. Even though it is possible to have achieved the same results on the New Norris House, without the use of an integrated design team, it would not have been as time and cost competitive. Integrated design teams enhance communication and expedite the design process by helping to eliminate much of the misunderstandings between professionals, unavoidable delays encountered when the project moves from one professional to another (owner to architect to engineers, etc), and redesigns. In order to integrate building systems, which can reduce some of the costs of sustainability, the constant communication experienced in integrated design teams is crucial. Until all potential owners recognize the importance of sustainability in the built environment, the only way design professionals can promote sustainable structures is if they are cost competitive and/or quickly recoup their higher costs. Without the innovative designs and prompt results of integrated design teams, including structural engineers, promoting sustainability in the building industry can be arduous.

When trying to advocate for sustainability, it is helpful to obtain examples. The New Norris House should continue to be monitored to ensure it is performing as anticipated, serving as a great educational tool for the public and design community. Also further research is needed, based on performance results, to determine the amount of time needed to recover the initial costs of sustainability focusing on the New Norris House as well as other LEED platinum structures.

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## **Appendix A: Professional Survey Results**

Cc:

Subject: Re: Help for an Interdisciplinary and Sustainable Project

Attachments:

• Type A/B  
• none/unless

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Michael,

integrated approach

Please find the following in response to your request for input. This is based on my thirty plus years of experience in the field of Structural Engineering.

1. What would your design responsibilities and process be for a residential home (even if your responsibilities would be minimal to none because structural engineers aren't generally required for residential homes)?

Structural Engineers are very frequently involved in residential homes but only in a limited manner. Most residential construction includes structural elements such as prefabricated trusses which are designed by Structural Engineers and on some of the more upscale homes (\$1M and up) it is not uncommon for specialty design features of steel and glulam framing. In addition in some parts of the country special foundations are required for poor soil conditions such as piling systems.

Normally the process is for the Architect to specify trusses or similar products and the builder to buy them from a supplier that engages the Structural Engineer. For specialty framing and foundations the Architect usually request the services of the Structural Engineer but the builder may also do this.

2. At what point would you become involved in the project? And what information are you given in order to begin the project?

Structural Engineers do not normally get involved by the Architect in the project until the last moment for special framing and foundations. As for trusses or similar products the Architect is normally done with the design and the construction has started before the products are ordered by the builder.

3. If, in this same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability?

Sustainability concepts such as the following are not normally achievable by the Structural Engineer:

- Employ Integrated Design Principles
- Optimize Energy Performance
- Protect and Conserve Water
- Enhance Indoor Environmental Quality
- Reduce Environmental impact of Materials

pg 2/3

The decision process for issues like these are made by the Architect, Builder, and or the material supplier. It is seldom that the Structural Engineer would do much more than crank some numbers and provide the requested designs. Generally this is the result of economic consideration since the more involvement by the Structural Engineer the less profit there is for the Architect, Builder, and or the material supplier.

Sincerely,

To: French, Mary Elizabeth  
Cc:  
Subject: Survey to professions  
Attachments:

Typ. B  
no influence  
1971

[View As Web Page](#)

Hi. This is Mary French and I need some assistance with my thesis. I have some questions for the industry concerning the design process that will help me to do a comparative analysis to hopefully show how our integrated design team process has helped us to efficiently produce an economical, sustainable home. The point I am trying to make is that in an integrated design team the roles played by each discipline are unlike the roles played in a traditional project setting. The integrated design team can make the design process more streamlined and allow each discipline to have a larger influence in the structure's green features. We hypothesize that the all disciplines except the architects had increased responsibilities; therefore, alleviating some of the stress and responsibilities of the architects. In order to make a comparative analysis, I would like to ask a few questions on a traditionally run project, (not an integrated design team), to see if your information is in agreement with my hypothesis.

1. What would your design responsibilities and process be for a residential home (even if your responsibilities would be minimal to none because structural engineers aren't generally required for residential homes)?

If involved, we would be responsible for all structural elements such as walls and floor joists and beam except for prefab floor and roof trusses. We would help the architect select the depth of the floor trusses if they are used. We would also be responsible for the lateral load resisting system. Which is generally wood shear walls. All foundation elements would also be our responsibility.

2. At what point would you become involved in the project? And what information are you given in order to begin the project? We generally get involved after the architect has meet with the owner and has gotten the rooms sized and laid out the way the owner wants. We then take a look at what it takes to support the loads for the spans the architect shows. If there is a problem with what the architect shows ( can span the distance with the depth restriction) we will bring this to his attention to see what can be done. The architect will provide us with a lay out of the residence showing the room sizes and their designation (bedroom, kitchen.....). They will also provide a few section at the exterior wall . There may be a plan showing the ceiling heights.

3. If, in this same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability? Nothing. Most structural materials come from renewable resources or can be recycled. Most residential bldgs are built to get the maximum square footage for the least dollar. If is can be built cheaper using sustainable materials then that is what will be done. Otherwise, sustainable construction does not come into play unless mandated by building codes.

• Type B  
• None without further instruction

Hi. This is Mary French and I need some assistance with my thesis. I have some questions for the industry concerning the design process that will help me to do a comparative analysis to hopefully show how our integrated design team process has helped us to efficiently produce an economical, sustainable home. The point I am trying to make is that in an integrated design team the roles played by each discipline are unlike the roles played in a traditional project setting. The integrated design team can make the design process more streamlined and allow each discipline to have a larger influence in the structure's green features. We hypothesize that the all disciplines except the architects had increased responsibilities; therefore, alleviating some of the stress and responsibilities of the architects. In order to make a comparative analysis, I would like to ask a few questions on a traditionally run project, (not an integrated design team), to see if your information is in agreement with my hypothesis.

1. What would your design responsibilities and process be for a residential home (even if your responsibilities would be minimal to none because structural engineers aren't generally required for residential homes)?

Answer: I have worked on residential homes, several in the area. I could perhaps design the foundation, the basement walls, and any unusual framing members that serve as main roof or floor beams.

2. At what point would you become involved in the project? And what information are you given in order to begin the project?

Answer: We would get involved at the point where the architect realizes he needs help from a structural engineer and seeks out that help, which is usually after most of the plans are drawn up. All we would need are the basic architectural plans to determine the applicable loads for our design.

3. If, in this same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability?

Answer: To be honest, the term sustainability means little to me. Unless the architect were to clue me in on what he was looking for, I would have nothing special in mind. They get concrete for the foundation, concrete or masonry for the walls, and wood or steel for the structure. That's it, nothing special. I have had little involvement with "green" issues in my career, so if the client were looking for "sustainability," I would tell the architect to spell out exactly what he wants, if anything different, or else get himself another engineer. The fees for residential work do not allow for much creativity or risk.

- Junk E-mail
- Calendar
- Contacts
- Tasks
- Folders
- Public Folders
- Options
- Log Off

To: French, Mary Elizabeth

Cc:

Subject: RE: TNSEA Board Meeting

Attachments:

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Mary,

In response to your questions, we do very little residential and I've done almost none. But of the residential stuff our company has done in the past, typically the architect is coming to us with fairly minor stuff like sizing a post, beam and footing line for them to put on their drawings. Rarely have we been asked to do full blown drawings and since we're not really set up for that kind of work, frankly we tend to shy away from it. Sustainability hasn't been a priority in the few projects we have done. Maybe one of the other guys from here will respond and have a different perspective, but that's been my experiences with residential.

Thanks,

- Type B

- none / no experience

- Calendar
- Contacts
- Tasks
- Folders
- Public Folders
- Options
- Log Off

To: French, Mary Elizabeth

Cc:

Subject: 3 questions

Attachments:

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1. What would your design responsibilities and process be for a residential home (even if your responsibilities would be minimal to none because structural engineers aren't generally required for residential homes)?

For residential my involvement usually occurs when the contractor has made a mistake or the interested parties thinks a mistake has been made.
2. At what point would you become involved in the project? And what information are you given in order to begin the project?

During or after construction: A site visit is imperative, and a description of the problem over time.
3. If, in this same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability?

Structural stability is required for sustainability but it is also required for waterproofing, limited maintenance, and air tightness. So as a structural engineer, doing the work that I do, in the economy we have, sustainability can not have any influence.

Good Luck

- Type A

- none / after construction

1. What would your design responsibilities and process be for a residential home (even if your responsibilities would be minimal to none because structural engineers aren't generally required for residential homes)?

Designing members that are beyond the capability of the lumber supplier, such as steel beams and columns for long spans,

2. At what point would you become involved in the project? And what information are you given in order to begin the project?

I work with several high end custom home builders that build homes from 1-6 million in value. The builder will start with a set of plans from say Southern Living and then modify these plans using a drafting service to meet the clients needs. He will then turn the plans over to his lumber supplier who will generate a set of plans showing TJI framing with microlam beams.

At this point he will review the plans with me to design members outside of the design capability of the supplier.

3. If, in this same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability?

None.

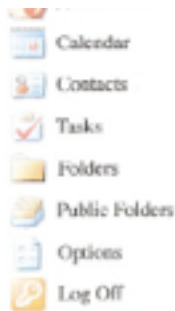
• integrated approach  
- framing  
\* maybe all possible but Macro level

Hi. This is Mary French and I need some assistance with my thesis. I have some questions for the industry concerning the design process that will help me to do a comparative analysis to hopefully show how our integrated design team process has helped us to efficiently produce an economical, sustainable home. The point I am trying to make is that in an integrated design team the roles played by each discipline are unlike the roles played in a traditional project setting. The integrated design team can make the design process more streamlined and allow each discipline to have a larger influence in the structure's green features. We hypothesize that the all disciplines except the architects had increased responsibilities; therefore, alleviating some of the stress and responsibilities of the architects. In order to make a comparative analysis, I would like to ask a few questions on a traditionally run project, (not an integrated design team), to see if your information is in agreement with my hypothesis.

What would your design responsibilities and process be for a residential home (even if your responsibilities would be minimal to none because structural engineers aren't generally required for residential homes)?

a. None. Our firm does not do residential work. May I expand the scope and reply for a multi-million dollar design for a military housing project requiring LEED Silver certification? Our firm does these projects. Structural engineer would participate in initial Charrett led by the architect. Focus would be on material selection to meet LEED requirements. We use BIM so the input would go into the model developed by the architect.

2. At what point would you become involved in the project? And what information are you given in order to begin the project?
  - a. Proposal phase and the entire RFP would be given. All client standards and relevant codes are accessed through company SharePoint site.
3. If, in this same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability?
  - a. Depends on the framing method, but GBC guidelines would be followed to maximize LEED points. This would be primarily led by the architect.



To: French, Mary Elizabeth  
Cc:  
Subject: survey  
Attachments:

• Learning forward integrated approach

[View As Web Page](#)

Dear Ms. French,

• Full impact only with into full integration

while I applaud you for pursuing your education, I question the premise of your thesis. I've been a structural engineer for 40 years. I'm licensed in 15 states, I've owned a very small firm for most of that time. I've been successful, and I've designed many small to medium sized commercial projects. I've been willing to take on most any project for which I'm qualified and for which the fee allowed me to make a profit. I've done maybe 3 or 4 houses in 40 years. 3 of these have been for friends at cost.

The fact is that house builders and owners can get house plans for a fraction of the cost that would be required for structural engineers to provide the design and CAD. I've quoted unbelievably low prices on proposed house designs, and the builders and owners have labeled me crazy because they can get house plans for a few hundred dollars.

Most houses, even big ones, are constructed using plans which most structural engineers would label as incomplete or negligent. This happens because most building departments do not require that house plans be prepared by licensed architects and engineers.

Nevertheless, here are the answers to your questions.

1. Responsibilities: design the structural elements and produce design drawings.

Process: meet with owners or architect, receive architectural base plans or owners plans ( sometimes obtained from a magazine ), design the structure, produce plans.

2. Start of involvement: sometimes from conception by owner, sometimes after the architect has produced preliminary drawings.

3. Sustainability: The sustainability question requires an additional process or sub process to evaluate each material used. This sub process involves long term economics. Structural engineers ( and architects ) are typically unable to evaluate even initial construction economics without the help of the builder and many house builders are unable or unwilling to consider new products or methods. Long term economics require the input of other team members like the mechanical and electrical engineers, and occasionally insurance agencies.

Good luck on your project.

• answers design team), to see if your information is in agreement with my hypothesis.

both A & B 1. What would your design responsibilities and process be for a residential home (even if your responsibilities would be minimal to none because structural engineers aren't generally required for residential homes)?

• of environmental  
preferable  
product As a geotechnical engineer we would be involved on a smaller home if there was an issue with a sinkhole or very poor soil conditions. Some larger homes (>\$500k) will usually get a geotech involved. We may also check the bearing capacity of the foundations in lieu of the local building codes.

2. At what point would you become involved in the project? And what information are you given in order to begin the project?

Sinkhole – If identified prior to construction, it may be to help site the location of the home during design, or identify the potential zone of influence. If not identified early, we would most likely become involved after a construction induced dropout has occurred. Consulting would include making recommendations for remediation of the sinkhole and observing the repair. It may also include the preparation and submittal of a Class V Injection Well Permit with TDEC. Information needed would include proposed building layout, SWPP and site grades.

Geotechnical – We would become involved during site layout and design. Information needed would be the proposed building layout, proposed site grades, column loads, and continuous footing loads.

3. If, in this same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability?

Recommending the use of "Green" concrete.

- Type B  
 'environ.  
 preferable  
 material

The point I am trying to make is that in an integrated design team the roles played by each discipline are unlike the roles played in a traditional project setting. The integrated design team can make the design process more streamlined and allow each discipline to have a larger influence in the structure's green features. We hypothesize that the all disciplines except the architects had increased responsibilities; therefore, alleviating some of the stress and responsibilities of the architects. In order to make a comparative analysis, I would like to ask a few questions on a traditionally run project, (not an integrated design team), to see if your information is in agreement with my hypothesis.

1. What would your design responsibilities and process be for a residential home (even if your responsibilities would be minimal to none because structural engineers aren't generally required for residential homes)?

In residential projects we, as structural engineers, get called upon typically in higher end homes where the intricate floor plans make for complicated load paths. Our responsibility is limited to helping the architect realize the architectural goal, using materials selected by the architect.

2. At what point would you become involved in the project? And what information are you given in order to begin the project?

We get involved once the architect has reached substantial completion of the project. Structural engineers typically have to make the concept work.

3. If, in this same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability?

Residential structures are typically built with wood or light gage metals (recycled), both of which, I believe, are regarded as sustainable. Additional contribution to sustainability by the structural engineer is limited.

1. What would your design responsibilities and process be for a residential home (even if your responsibilities would be minimal to none because structural engineers aren't generally required for residential homes)?

This typically varies with the complexity of the home. At the least, I would review the architectural drawings and provide comments or information to be added to them. For a more complex project, I would provide framing plans, a few standard details based on the materials used, and any unique details required due to unusual geometry or high loads.

Type B: environmentally-preferable materials

2. At what point would you become involved in the project? And what information are you given in order to begin the project?

After floor plans and exterior elevations are completed by the architect. Floor plans, elevations, and maybe a building section.

3. If, in this same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability?

Recommend recycled materials be specified with respect to steel, concrete, masonry. Recommend the use of certified sustainably harvested wood products.

Junk E-mail
 Calendar
 Contacts
 Tasks
 Folders
 Public Folders
 Outlook

To: French, Mary Elizabeth

Cc:

Subject: RE: East Tn SEA - Survey Request

Attachments:

[View As Web Page](#)

The materials would most likely be chosen and I would recommend the "greener" version.

Junk E-mail
 Calendar
 Contacts
 Tasks
 Folders
 Public Folders
 Options
 Log Off

To: French, Mary Elizabeth

Cc:

Subject: Sustainability questionnaire

Attachments:

*Type B material preferable*

[View As Web Page](#)

- What would your design responsibilities and process be for a residential home (even if your responsibilities would be minimal to none because structural engineers aren't generally required for residential homes)?

Perform design of structural components including rafters, stud walls, floor joists, floor beams, footings, roof sheathing considering diaphragm requirements, wall shear panels, and connections.

- At what point would you become involved in the project?

After the architect has developed the floor plan, elevations and some but not all wall sections.

- And what information are you given in order to begin the project?

The floor plan, elevations and some but not all wall sections.

- If, in this same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability?

Make recommendations concerning opportunities for material reuse and use of recycled material.

• Type B  
• environ  
preferable  
products  
(local)

Hi. This is Mary French and I need some assistance with my thesis. I have some questions for the industry concerning the design process that will help me to do a comparative analysis to hopefully show how our integrated design team process has helped us to efficiently produce an economical, sustainable home. The point I am trying to make is that in an integrated design team the roles played by each discipline are unlike the roles played in a traditional project setting. The integrated design team can make the design process more streamlined and allow each discipline to have a larger influence in the structure's green features. We hypothesize that the all disciplines except the architects had increased responsibilities; therefore, alleviating some of the stress and responsibilities of the architects. In order to make a comparative analysis, I would like to ask a few questions on a traditionally run project, (not an integrated design team), to see if your information is in agreement with my hypothesis.

1. What would your design responsibilities and process be for a residential home (even if your responsibilities would be minimal to none because structural engineers aren't generally required for residential homes)?

I would be responsible for the following design:

Foundations  
Walls  
Floors  
Roof  
Lateral Stability

2. At what point would you become involved in the project? And what information are you given in order to begin the project?

This depends on the skill level of the Architect. Normally, architects are capable of designing all of the above for residential structures. I am generally asked to get involved if the structure is out of the ordinary. If it can be assumed that the above design will be required of me, my involvement begins after the Architect has set the floor plan and elevations.

3. If, in this same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability?

None. Well, I might be inclined to advise the client to use local products, but beyond that, most structural components would be, in my opinion, considered sustainable.

• Type B  
• material  
efficiency  
OVE

Hi. This is Mary French and I need some assistance with my thesis. I have some questions for the industry concerning the design process that will help me to do a comparative analysis to hopefully show how our integrated design team process has helped us to efficiently produce an economical, sustainable home. The point I am trying to make is that in an integrated design team the roles played by each discipline are unlike the roles played in a traditional project setting. The integrated design team can make the design process more streamlined and allow each discipline to have a larger influence in the structure's green features. We hypothesize that the all disciplines except the architects had increased responsibilities; therefore, alleviating some of the stress and responsibilities of the architects. In order to make a comparative analysis, I would like to ask a few questions on a traditionally run project, (not an integrated design team), to see if your information is in agreement with my hypothesis.

1. What would your design responsibilities and process be for a residential home (even if your responsibilities would be minimal to none because structural engineers aren't generally required for residential homes)?

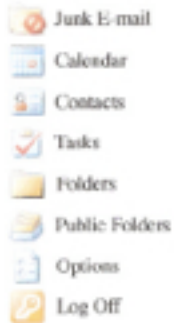
We typically don't do much engineering on average to smaller homes. For large custom homes, we provide framing plans, foundation plans, and some structural detailing including basement wall design. Depending on the budget, we can provide a full structural drawing package or sketches of problem areas.

2. At what point would you become involved in the project? And what information are you given in order to begin the project?

We usually get involved once the architectural design is nearly complete. We need the plans (including roof plan) elevations, and building sections.

3. If, in this same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability?

We would try to minimize material usage, and if possible, we would use the "optimized" framing system.



- Type B
- material efficiency (advanced framing)

To: French, Mary Elizabeth  
Cc:  
Subject: RE: Can you please help me with my thesis on structural engineering and sustainability  
Attachments:

pg 1/1

[View As Web Page](#)

1. What would your design responsibilities and process be for a residential home (even if your responsibilities would be minimal to none because structural engineers aren't generally required for residential homes)?

Check Memphis/Shelby County Code for seismic requirements and compliance with IRC.

2. At what point would you become involved in the project? And what information are you given in order to begin the project?

After architectural floorplans and elevations are finished, they would be given to me for design of lateral systems for building. Depending on the complication of the structure, I might be required to design other structural elements, but that is dependant on scope.

3. If, in this same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability?

Institute Smart Framing concepts to the project to lessen building materials and increase energy efficiency. This lessens the number of studs required and therefore you would have more insulated walls and improve your R value.

• Type B  
• enviro. products  
• energy efficient  
envelope

Hi. This is Mary French and I need some assistance with my thesis. I have some questions for the industry concerning the design process that will help me to do a comparative analysis to hopefully show how our integrated design team process has helped us to efficiently produce an economical, sustainable home. The point I am trying to make is that in an integrated design team the roles played by each discipline are unlike the roles played in a traditional project setting. The integrated design team can make the design process more streamlined and allow each discipline to have a larger influence in the structure's green features. We hypothesize that the all disciplines except the architects had increased responsibilities; therefore, alleviating some of the stress and responsibilities of the architects. In order to make a comparative analysis, I would like to ask a few questions on a traditionally run project, (not an integrated design team), to see if your information is in agreement with my hypothesis.

1. What would your design responsibilities and process be for a residential home (even if your responsibilities would be minimal to none because structural engineers aren't generally required for residential homes)?

We recently designed and served as general contractor for the construction of our own home. I am a structural and my husband is geotechnical engineer. The structural role would be for the design of main beams, large door openings, unusual structural features. The truss manufacturer designs the trusses. We have consulted on other residential projects: for decks, large openings, removal of truss bracing and such.

2. At what point would you become involved in the project? And what information are you given in order to begin the project?

At the planning stage, hopefully when features can be altered before concepts are firm.

3. If, in this same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability?

Use of materials that are more energy efficient, altering size of windows, using recycled materials.

Type A/B  
Durability Measures  
and materials

1. What would your design responsibilities and process be for a residential home (even if your responsibilities would be minimal to none because structural engineers aren't generally required for residential homes)?

Structural engineers would get involved when there are non-prescriptive design requirements. Normally for larger homes and/ or cut up framing plans. Example would be a large / long opening that is in a load-bearing wall. Also, if the home is designed with light gauge steel studs a structural engineer might be involved. The State of TN requires a structural engineer for homes larger than 5,000 SF.

2. At what point would you become involved in the project? And what information are you given in order to begin the project?

Funny you ask. Should be involved in the design process, but normally called in after the fact when there are problems during construction or after it is completely built.

3. If, in this same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability?

Light gauge steel increases the life of a structure plus eliminates termite contracts. Using metal roofs in lieu of asphalt shingles would be a big green item. Painted Kynar finishes on metal give recognized green values.

1. What would your design responsibilities and process be for a residential home (even if your responsibilities would be minimal to none because structural engineers aren't generally required for residential homes)?

*Review geotechnical evaluation of site foundation.*

*Design the footing and piers and foundation walls.*

*Select the framing materials; steel, concrete, wood, fiberglass, etc.*

*Design floor and roof framing for dead and live loads.*

*Design walls and stairs for dead, live and lateral loads due to Earthquake and wind.*

*Design any retaining walls on the site which are dictated by the Terrain.*

2. At what point would you become involved in the project? And what information are you given in order to begin the project?

*The structural engineer would make preliminary evaluations of the site and soil conditions to develop a scope of work. He would advise the architect and owner about what to expect before developing plans and specifications and a project budget. The preferences of the architect and owner should be integrated into the framework of the building at the outset.*

3. If, in this same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability?

*The structural framework and foundation should be selected based on the owner's expectations for the life of the structure.*

*Sometimes an owner may expect to stay in the residence for only a few years and would like to build for the lowest costs and maximum resale value. On the other hand, another owner may see this residence as his or her dream home and plan to live in it until they pass away. The owner may also want to know if the*

pg 2/2

*Energy efficiency measures will be a good investment over the life of the structure. Long term energy savings could offset the initial costs of the installation. He might choose reinforced concrete for the structure for durability and resistance to earthquake and or tornado damages. All of these decisions rest with the owner before work can begin for developing plans and specifications for the contractor to provide a competitive bid.*

• thermal  
efficiency  
(envelope)  
• passive  
systems

Hi. This is Mary French and I need some assistance with my thesis. I have some questions for the industry concerning the design process that will help me to do a comparative analysis to hopefully show how our integrated design team process has helped us to efficiently produce an economical, sustainable home. The point I am trying to make is that in an integrated design team the roles played by each discipline are unlike the roles played in a traditional project setting. The integrated design team can make the design process more streamlined and allow each discipline to have a larger influence in the structure's green features. We hypothesize that the all disciplines except the architects had increased responsibilities; therefore, alleviating some of the stress and responsibilities of the architects. In order to make a comparative analysis, I would like to ask a few questions on a traditionally run project, (not an integrated design team), to see if your information is in agreement with my hypothesis.

pg 1/1

Type B  
environmentally-  
preferable materials

1. What would your design responsibilities and process be for a residential home (even if your responsibilities would be minimal to none because structural engineers aren't generally required for residential homes)?

*Response: Foundation (footer and wall), floor, porches and stairwell, and roof design.*

2. At what point would you become involved in the project? And what information are you given in order to begin the project?

*Response: Following conceptual design approval by owner. Provided with regional locations, unique location code requirements, site conditions and structure's general geometry, i.e., foundation depth and soil conditions, specific structural feature and unique building materials, etc..*

3. If, in this same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability?

*Response: The architect's owner approved conceptual design would dictate the major features I would prepare my design within. In addition to those include in #2 (above), and within the approved conceptual design, I would focus on improvements to the building's structural envelope utilizing and/or supporting the following:*

- local materials suitable to the regional and specific structure's locations,
- thermally resistant structural materials,
- accommodating incorporation of high-performance (super efficient Energy Star™ and Green Building™ rated systems and equipment) and/or natural systems:
  - high-performance heating, ventilation, humidity control and air-conditioning (HVAC) systems,
  - lighting system,
  - water system, i.e., conservation and efficiency measures,

• Type B  
large-scale  
passive  
solar  
systems  
• macro-level

some questions for the industry concerning the design process that will help me to do a comparative analysis to hopefully show how our integrated design team process has helped us to efficiently produce an economical, sustainable home. The point I am trying to make is that in an integrated design team the roles played by each discipline are unlike the roles played in a traditional project setting. The integrated design team can make the design process more streamlined and allow each discipline to have a larger influence in the structure's green features. We hypothesize that the all disciplines except the architects had increased responsibilities; therefore, alleviating some of the stress and responsibilities of the architects. In order to make a comparative analysis, I would like to ask a few questions on a traditionally run project, (not an integrated design team), to see if your information is in agreement with my hypothesis.

1. What would your design responsibilities and process be for a residential home (even if your responsibilities would be minimal to none because structural engineers aren't generally required for residential homes)?

Actually, Mary, although I don't have experience in the residential field, I think the way this is done is they work on a reference model that is then mass-produced from the blueprints or plans, whether pre-fabricated (as for mobile homes) or built on site. Those plans have to be approved and stamped by a professional engineer. The different disciplines are addressed by engineers qualified in those disciplines. This means that the plans will have the seals of civil (siting, drainage, access), structural, mechanical (HVAC and plumbing) and electrical engineers.

2. At what point would you become involved in the project? And what information are you given in order to begin the project?

Since structural deals with setting up the basic underlying frame and foundation, which affects the space that can be available for everything else, I would surmise that it should be the first one to get involved, following civil's site work, for on-site builds.

Input data required should include the desired living space (aka, square footage) and general style of the house (architectural) such as one floor if a ranch-style house, or two; basement or not (site dependent), etcetera. Many of the necessary design parameters would actually come from the applicable building code which provides the necessary guidelines to determine many of the loads. The architect would also become involved in limiting the size of beams and columns to be used.

3. If, in this same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability?

Mary, I frankly think that the biggest impact, as far as residential construction goes, exists at the macro level, meaning city planning. While urban sprawl is always deplorable, some areas of our ecosystem are more sensitive than others, such as wetlands. So, it is desirable to steer that suburban sprawl away from these areas.

At the single unit level, I'm a firm believer in smart designs that use available resources, such as passive solar. This used to be a big idea back during the Eighties. I'm surprised it gets such short shrift these days. Passive solar ideas involve such simple steps as facing south, to get the highest solar gain in the house, and use of glass (greenhouse effect) on that south facing side to allow the sun's rays in. A heat-retaining Trombe brick wall would be constructed opposite that large glass window pane(s) and their combined heat-retaining during the winter would greatly reduce heating costs, passively.

This is only one of many examples. I think technologically active means should not be deployed, if at all, until the freely available passive ideas have been exhausted.

• Type B  
• none/some recycled content materials

pg 1/1

Hi. This is Mary French and I need some assistance with my thesis. I have some questions for the industry concerning the design process that will help me to do a comparative analysis to hopefully show how our integrated design team process has helped us to efficiently produce an economical, sustainable home. The point I am trying to make is that in an integrated design team the roles played by each discipline are unlike the roles played in a traditional project setting. The integrated design team can make the design process more streamlined and allow each discipline to have a larger influence in the structure's green features. We hypothesize that the all disciplines except the architects had increased responsibilities; therefore, alleviating some of the stress and responsibilities of the architects. In order to make a comparative analysis, I would like to ask a few questions on a traditionally run project, (not an integrated design team), to see if your information is in agreement with my hypothesis.

1. What would your design responsibilities and process be for a residential home (even if your responsibilities would be minimal to none because structural engineers aren't generally required for residential homes)?

Foundation plan, framing plan, lateral stability

2. At what point would you become involved in the project? And what information are you given in order to begin the project?

Typically I get involved once the architect has met with the owner and established a basic set of drawings. This set of drawings is what I work off of.

3. If, in this same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability?

Structurally, there isn't much we do differently. Maybe use fly ash in concrete, use recycled concrete, and recycled reinforcing.

Thanks

• Type A/B  
(geotech)  
• Storm water  
control

process has helped us to efficiently produce an economical, sustainable home. The point I am trying to make is that in an integrated design team the roles played by each discipline are unlike the roles played in a traditional project setting. The integrated design team can make the design process more streamlined and allow each discipline to have a larger influence in the structure's green features. We hypothesize that the all disciplines except the architects had increased responsibilities; therefore, alleviating some of the stress and responsibilities of the architects. In order to make a comparative analysis, I would like to ask a few questions on a traditionally run project, (not an integrated design team), to see if your information is in agreement with my hypothesis.

1. What would your design responsibilities and process be for a residential home (even if your responsibilities would be minimal to none because structural engineers aren't generally required for residential homes)?

As an Environmental Consultant, our role would be minimal, although sometimes we help customers install very economical systems to mitigate radon or delineate wetlands, in the original design phase. As Civil/Site Designers, we do the site design and obtain the permits. We prepare Stormwater Pollution Prevention Plans and sometimes Aquatic Resource Alteration Permits and 401 Water Quality Certifications if wetlands or streams are going to be impacted.

2. At what point would you become involved in the project? And what information are you given in order to begin the project?

We should be involved right from the beginning, but sometimes are not. We often have to help site owners address permitting problems or mitigate for things that should have been done in the beginning.

3. If, in this same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability?

Perhaps in specifying materials for silt fencing or site stabilization. We don't really specify building materials.

Environmental

Hi. This is Mary French and I need some assistance with my thesis. I have some questions for the industry concerning the design process that will help me to do a comparative analysis to hopefully show how our integrated design team process has helped us to efficiently produce an economical, sustainable home. The point I am trying to make is that in an integrated design team the roles played by each discipline are unlike the roles played in a traditional project setting. The integrated design team can make the design process more streamlined and allow each discipline to have a larger influence in the structure's green features. We hypothesize that the all disciplines except the architects had increased responsibilities; therefore, alleviating some of the stress and responsibilities of the architects. In order to make a comparative analysis, I would like to ask a few questions on a traditionally run project, (not an integrated design team), to see if your information is in agreement with my hypothesis.

control permeable  
soil  
surfaces  
pg 1/1

1. What would your design responsibilities and process be for a residential home (even if your responsibilities would be minimal to none because structural engineers aren't generally required for residential homes)?
  - Site Visit
  - Review of governing regulations
  - Prepare grading, drainage, erosion control and utility plan and if over 1 acre a storm water pollution prevention plan.
2. At what point would you become involved in the project? And what information are you given in order to begin the project?
  - During site planning engineer needs to have input.
  - Topographical survey will be needed. (showing zoning setbacks and existing utilities).
  - Building footprint and service points.
  - Building utility needs.
3. If, in this same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability?
  - Storm water quality/quantity units would be considered.
  - Rainfall/Brown water collection for irrigation considered.
  - Low albedo pavements considered.
  - Green space maximization.

Environmental

Type B  
• environ. preferable materials, no change in material

Hi. This is Mary French and I need some assistance with my thesis. I have some questions for the industry concerning the design process that will help me to do a comparative analysis to hopefully show how our integrated design team process has helped us to efficiently produce an economical, sustainable home. The point I am trying to make is that in an integrated design team the roles played by each discipline are unlike the roles played in a traditional project setting. The integrated design team can make the design process more streamlined and allow each discipline to have a larger influence in the structure's green features. We hypothesize that the all disciplines except the architects had increased responsibilities; therefore, alleviating some of the stress and responsibilities of the architects. In order to make a comparative analysis, I would like to ask a few questions on a traditionally run project, (not an integrated design team), to see if your information is in agreement with my hypothesis.

1. What would your design responsibilities and process be for a residential home (even if your responsibilities would be minimal to none because structural engineers aren't generally required for residential homes)? I've designed homes out of light gauge steel, wood, concrete, structural steel and masonry. Some were more traditionally framed homes and some were much larger more monumental homes. On most homes I would be responsible for foundation and pier design, floor beams, floor joists, wall stud size, posts as necessary to carry upper floor beams or posts, roof framing members, wall and roof sheathing sizing, and lateral load resisting elements (plywood or OSB shear walls, Simpson Hold-downs, etc.)
2. At what point would you become involved in the project? And what information are you given in order to begin the project? The Structural Engineer typically becomes involved after the Architect has a preliminary (or maybe final) set of drawings including the floor plans, roof plans, elevations, building sections, etc. Considerations may not have been made for large open spaces, tall open foyer walls, large window walls, large (HEAVY) fireplaces, etc. in the initial architectural layout of the house. Therefore the engineer has to work around what has already been provided to try to beef up structural members as required to support the dead, live, wind, and seismic loads the structure will encounter. Sometimes this can be very difficult as Architects and owners can be very particular about open floor plans, tall walls without bump-outs for columns or wind beams, window openings, etc.
3. If, in this same project, you were asked to keep sustainability in mind, what influences could you or would you make to the structure's sustainability? Obviously the LEED checklist has all the items required, but things I would recommend are as follows. Recycled material can be a major factor - Light Gauge Steel is probably more that 70% recycled, and so is metal deck. Structural Steel is typically more than 95% recycled. Those are both becoming more widespread as residential building materials, especially on more custom or atypical homes. Distance from the point of origin to the jobsite should also be considered due to shipping (and therefore fuel) costs and pollution. You could try to get reclaimed lumber from old barns or older buildings downtown but sometimes that can be pricey.

To: French, Mary Elizabeth  
Cc:  
Subject: RE: Survey response  
Attachments:

[View As Web Page](#)

Typically on a standard project, the materials of construction are already chosen for the engineer. So we have to work with what we are given. More recently on commercial and military projects LEED is a key driver so high recycled content materials are chosen. Generally as the engineer of record you don't recommend a change to another material due to it being a more green option, you work with what the architect dictates.

Hope this helps. Good luck with the thesis and keep me posted about the project.

## **Appendix B: Design Calculations**

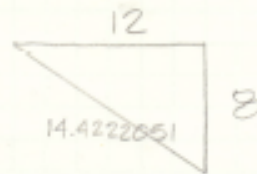
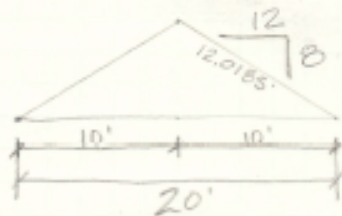
## NEW NORRIS HOUSE

- PRELIMINARY SIZING CALCULATIONS  
(Benefit for Architecture during design process)

### ROOF:

DEAD LOAD (ASSUMED) = 20 psf

- somewhat high assumption considering our plans for efficient framing
- once all materials/cladding, etc. are decided, more accurate loads will be used for headers, etc.



### LIVE LOAD:

$$L_r = 20 \text{ psf} (R_1)(R_2)$$

$$R_1 = 1.2 - 0.001 A_T \quad (R_1)_{\min} = 0.6 \quad A_T = \text{tributary area}$$

$$R_2 = 1.2 - 0.05 F \quad (R_2)_{\min} = 0.6 \quad F = F:12 \text{ slope ratio}$$

- Roof Joists: Spacing = 24 in

$$L_r = (20)(1)(1.2 - 0.05 \cdot 8) = 16 \text{ psf}$$

$$TL = (36 \text{ psf})(2') = 72 \text{ plf}$$

$$M = \frac{(72 \text{ plf})(10')}{8} (12.0185) = 1081.665 \text{ lb} \cdot \text{ft} = 12979.98 \text{ lb} \cdot \text{in}$$

$$\text{Try } 2 \times 10\text{'s} \quad S_{\text{req'd}} = \frac{12979.98}{\left( \frac{1.15 \cdot 1050}{L_c} \right) L_b} = 10.749 \text{ in}^3 < 21.39 \text{ in}^3$$

$$\text{Try } 2 \times 8\text{'s} \quad S_{\text{req'd}} = \frac{12979.98}{(1.15 \cdot 1200)} = 9.406 \text{ in}^3 < 13.14 \text{ in}^3$$

∴ OKAY

Try No. 1  $2 \times 6$  SYP  $\frac{12979.98}{(1.15 \cdot 1650)} = 6.84 \text{ in}^3 < 7.563 \text{ in}^3$

$\therefore$  OKAY

Deflection:  $w_{TL} = 72 \text{ plf} \cdot 6 \text{ pli}$   $w_{UL} = 32 \text{ plf} \cdot 2.667 \text{ pli}$

$(I_{\text{req'd}})_{TL} = \frac{5wL^4}{384EA}$   $\Delta_{TL} = \frac{L}{240} = \frac{12.0185' \cdot 12''}{240} = 0.601 \text{ in}$

$(I_{\text{req'd}})_{UL} = 24.33 \text{ in}^4 (E=1.6); 22.903 \text{ in}^4 (E=1.7)$

No. 1 SYP  $2 \times 6$  will not work ( $I = 20.80 \text{ in}^4$ )

$(I_{\text{req'd}})_{UL} = 16.2252 \text{ in}^4$   $\Delta_{UL} = \frac{L}{360} = 0.4006 \text{ in}$

$2 \times 8$   $I = 47.63 \text{ in}^4 \therefore$  OKAY

## • RIDGE BEAMS

• OPTION 1:  $L = 10'$

$L_u = 12.0185'$   $A_T \leq 100 \text{ ft}^2 \therefore R_1 = 1 \text{ in}$   $L_r = 16 \text{ psf}$

$q = 36 \text{ psf}$   $w = q L_u = (36 \text{ psf})(12.0185') = 432.666 \text{ plf}$

$w_u = (1.2 \cdot 20 + 1.6 \cdot 16)(12.0185') = 596.1176 \text{ plf}$

$M = \frac{wL^2}{8} = 5408.325 \text{ lb} \cdot \text{ft} = 64899.9 \text{ lb} \cdot \text{in}$

$M_u = \frac{w_u L^2}{8} = 7451.47 \text{ lb} \cdot \text{ft} = 89417.64 \text{ lb} \cdot \text{in}$

TRY  $2 \times 10$  (No. 2)  $F_b = 1050 \text{ psi}$   $C_L \leq L_u = 24'$

$L_e = 1.68 L_u = 40.32 \text{ in}$   $R_b = 12.87178$   $R_b^2 = 165.76$

$F_{bE} = 4198.8417$   $F_b' = 1050 \text{ psi}$   $C_L = 0.9839$

$F_b' = 1033.14 \text{ psi}$

$S_{\text{req'd}} = 62.818 \text{ in}^3 = \underline{\underline{(3) 2 \times 10's}}$

$P = 4326.66 \text{ lbs}$   $P_{\text{ends}} = 2163.33 \text{ lbs}$

TRY 2x12 (No. 1 SYP)  $F_b = 1250 \text{ psi}$

$$L_e = 40.32 \text{ in } C_L: F_{bc} = 4488.417 \quad F_{bc}/F_b' = 3.5907$$

$$C_L = 0.981538 \quad F_b' = 1226.922558 \text{ psi}$$

$$S_{req'd} = 52.8965 \text{ in}^3 \therefore (2) 2 \times 12$$

• OPTION 2:  $L = 15'$   $R_1 = 1$

$$W = 432.666 \text{ plf} \quad W_u = 596.1176 \text{ plf}$$

$$M = 12168.73125 \text{ lb} \cdot \text{ft} = 146024.775 \text{ lb} \cdot \text{in}$$

$$M_u = 16765.8075 \text{ lb} \cdot \text{ft} = 201189.69 \text{ lb} \cdot \text{in}$$

$$\text{TRY } 2 \times 12 \text{ (No. 1 SYP)} \quad F_b = 1250 \quad F_b' = 1215.69188 \text{ psi}$$

$$S_{req'd} = 120.1166 \text{ in}^3 \therefore (4) 2 \times 12 \text{ No. 1 SYP}$$

$$\text{TRY LVL } (1\frac{3}{4}'' \times 11\frac{7}{8}'') \quad F_b = 2900 \text{ psi} \quad F_b' = 2779 \text{ psi}$$

$$S_{req'd} = 53.51 \text{ in}^3 \therefore (2) 1\frac{3}{4}'' \times 11\frac{7}{8}'' \text{ LVL}$$

$$\text{TRY STEEL} \quad M_n \geq \frac{M_u}{\phi} \quad M_n \geq 223544.1 \text{ lb} \cdot \text{in}$$

$$Z_{req'd} = 4.86 \text{ in}^3 \therefore \text{HSS } 6 \times 2 \times \frac{1}{4}$$

$$P = 6489.99 \text{ lbs} \quad P_{ends} = 3244.995 \text{ lb}$$

$$P_u = 8941.764 \text{ lb} \quad (P_u)_{ends} = 4470.882 \text{ lb}$$

• OPTION 3:  $L = 30'$   $R_1$

$$W = 432.666 \text{ plf} \quad W_u = 596.1176 \text{ plf}$$

$$M = 48674.925 \text{ lb} \cdot \text{ft} = 584.0991 \text{ k} \cdot \text{in}$$

$$M_u = 67063.23 \text{ lb} \cdot \text{ft} = 804.75876 \text{ k} \cdot \text{in}$$

$$\text{TRY LVL } 1\frac{3}{4}'' \times 18'' \quad F_b = 2772.25 \quad F_b' = 2757.8286$$

$$S_{req'd} = 211.797 \text{ in}^3 \therefore (3) 1\frac{3}{4}'' \times 18'' \text{ LVL}$$

$$\text{TRY STEEL} \quad M_n \geq 894.1764 \text{ k} \cdot \text{in}$$

$$Z_{req'd} = 19.44 \text{ in}^3 \therefore \text{HSS } 8 \times 3 \times \frac{1}{2} \quad \text{HSS } 9 \times 3 \times \frac{3}{8}$$

\* NOTE  $R_1 = 0.9$   $L_r = 14.4$ ; SO SIZES MAY DECREASE

STUDS: \* Can we reuse old 2x4's  $F_c$  (ASSUMED) = 1600 psi

$$\cdot 36 \text{ psf} \cdot 2' \cdot 10' \cdot 1/2 = 360 \text{ lbs} - \text{ROOF}$$

$$\cdot 55 \text{ psf} \cdot 2' \cdot 10' \cdot 1/2 = 550 \text{ lbs} - \text{FLOOR}$$

$$\cdot 15 \text{ psf} \cdot 2' \cdot 10' = \frac{300 \text{ lbs}}{1210 \text{ lbs}} - \text{WALL}$$

ASSUMED:

$$l_{e1}/d_1 = (9.5')(12'')/3.625 = 31.448$$

$$l_{e2}/d_2 = (4.75')(12'')/1.625 = 35.017 \leftarrow \text{CONTROLS}$$

$$F_{ce} = \frac{0.822 (620,000)}{(l_{e2}/d_2)^2} \leftarrow E_{min} \text{ ASSUMED (No. 1 SYP)}$$
$$= 414.21$$

$$C_p = 0.2432 \quad F_c' = 389.2 \text{ psi} \quad P_{allow} = 2292.6 \text{ lbs}$$

$\therefore$  OKAY

TRY 2x4 SYP STUD  $F_c = 975 \text{ psi}$

$$\text{ASSUMED } l_{e2}/d_2 = (4.75')(12'')/1.5 = 38$$

$$F_{ce} = 290.32 \text{ psi} \quad C_p = 0.2766 \quad F_c' = 255.86 \text{ psi}$$

$$P_{all} = 1343.3 \text{ lbs} \quad \therefore \text{OKAY}$$

- IF NEW STUD-QUALITY 2x4s WILL WORK AT 24" O.C. THEN OLD, BETTER-QUALITY STUDS SHOULD BE FINE

\*NOTE HAVE NOT CALCULATED IN COMBINATION WITH WIND YET

## FLOOR:

$$LL = 40 \text{ psf} \cdot 2' = 80 \text{ plf}$$

DL:

LOFT:

|                   |         |
|-------------------|---------|
| Hardwood flooring | 4 psf   |
| Plywood           | 2.4 psf |
| GPI 20 (9 1/2")   | 2.3 psf |
| Insulation        | 2 psf   |
| Mechanical        | 2 psf   |
| Gypsum            | 2.7 psf |

$$13.15 \text{ psf} \cdot 2' = 26.3 \text{ plf} + 2.3 = 28.6 \text{ plf} \approx 29 \text{ plf}$$

$$\text{Total} = 109 \text{ plf}$$

$$M = \frac{wL^2}{8} = \frac{(109 \text{ plf})(10')^2}{8} = 1362.5 \text{ lb} \cdot \text{ft} = 16350 \text{ lb} \cdot \text{in}$$

$$V = (109 \text{ plf})(10'/2) = 545 \text{ lb}$$

$$\Delta_{\text{allowable}} \quad LL = L/360 = 0.33 \text{ in} \quad DL = 0.5 \text{ in}$$

$$w_{TL} = 109 \text{ plf} = 9.0833 \text{ pli} \quad w_{LL} = 4.667 \text{ pli}$$

$$\Delta_{TL} = \frac{5wL^4}{384EI} = \frac{(5)(9.0833)(120')^4}{(384)(159 \times 10^6)} = 0.154 \text{ in}$$

$$\Delta_{LL} = \frac{5wL^4}{384EI} = \frac{(5)(4.667)(120')^4}{(384)(159 \times 10^6)} = 0.1132 \therefore \text{OKAY}$$

GPI 20 9 1/2" OKAY

$$\text{TRY } 2 \times 8\text{'s} \quad S = 13.14062 \text{ in}^3 \quad I = 47.63476562 \text{ in}^4$$

$$S_{\text{req'd}} = \frac{16350 \text{ lb} \cdot \text{in}}{(1200/1.15)} = 11.85 \text{ in}^3 \therefore \text{OKAY}$$

$$\Delta_{TL} = 0.322 \text{ in} \checkmark \quad \Delta_{LL} = 0.236 \text{ in} \checkmark$$

2 x 8's @ 24" OKAY

### FIRST FLOOR:

Hardwood flooring 4  
Plywood 2.4  
Insulation 2

$$\frac{8.4 \text{ psf} \cdot 2' = 16.8 \text{ plf} + 2.8 \text{ plf} = 19.6 \text{ plf} \approx 20 \text{ plf}$$

$$\text{Total} = 100 \text{ plf}$$

$$M = \frac{wL^2}{8} = \frac{(100 \text{ plf})(10')^2}{8} = 1250 \text{ lb}\cdot\text{ft} = 15000 \text{ lb}\cdot\text{in}$$

$$V = 500 \text{ lbs}$$

$$w_k = 8.333 \text{ pli} \quad w_{LL} = 6.6667 \text{ pli}$$

$$S_{req'd} = \frac{15000 \text{ lb}\cdot\text{in}}{(1200 \cdot 115)} = 10.87 \text{ in}^3$$

$\Delta$  OKAY

2x8 @ 24" o.c. OKAY

### GIRDERS:

$$\text{LOFT: } 109 \text{ plf} / 2' = 54.5 \text{ psf} \cdot 10' / 2 = 272.5 \text{ plf}$$

$$L = 10'$$

$$M = \frac{wL^2}{8} = \frac{(272.5 \text{ plf})(10')^2}{8} = 3406.25 \text{ lb}\cdot\text{ft} = 40875 \text{ lb}\cdot\text{in}$$

$$S_{req'd} = \frac{40875 \text{ lb}\cdot\text{in}}{(1050 \text{ psi} \cdot 0.97)} = 40.1325 \text{ in}^3 \therefore (2) 2 \times 10's$$

$$S_{req'd} = \frac{40875}{(1200 \text{ psi})} = 34.0625 \text{ in}^3 \quad (3) 2 \times 8's$$

$$w_{TL} = 22.708 \text{ pli} \quad w_{LL} = 16.667 \text{ pli}$$

$$\Delta_{TL} = 0.5 \text{ in} \quad \Delta_{LL} = 0.333 \text{ in}$$

$$(I_{req'd})_{TL} = 76.640625 \text{ in}^4 \quad (2) 2 \times 8's \text{ or } (1) 2 \times 10$$

$$(I_{req'd})_{LL} = 84.375 \text{ in}^4 \quad (2) 2 \times 8's \text{ or } (1) 2 \times 10$$

$$l = 20'$$

$$M = \frac{(272.5)(20')^2}{8} = 13625 \text{ lb}\cdot\text{ft} = 163500 \text{ lb}\cdot\text{in}$$

$$S_{\text{req'd}} = \frac{163500}{1050 \text{ psi}} = 155.714 \quad (8) \ 2 \times 10's$$

$$S_{\text{req'd}} = \frac{163500}{2900 \text{ psi}} = 56.38 \text{ in}^3 \quad (3) \ 1\frac{3}{4}" \times 9\frac{1}{4}" \text{ LVL}$$

$$(2) \ 1\frac{3}{4}" \times 11\frac{7}{8}" \text{ LVL}$$

$$\Delta_{TL} = 1" \quad \Delta_{LL} = 0.667$$

$$(I_{\text{req'd}})_{TL} = 516.32 \text{ in}^4 \quad (3) \ 1\frac{3}{4}" \times 11\frac{7}{8}" \text{ LVL}$$

$$(5) \ 1\frac{3}{4}" \times 9\frac{1}{4}" \text{ LVL}$$

$$(I_{\text{req'd}})_{LL} = 568.42 \text{ in}^4 \quad (5) \ 1\frac{3}{4}" \times 9\frac{1}{4}" \text{ LVL}$$

$$(3) \ 1\frac{3}{4}" \times 11\frac{7}{8}" \text{ LVL}$$

$$\text{FIRST FLOOR: } 50 \text{ psl} \cdot 10' = 500 \text{ plf}$$

$$l = 10' \quad M = \frac{(500 \text{ plf})(10')^2}{8} = 6250 \text{ lb}\cdot\text{ft} = 75000 \text{ lb}\cdot\text{in}$$

$$S_{\text{req'd}} = \frac{75000 \text{ lb}\cdot\text{in}}{1050 \text{ psi}} = 71.43 \text{ in}^3 \quad (4) \ 2 \times 10's$$

$$w_{TL} = 41.667 \text{ pli} \quad w_{LL} = 33.33 \text{ pli}$$

$$(I_{\text{req'd}})_{TL} = 140.625 \text{ in}^4 \quad \therefore (2) \ 2 \times 10's$$

$$(I_{\text{req'd}})_{LL} = 168.75 \text{ in}^4 \quad \therefore (2) \ 2 \times 10's$$

$$l = 15' \quad M = \frac{(500 \text{ plf})(15')^2}{8} = 14062.5 \text{ lb}\cdot\text{ft} = 168750 \text{ lb}\cdot\text{in}$$

$$S_{\text{req'd}} = \frac{168750}{2900} = 58.2 \text{ in}^3 \quad (2) \ 1\frac{3}{4}" \times 11\frac{7}{8}" \text{ LVL}$$

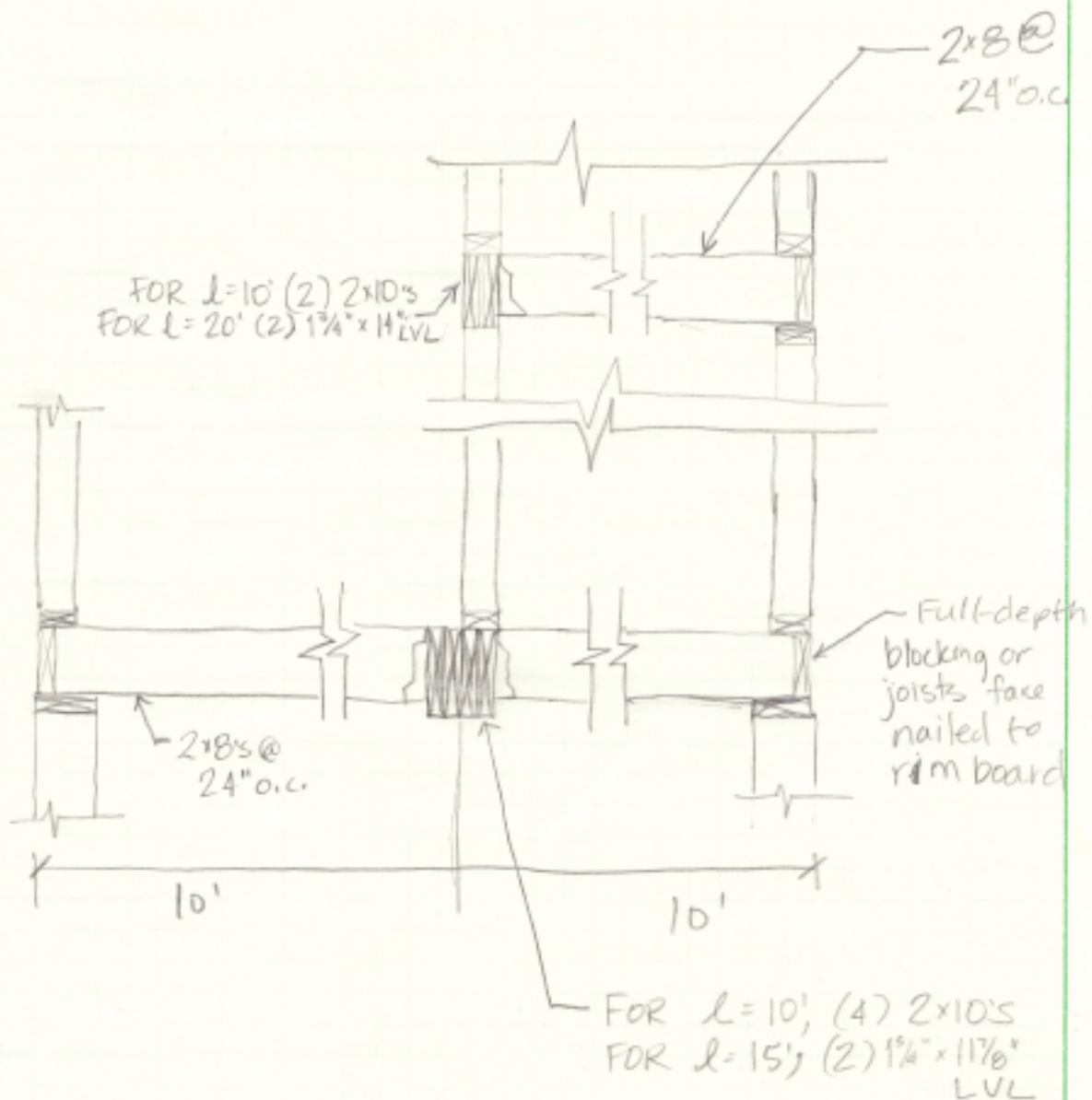
$$\Delta_{TL} = 0.75" \quad \Delta_{LL} = 0.5"$$

$$(I_{\text{req'd}})_{TL} = 379.6875 \quad (2) \ 1\frac{3}{4}" \times 11\frac{7}{8}" \text{ LVL}$$

$$(I_{\text{req'd}})_{LL} = 455.625 \quad (2) \ 1\frac{3}{4}" \times 11\frac{7}{8}" \text{ LVL}$$

## GENERAL FRAMING:

\*I left out the roof since you guys already have that information

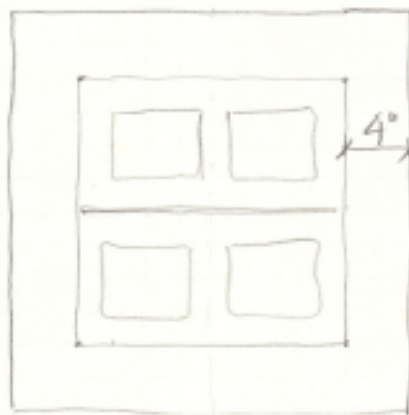


FOOTINGS: ASSUME ALLOWABLE SOIL PRESSURE = 2000 psf  
 $(50 \text{ psf})(10')(10') = \frac{5000 \text{ lbs}}{2000 \text{ psf}} = \sqrt{2.5 \text{ ft}^2} = 1.58'$

USE  $F2' \times 2'$

shear  $\approx$  punching

$$d = 12" - 3" - 0.5" = 8.5"$$



∴ no critical section

DECK:

$$DL = 10 \text{ psf}$$

$$LL = 40 \text{ psf}$$

$$\frac{50 \text{ psf}}{50 \text{ psf}} \quad l = 9' - 9" = 9.75' \quad \text{overhang} = 3'$$

$$\text{Floor: } (50)(2') = 100 \text{ plf}$$

$$M = \frac{wl^2}{8} = \frac{(100 \text{ plf})(9.75')^2}{8} = 1188.28125 \text{ lb}\cdot\text{ft} = 14259.375 \text{ lb}\cdot\text{in}$$

$$\text{TRY } 2 \times 8\text{'s} \quad S_{req'd} = \frac{14259.375}{(1200 \text{ psi} \cdot 0.25)} = 13.98 \text{ in}^3 \quad \text{NO GOOD}$$

USE  $2 \times 10\text{'s}$

OVERHANG PORTION

$$\text{Overhang} = 3' = a \quad l = 9.75'$$

$$R_1 = V_1 = \frac{w}{2l} (l^2 - a^2) = \frac{100}{2 \cdot 9.75} (9.75^2 - 3^2) = 441.3 \text{ lbs}$$

$$R_2 = V_2 + V_3 = \frac{w}{2l} (l+a)^2 = \frac{100}{2 \cdot 9.75} (12.75)^2 = 833.7$$

$$V_2 = wa = 300 \text{ lbs} \quad V_3 = 533.7 \text{ lbs}$$

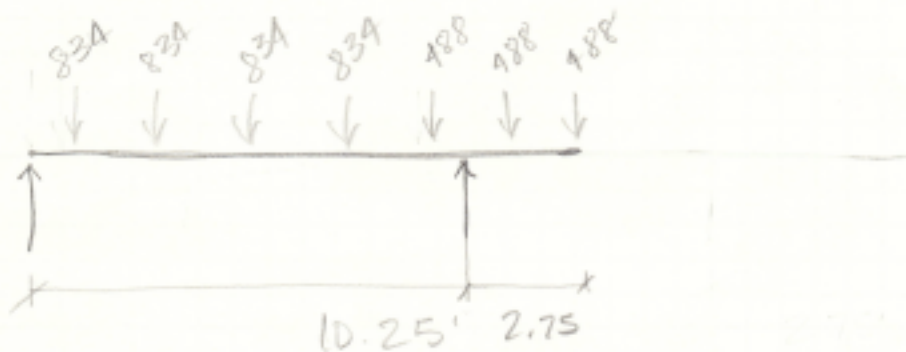
$$M_1 = \frac{w}{8l^2} (l+a)^2 (l-a)^2 = \frac{100}{8 \cdot (9.75)^2} (12.75)^2 (6.75)^2 = 973.9 \text{ lb}\cdot\text{ft}$$

$$M_1 = 11687.2 \text{ lb}\cdot\text{in}$$

$$M_2 = \frac{wa^2}{2} = \frac{100(3)^2}{2} = 450 \text{ lb}\cdot\text{ft} = 5400 \text{ lb}\cdot\text{in}$$

2x10'S OKAY

GIRDERS:



SEE ~~B~~ PRINTOUT



Deck girder at interior

(2) 2x10

Current Date: 11/19/2009 5:16 PM

Units system: English

File name: N:\AAAMary Photos\New Norris\deck\_girder\_edge.rcb\

## Continuous Beam

Design code ANSI/AF&PA NDS-ASD-2005

### GENERAL INFORMATION:

#### Spans:

| Span | Span length<br>[ft] | Section  | Material  |
|------|---------------------|----------|-----------|
| 1    | 10.25               | S4S 2x10 | SPine_No2 |
| 2    | 2.75                | S4S 2x10 | SPine_No2 |

#### Nodes:

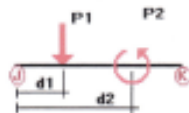
| Distance<br>[ft] | Restraint | Tx | Ty | Rz |
|------------------|-----------|----|----|----|
| 0.00             | Pinned    | 1  | 1  | 0  |
| 10.25            | Pinned    | 1  | 1  | 0  |
| 13.00            | Free      | 0  | 0  | 0  |



### Load conditions:

| Condition | Description | Comb. | Category | Duration  |
|-----------|-------------|-------|----------|-----------|
| DL        | Dead Load   | No    | DL       | permanent |
| LL        | Live Load   | No    | LL       | 7 days    |
| S1        | DL+LL       | Yes   | Service  | --        |
| D1        | DL+LL       | Yes   | Design   | --        |

### Concentrated forces and moments



| Condition | Span | Dist<br>[ft] | P<br>[Kip] | M<br>[Kip*ft] |
|-----------|------|--------------|------------|---------------|
| DL        | 1    | 1.00         | -0.49      | 0.00          |
| DL        | 1    | 3.00         | -0.49      | 0.00          |
| DL        | 1    | 5.00         | -0.49      | 0.00          |
| DL        | 1    | 7.00         | -0.49      | 0.00          |
| DL        | 1    | 9.00         | -0.49      | 0.00          |
| DL        | 2    | 11.00        | -0.49      | 0.00          |
| DL        | 2    | 13.00        | -0.49      | 0.00          |

#### Loads summary



#### Reactions:

| Nodes | Load condition | Rx<br>[Kip] | Ry<br>[Kip] | Mz<br>[Kip*ft] |
|-------|----------------|-------------|-------------|----------------|
| 1     | D1             | 0.00        | 1.12        | 0.00           |
| 2     | D1             | 0.00        | 2.39        | 0.00           |
| 3     | D1             | 0.00        | 0.00        | 0.00           |
| 1     | Min.           | 0.00        | 1.12        | 0.00           |
| 2     | Min.           | 0.00        | 2.39        | 0.00           |
| 3     | Min.           | 0.00        | 0.00        | 0.00           |
| 1     | Max.           | 0.00        | 1.12        | 0.00           |
| 2     | Max.           | 0.00        | 2.39        | 0.00           |
| 3     | Max.           | 0.00        | 0.00        | 0.00           |

#### Member forces and inflection points

| Station<br>[%] | Condition | Distance<br>[ft] | Shear V<br>[Kip] | Moment M<br>[Kip*ft] |
|----------------|-----------|------------------|------------------|----------------------|
| 0              | D1        | 0.00             | -1.12            | 0.00                 |
| 37             | D1        | 4.87             | -0.11            | 2.56                 |
| 69             | D1        | 8.99             | 0.90             | 0.01                 |
| 79             | D1        | 10.25            | 1.40             | -1.73                |
| 79             | D1        | 10.25            | -1.00            | -1.73                |
| 100            | D1        | 13.00            | 0.00             | 0.00                 |

#### Critical deflections

| Condition | Span | Distance<br>[ft] | @<br>[%] | Deflection |         | Allowable<br>[in] |
|-----------|------|------------------|----------|------------|---------|-------------------|
|           |      |                  |          | [in]       | f(L)    |                   |
| S1        | 1    | 4.87             | 37.45    | 0.14110    | (L/872) | 0.34167           |

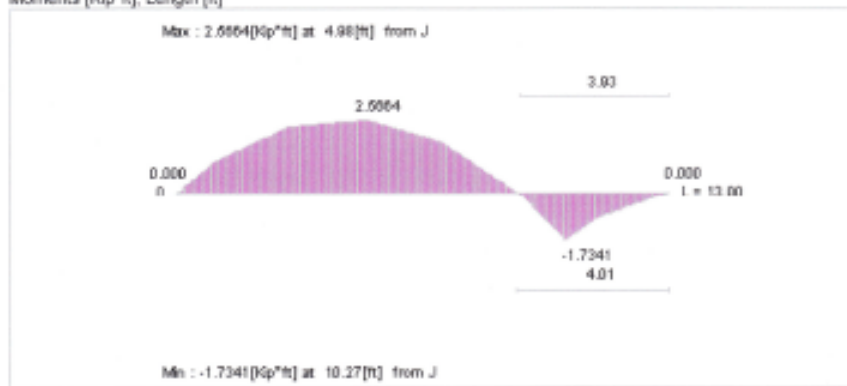
#### Free nodes deformations

| Node                  | TY<br>[in] | RZ<br>[Rad] |
|-----------------------|------------|-------------|
| Combination: S1=DL+LL |            |             |
| 3                     | 0.06054    | 0.00159     |

#### Envelopes :

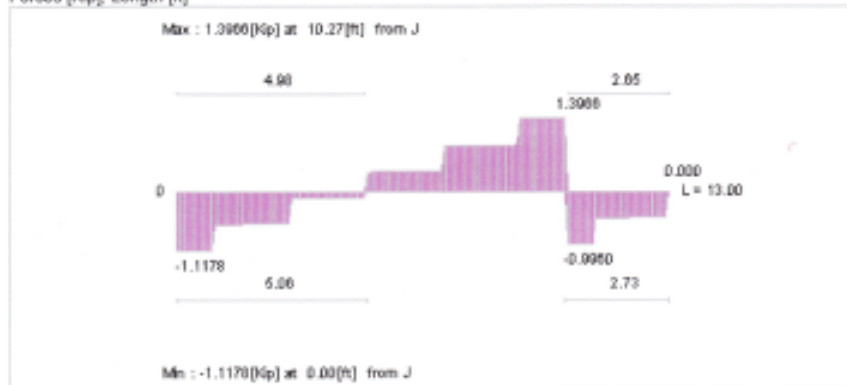
M33 bending moment

Moments [Kip\*ft], Length [ft]



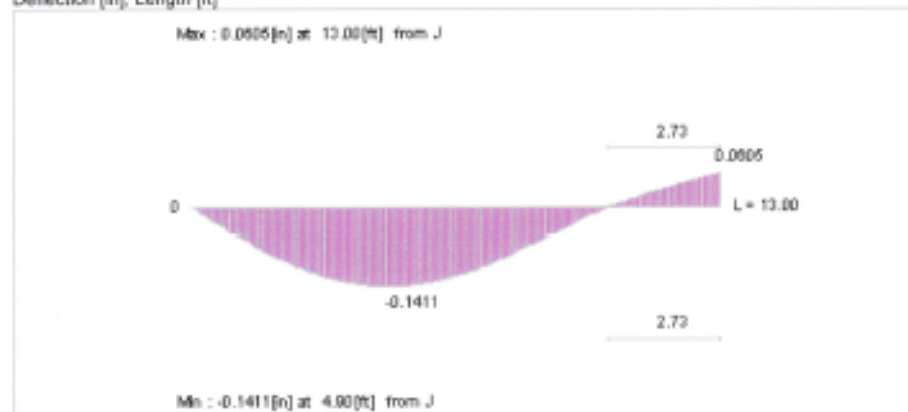
V2 shear forces:

Forces [Kip], Length [ft]



# Vertical Translation

Deflection [in], Length [ft]

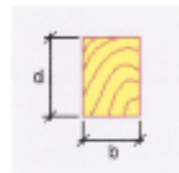


## DESIGN:

Span : 1 (S4S 2\_2x10\_SPine\_No2)  
Design status : OK

## PROPERTIES

Section : S4S 2\_2x10



Width (b) : 3.00 [in]  
Height (d) : 9.25 [in]

| Section properties                      | Unit               | Major axis | Minor axis |
|-----------------------------------------|--------------------|------------|------------|
| Full unreduced cross-sectional area (A) | [in <sup>2</sup> ] | 27.75      |            |
| Moment of Inertia (principal axes) (I)  | [in <sup>4</sup> ] | 197.86     | 20.81      |
| Elastic section modulus (S)             | [in <sup>3</sup> ] | 42.78      | 13.87      |

Material : SPine\_No2

| Properties                | Value         |
|---------------------------|---------------|
| Type:                     | Lumber        |
| Species:                  | Southern Pine |
| Grade:                    | No.2          |
| Coefficient of variation: | 0.25          |

## DESIGN CRITERIA

| Description          | Unit | Value     |
|----------------------|------|-----------|
| Temperature:         | --   | T<=100F   |
| Moisture conditions: | --   | Wet       |
| Wood:                | --   | Unincised |
| Repetitive member    | --   | No        |
| Type:                | --   | Beam      |
| End notches at top:  | --   | Bottom    |
| Notch length:        | [in] | 0.00      |
| Notch depth:         | [in] | 0.00      |

| Description                           | Unit | Major axis | Minor axis |
|---------------------------------------|------|------------|------------|
| Physical length                       | [ft] | 10.25      |            |
| Effective length for bending (Le)     | [ft] | 19.52      |            |
| Unbraced length for bending (Lu)      | [ft] | 10.25      |            |
| Unbraced compression length (Lx, Ly)  | [ft] | 10.25      | 10.25      |
| Effective length factor (K)           | --   | 1.00       | 1.00       |
| Lateral bracing                       | --   | No         | Yes        |
| Bearing length (Lb)                   | [in] | 0.50       |            |
| Length between inflection points (Li) | [ft] | 10.25      |            |

#### SERVICE CONDITIONS

| Verification                             | Unit | Value | Ctrl EQ      | Reference |
|------------------------------------------|------|-------|--------------|-----------|
| Deflection in compression and/or bending | --   | -0.01 | S1 at 47.50% |           |

#### DESIGN CHECKS

##### DESIGN FOR TENSION



|          |   |                |           |               |
|----------|---|----------------|-----------|---------------|
| Ratio    | : | 0.00           |           |               |
| Capacity | : | 0.72 [Kip/in2] | Ctrl Eq.  | : D1 at 0.00% |
| Demand   | : | 0.00 [Kip/in2] | Reference | : (Sec. 3.8)  |

| Intermediate results                | Unit      | Value | Reference |
|-------------------------------------|-----------|-------|-----------|
| Axial design value for tension (Ft) | [Kip/in2] | 0.58  |           |
| Tension axial force (P+)            | [Kip]     | 0.00  |           |

##### DESIGN FOR COMPRESSION



|          |   |                |           |                |
|----------|---|----------------|-----------|----------------|
| Ratio    | : | 0.00           |           |                |
| Capacity | : | 0.25 [Kip/in2] | Ctrl Eq.  | : D1 at 0.00%  |
| Demand   | : | 0.00 [Kip/in2] | Reference | : (Sec. 3.6.3) |

| Intermediate results                                 | Unit      | Value  | Reference    |
|------------------------------------------------------|-----------|--------|--------------|
| Axial design value for compression (Fc)              | [Kip/in2] | 1.50   |              |
| Compression axial force (P-)                         | [Kip]     | 0.00   |              |
| Modulus of elasticity for stability (Emin)           | [Kip/in2] | 580.00 |              |
| Adjusted modulus of elasticity for stability (Emin') | [Kip/in2] | 522.00 |              |
| Critical buckling design value (FcE1)                | [Kip/in2] | 2.43   | (Sec. 3.9.2) |
| Critical buckling design value (FcE2)                | [Kip/in2] | 0.26   | (Sec. 3.9.2) |

## DESIGN FOR FLEXUR



### Bending about major axis, M33

|          |   |                |           |                |
|----------|---|----------------|-----------|----------------|
| Ratio    | : | 0.60           |           |                |
| Capacity | : | 1.18 [Kip/in2] | Ctrl Eq.  | : D1 at 90.00% |
| Demand   | : | 0.71 [Kip/in2] | Reference | : (Sec. 3.3)   |

| Intermediate results                 | Unit      | Value | Reference      |
|--------------------------------------|-----------|-------|----------------|
| Bending design value (Fb)            | [Kip/in2] | 1.06  |                |
| Bending moment (Mox)                 | [Kip*ft]  | 2.52  |                |
| Slenderness Ratio (RB)               | —         | 15.52 | (Eq. 3.3-5)    |
| Critical buckling design value (FbE) | [Kip/in2] | 2.60  | (Sec. 3.3.3.8) |

### Bending about minor axis, M22

|          |   |                |           |               |
|----------|---|----------------|-----------|---------------|
| Ratio    | : | 0.00           |           |               |
| Capacity | : | 1.47 [Kip/in2] | Ctrl Eq.  | : D1 at 0.00% |
| Demand   | : | 0.00 [Kip/in2] | Reference | : (Sec. 3.3)  |

| Intermediate results                     | Unit      | Value | Reference |
|------------------------------------------|-----------|-------|-----------|
| Bending design value (Fb <sub>yy</sub> ) | [Kip/in2] | 1.05  |           |
| Bending moment (M <sub>yy</sub> )        | [Kip*ft]  | 0.00  |           |

## DESIGN FOR SHEAR



### Shear parallel to minor axis, V2

|          |   |                |           |                 |
|----------|---|----------------|-----------|-----------------|
| Ratio    | : | 0.36           |           |                 |
| Capacity | : | 0.21 [Kip/in2] | Ctrl Eq.  | : D1 at 100.00% |
| Demand   | : | 0.08 [Kip/in2] | Reference | : (Sec. 3.4)    |

| Intermediate results          | Unit      | Value | Reference    |
|-------------------------------|-----------|-------|--------------|
| Shear design value (Fv)       | [Kip/in2] | 0.18  |              |
| Shear Force (V <sub>y</sub> ) | [Kip]     | 1.40  |              |
| Notch factor (CN)             | —         | 1.00  | (Sec. 3.4.3) |

### Shear parallel to major axis, V3

|          |   |                |           |                |
|----------|---|----------------|-----------|----------------|
| Ratio    | : | 0.00           |           |                |
| Capacity | : | 0.21 [Kip/in2] | Ctrl Eq.  | : D1 at 0.00%  |
| Demand   | : | 0.00 [Kip/in2] | Reference | : (Sec. 3.4.2) |

| Intermediate results          | Unit      | Value | Reference |
|-------------------------------|-----------|-------|-----------|
| Shear design value (Fv)       | [Kip/in2] | 0.18  |           |
| Shear Force (V <sub>y</sub> ) | [Kip]     | 0.00  |           |

## DESIGN FOR TORSION



|          |   |                |           |               |
|----------|---|----------------|-----------|---------------|
| Ratio    | : | 0.00           |           |               |
| Capacity | : | 0.14 [Kip/in2] | Ctrl Eq.  | : D1 at 0.00% |
| Demand   | : | 0.00 [Kip/in2] | Reference | : (WEC-H)     |

| Intermediate results                    | Unit                   | Value | Reference |
|-----------------------------------------|------------------------|-------|-----------|
| Torsion design value (F <sub>vt</sub> ) | [Kip/in <sup>2</sup> ] | 0.12  |           |
| Torsion moment (M <sub>tor</sub> )      | [Kip*ft]               | 0.00  |           |

#### DESIGN FOR BEARING (Informative)

| Intermediate results                                              | Unit                   | Value | Reference     |
|-------------------------------------------------------------------|------------------------|-------|---------------|
| Maximum reaction (R <sub>max</sub> )                              | [Kip]                  | 2.25  | (Sec. 3.10.3) |
| Load angle (θ)                                                    | —                      | 0.00  |               |
| Axial design value for compression (F <sub>c</sub> <sup>+</sup> ) | [Kip/in <sup>2</sup> ] | 1.50  |               |
| Comp. design value perpendicular to grain (F <sub>cp</sub> )      | [Kip/in <sup>2</sup> ] | 0.57  |               |

#### INTERACTION



##### Combined axial and bending interaction value

Ratio : 0.60

Ctrl Eq. : D1 at 50.00%  
Reference : (Eq. 3.9-3)

#### CRITICAL STRENGTH RATIO



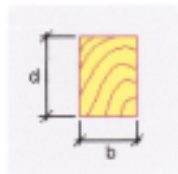
Ratio : 0.60  
Ctrl Eq. : D1 at 50.00%

Reference : (Sec. 3.3)

Span : 2 (S4S 2\_2x10\_SPine\_No2)  
Design status : OK

#### PROPERTIES

Section : S4S 2\_2x10



Width (b) : 3.00 [in]  
Height (d) : 9.25 [in]

| Section properties                      | Unit               | Major axis | Minor axis |
|-----------------------------------------|--------------------|------------|------------|
| Full unreduced cross-sectional area (A) | [in <sup>2</sup> ] | 27.75      |            |
| Moment of inertia (principal axes) (I)  | [in <sup>4</sup> ] | 197.86     | 20.81      |
| Elastic section modulus (S)             | [in <sup>3</sup> ] | 42.78      | 13.87      |

Material : SPine\_No2

| Properties                | Value         |
|---------------------------|---------------|
| Type:                     | Lumber        |
| Species:                  | Southern Pine |
| Grade:                    | No.2          |
| Coefficient of variation: | 0.25          |

#### DESIGN CRITERIA

| Description          | Unit | Value     |
|----------------------|------|-----------|
| Temperature:         | --   | T<=100F   |
| Moisture conditions: | --   | Wet       |
| Wood:                | --   | Unincised |
| Repetitive member:   | --   | No        |
| Type:                | --   | Beam      |
| End notches at top:  | --   | Bottom    |
| Notch length:        | [in] | 0.00      |
| Notch depth:         | [in] | 0.00      |

| Description                           | Unit | Major axis | Minor axis |
|---------------------------------------|------|------------|------------|
| Physical length                       | [ft] | 2.75       |            |
| Effective length for bending (Le)     | [ft] | 19.52      |            |
| Unbraced length for bending (Lu)      | [ft] | 10.25      |            |
| Unbraced compression length (Lx, Ly)  | [ft] | 2.75       | 2.75       |
| Effective length factor (K)           | --   | 1.00       | 1.00       |
| Lateral bracing                       | --   | No         | Yes        |
| Bearing length (Lb)                   | [in] | 0.50       |            |
| Length between inflection points (Li) | [ft] | 2.75       |            |

#### SERVICE CONDITIONS

| Verification                             | Unit | Value | Ctrl EQ       | Reference |
|------------------------------------------|------|-------|---------------|-----------|
| Deflection in compression and/or bending | --   | 0.01  | S1 at 100.00% |           |

#### DESIGN CHECKS

##### DESIGN FOR TENSIO



|          |   |                |           |   |             |
|----------|---|----------------|-----------|---|-------------|
| Ratio    | : | 0.00           | Ctrl Eq.  | : | D1 at 0.00% |
| Capacity | : | 0.72 [Kip/in2] | Reference | : | (Sec. 3.8)  |
| Demand   | : | 0.00 [Kip/in2] |           |   |             |

| Intermediate results                | Unit      | Value | Reference |
|-------------------------------------|-----------|-------|-----------|
| Axial design value for tension (Ft) | [Kip/in2] | 0.58  |           |
| Tension axial force (P+)            | [Kip]     | 0.00  |           |

##### DESIGN FOR COMPRESSION



|          |   |                |           |   |              |
|----------|---|----------------|-----------|---|--------------|
| Ratio    | : | 0.00           | Ctrl Eq.  | : | D1 at 0.00%  |
| Capacity | : | 1.34 [Kip/in2] | Reference | : | (Sec. 3.6.3) |
| Demand   | : | 0.00 [Kip/in2] |           |   |              |

| Intermediate results                                 | Unit                   | Value  | Reference    |
|------------------------------------------------------|------------------------|--------|--------------|
| Axial design value for compression (Fc)              | [Kip/in <sup>2</sup> ] | 1.50   |              |
| Compression axial force (P-)                         | [Kip]                  | 0.00   |              |
| Modulus of elasticity for stability (Emin)           | [Kip/in <sup>2</sup> ] | 580.00 |              |
| Adjusted modulus of elasticity for stability (Emin') | [Kip/in <sup>2</sup> ] | 522.00 |              |
| Critical buckling design value (FcE1)                | [Kip/in <sup>2</sup> ] | 33.71  | (Sec. 3.9.2) |
| Critical buckling design value (FcE2)                | [Kip/in <sup>2</sup> ] | 3.55   | (Sec. 3.9.2) |

#### DESIGN FOR FLEXUR



##### Bending about major axis, M33

|          |   |                             |           |               |
|----------|---|-----------------------------|-----------|---------------|
| Ratio    | : | 0.41                        |           |               |
| Capacity | : | 1.18 [Kip/in <sup>2</sup> ] | Ctrl Eq   | : D1 at 0.00% |
| Demand   | : | 0.49 [Kip/in <sup>2</sup> ] | Reference | : (Sec. 3.3)  |

| Intermediate results                 | Unit                   | Value | Reference      |
|--------------------------------------|------------------------|-------|----------------|
| Bending design value (Fb)            | [Kip/in <sup>2</sup> ] | 1.05  |                |
| Bending moment (Mxx)                 | [Kip*ft]               | -1.73 |                |
| Slenderness Ratio (RB)               | —                      | 15.52 | (Eq. 3.3-5)    |
| Critical buckling design value (FbE) | [Kip/in <sup>2</sup> ] | 2.60  | (Sec. 3.3.3.8) |

##### Bending about minor axis, M22

|          |   |                             |           |               |
|----------|---|-----------------------------|-----------|---------------|
| Ratio    | : | 0.00                        |           |               |
| Capacity | : | 1.47 [Kip/in <sup>2</sup> ] | Ctrl Eq.  | : D1 at 0.00% |
| Demand   | : | 0.00 [Kip/in <sup>2</sup> ] | Reference | : (Sec. 3.3)  |

| Intermediate results        | Unit                   | Value | Reference |
|-----------------------------|------------------------|-------|-----------|
| Bending design value (Fbyy) | [Kip/in <sup>2</sup> ] | 1.05  |           |
| Bending moment (Myy)        | [Kip*ft]               | 0.00  |           |

#### DESIGN FOR SHEAR



##### Shear parallel to minor axis, V2

|          |   |                             |           |               |
|----------|---|-----------------------------|-----------|---------------|
| Ratio    | : | 0.25                        |           |               |
| Capacity | : | 0.21 [Kip/in <sup>2</sup> ] | Ctrl Eq.  | : D1 at 0.00% |
| Demand   | : | 0.05 [Kip/in <sup>2</sup> ] | Reference | : (Sec. 3.4)  |

| Intermediate results    | Unit                   | Value | Reference    |
|-------------------------|------------------------|-------|--------------|
| Shear design value (Fv) | [Kip/in <sup>2</sup> ] | 0.18  |              |
| Shear Force (Vy)        | [Kip]                  | -1.00 |              |
| Notch factor (CN)       | —                      | 1.00  | (Sec. 3.4.3) |

##### Shear parallel to major axis, V3

|          |   |                             |           |                |
|----------|---|-----------------------------|-----------|----------------|
| Ratio    | : | 0.00                        |           |                |
| Capacity | : | 0.21 [Kip/in <sup>2</sup> ] | Ctrl Eq.  | : D1 at 0.00%  |
| Demand   | : | 0.00 [Kip/in <sup>2</sup> ] | Reference | : (Sec. 3.4.2) |

| Intermediate results                 | Unit                   | Value | Reference |
|--------------------------------------|------------------------|-------|-----------|
| Shear design value (F <sub>v</sub> ) | [Kip/in <sup>2</sup> ] | 0.18  |           |
| Shear Force (V <sub>y</sub> )        | [Kip]                  | 0.00  |           |

#### DESIGN FOR TORSION



|          |   |                             |           |               |
|----------|---|-----------------------------|-----------|---------------|
| Ratio    | : | 0.00                        |           |               |
| Capacity | : | 0.14 [Kip/in <sup>2</sup> ] | Ctrl Eq.  | : D1 at 0.00% |
| Demand   | : | 0.00 [Kip/in <sup>2</sup> ] | Reference | : (WEC-H)     |

| Intermediate results                    | Unit                   | Value | Reference |
|-----------------------------------------|------------------------|-------|-----------|
| Torsion design value (F <sub>vt</sub> ) | [Kip/in <sup>2</sup> ] | 0.12  |           |
| Torsion moment (M <sub>tor</sub> )      | [Kip*ft]               | 0.00  |           |

#### DESIGN FOR BEARING (informative)

| Intermediate results                                         | Unit                   | Value | Reference     |
|--------------------------------------------------------------|------------------------|-------|---------------|
| Maximum reaction (R <sub>max</sub> )                         | [Kip]                  | 2.25  | (Sec. 3.10.3) |
| Load angle (θ)                                               | —                      | 0.00  |               |
| Axial design value for compression (F <sub>c</sub> )         | [Kip/in <sup>2</sup> ] | 1.50  |               |
| Comp. design value perpendicular to grain (F <sub>cp</sub> ) | [Kip/in <sup>2</sup> ] | 0.57  |               |

#### INTERACTION



##### Combined axial and bending interaction value

|       |   |      |           |               |
|-------|---|------|-----------|---------------|
| Ratio | : | 0.41 |           |               |
|       |   |      | Ctrl Eq.  | : D1 at 0.00% |
|       |   |      | Reference | : (Eq. 3.9-3) |

#### CRITICAL STRENGTH RATIO



|         |   |             |           |              |
|---------|---|-------------|-----------|--------------|
| Ratio   | : | 0.41        |           |              |
| Ctrl Eq | : | D1 at 0.00% | Reference | : (Sec. 3.3) |

ROOF :

$$LL = 16 \text{ psf } (\underline{25.6})$$



$$8, 12, 14.4222$$

$$DL (\text{ASSUMED}) = 20 \text{ psf } (\underline{24})$$

$$\frac{12}{14} = \frac{5}{x}$$

Option 1:

$$l = 10' \quad l_u = 12.02' \quad q = 36 \text{ psf} \quad w = q l_u = 432.66 \text{ plf}$$

$$M = \frac{w l^2}{8} = 5408.3269 \text{ lb} \cdot \text{ft} = 64899.9229 \text{ lb} \cdot \text{in}$$

$$w_u = 596.11781$$

$$M_u = 7451.4726 \text{ lb} \cdot \text{ft} = 89417.67163 \text{ lb} \cdot \text{in}$$

$$* \text{ ~~2~~ } 2 \times 10 \text{ (No. 2)} \quad F_b = 1050 \text{ psi} \quad S_{req'd} = \frac{61.809 \text{ in}^3}{21.39 \text{ in}^3} = 2.89$$

$$(3) 2 \times 10 \text{ (No. 2)}$$

$$* 2 \times 10 \text{ (No. 2)} \quad F_b = 1300 \text{ psi} \quad S_{req'd} = \frac{49.923 \text{ in}^3}{21.39} = 2.331$$

$$(3) 2 \times 10 \text{ (No. 1)}$$

Option 2:

$$w = 432.66 \text{ plf} \quad l = 15'$$

$$M = \frac{w l^2}{8} = 12168.73125 = 146024.775 \text{ lb} \cdot \text{in}$$

$$* \text{ No. 1 } 2 \times 12 \quad F_b = 1250 \text{ psi} \quad S_{req'd} = \frac{116.81982 \text{ in}^3}{31.64 \text{ in}^3} = 3.69$$

$$\therefore (4) \text{ No. 1 SYP } 2 \times 12$$

$$* \text{ LVL } (1\frac{3}{4}'' \times 11\frac{7}{8}'' \quad S = 41.13 \text{ in}^3) \quad F_b = 2900 \text{ psi} \quad S_{req'd} = 50.35$$

$$\therefore 3\frac{1}{2}'' \times 11\frac{7}{8}''$$

$$M_u = \frac{261189.76 \text{ lb} \cdot \text{in}}{0.9} = 223544.17875 \text{ lb} \cdot \text{in} \leq M_n$$

$$Z_{req'd} = 4.86 \text{ in}^3 \quad \text{HSS } 5 \times 3 \times \frac{3}{16} \quad \text{HSS } 6 \times 2 \times \frac{1}{4}$$

Option 3:

$$M_u = 67063.253625 \text{ lb}\cdot\text{ft} = \frac{804759.0435 \text{ lb}\cdot\text{in}}{0.9} = 894176.715 \text{ lb}\cdot\text{in}$$

$$Z_{reqd} = 19.4386 \text{ in}^3$$

HSS 7x5x1/2  
HSS 8x3x1/2  
HSS 8x4x1/2  
HSS 8x6x3/16

?



$$R = \frac{w}{2l} (l+a)^2 = \frac{45}{2(10)} (13')^2 = 380.25 \text{ p/f}$$

$$M = \frac{wl^2}{8} = \frac{128334.375 \text{ lb}\cdot\text{in}}{1250 \text{ psi}} \cdot \frac{102.6675 \text{ in}^3}{31.64} = 3.2$$

$$\therefore 3.24$$



$$R_u = \frac{82}{2l} (l+a)^2 = 692.9 \quad M_u = 233853.75 \text{ lb}\cdot\text{in} \quad Z = 5.084$$

$$\text{HSS } 6 \times 4 \times 3/16 \quad \text{HSS } 6 \times 3 \times 3/16$$

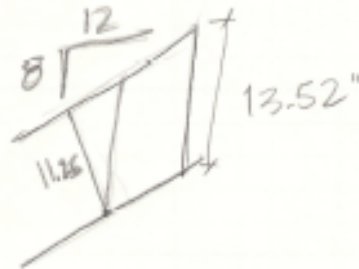


ROOF RIDGE:  $l = 20'$

$$DL = 20 \text{ psf}$$

$$LL = \frac{16 \text{ psf}}{36 \text{ psf}}$$

$$W = 360 \text{ plf}$$



$$M = \frac{(360 \text{ plf})(20')^2}{8} = 18000 \text{ lb}\cdot\text{ft} = 216000 \text{ lb}\cdot\text{in}$$

$$F_b = 2900 \text{ psi} \quad (\text{TRY } 14'' \text{ Deep LVL})$$

$$f_b' = (2900)(12/14)^{1/4} = 2851$$

$$S_{\text{req'd}} = \frac{216000 \text{ lb}\cdot\text{in}}{2851 \text{ psi}} = 75.76 \text{ in}^3 \quad h_{\text{req'd}} = ?$$

$$S = \frac{bh^2}{6} \quad h_{\text{req'd}} = 11.4 \text{ in}$$

$$W_u = (20 \text{ psf})(10') = 200 \text{ psf} / 12'' = 16.667 \text{ pli}$$

$$W_{LL} = (16 \text{ psf})(10') = 160 \text{ plf} / 12'' = 13.333 \text{ pli}$$

$$\Delta_{DL} = \frac{l}{240} = \frac{(20' \cdot 12'')}{240} = 1'' \quad \Delta_{LL} = \frac{(240'')}{360} = 0.6667''$$

$$(I_{\text{req'd}})_{DL} = \frac{(5)(16.667)(240'')^4}{(384)(2000000)(1)} = 360 \text{ in}^4 \quad h_{\text{req'd}} = ?$$

$$h_{\text{req'd}} = 10.73 \text{ in}$$

$$(I_{\text{req'd}})_{LL} = \frac{(5)(13.333)(240'')^4}{(384)(2000000)(0.6667)} = 432 \text{ in}^4 \quad h_{\text{req'd}} = 11.4 \text{ in}$$

USE (2)  $1\frac{3}{4}'' \times 14''$  LVL trimmed down to

\* Roof joist  $R_x \approx 450 \text{ lbs}$

USE LSSU210 (Slopeable joist hanger)

- Allowable  $\downarrow = 1110 \text{ lbs}$

- Allowable  $\uparrow = 730 \text{ lbs}$

$$\text{RIDGE: } (R_x)_{\text{ext.}} = 3600 \quad (R_z)_{\text{int.}} = 5400$$

# LOFT CONNECTIONS:

$$R_x = 481.25 \text{ lbs}$$

@ Girder use LUS26

AT STUDS:

TRY (2)  $\frac{1}{2}" \phi$  Lag screws  $Z = 250 \text{ lbs}$

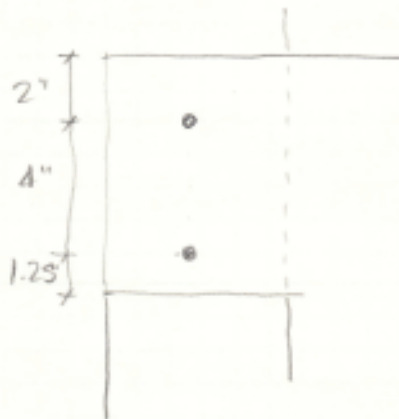
$$Z' = Z C_D C_M C_t C_g C_A C_{eq}$$

$$Z = 250 \quad C_D = 1.0 \quad C_M = 1.0 \quad C_t = 1.0$$

$C_g$ :

$$n = 2 \quad E_m = 1,600,000 \quad E_s = 1,400,000$$

$$A_s = (1.5)(5.5) = 8.25 \text{ in}^2 \quad A_m = 10.875 \text{ in}^2$$



$$S = 4"$$

$$\gamma = (180,000)(D^{1.6}) \quad D = 0.5"$$

$$\gamma = 63639.61 \text{ lb/in}$$

$$U = 1 + \gamma \frac{S}{2} \left[ \frac{1}{E_m A_m} + \frac{1}{E_s A_s} \right]$$

$$U = 1.0183$$

$$m = U - \sqrt{U^2 - 1} = 0.825966 \quad R_{ex} = 0.6638$$

$$C_g = \left[ \frac{m(1-m^{2n})}{n[(1-R_{ex}m^n)(1+m) - 1 \cdot m^{2n}]} \right] \left[ \frac{1+R_{ex}}{1-m} \right] = 0.10422 \cdot 9.56 = 0.996375$$

$$C_A = 1.0$$

$$C_{eq} = 1.0 \quad Z' = (250)(0.996375) = (249 \text{ lbs} \times 2) = 498 \text{ lbs}$$

$$498 \text{ lbs} > 481.25 \text{ lbs}$$

## LOFT BEAM:

$$(49 \text{ psf})(5') = 245 \text{ plf} \quad (10') = 2450 \text{ lbs}$$

$$(R_x)_{ext} = 2450 \quad (R_x)_{int} = 2450$$

## COLUMNS:

Interior:  $\frac{2450}{5400} \times 8000 \text{ lbs}$



$$d_1 = 3.5" \quad l_1 = 7.5'$$

$$d_2 = 4.5" \quad l_2 = 15' \quad K_e = 1.0$$

$$l_1/d_1 = 25.714$$

$$l_2/d_2 = \underline{40}$$

$$F_c^* = 850 \text{ psi} \quad E = 1400,000 \quad F_{min} = 510,000$$

$$F_{ce} = \frac{(1.822)(510,000)}{(40)^2} = 262.0125$$

$$C_p = \frac{1 + (F_{ce}/F_c)}{2c} - \sqrt{\left[ \frac{1 + (F_{ce}/F_c)}{2c} \right]^2 - \frac{F_{ce}/F_c}{c}} = 0.28544$$

$$F_c' = 242.628 \text{ psi} \quad P_{all} = 3821.4 \text{ lbs}$$

TRY (1)  $2 \times 4$ 's  $l_2/d_2 = 30$

$$F_{ce} = 465.8 \text{ psi} \quad F_{ce}/F_c = 0.548 \quad C_p = 0.466$$

$$F_c' = 396.5 \quad \underline{P_{all} = 8326 \text{ lbs}} \quad \text{OKAY}$$

BCLR by Simpson @ base

## Exterior:

Try (3)  $2 \times 6$ 's  $P = 2450 + 3600 = 6050 = \underline{6100}$

$$l_1/d_1 = (8')(12)/5.5" = 17.5$$

- continuously supported in other direction with sheathing

USE (1)  $2 \times 6$ 's until wind loading calculations

## WIND LOADS:

Basic Wind speed,  $V = 90$  mph $K_1 = 0.85$  (MWFRS & Components & Cladding)Building Category II,  $I = 1.0$ 

Surface Roughness B, Exposure Category B

 $G_{CF}$ : (8:12 pitch =  $33.69^\circ$ )

|    |       |
|----|-------|
| 1  | 0.56  |
| 2  | 0.21  |
| 3  | -0.43 |
| 4  | -0.37 |
| 5  | -0.45 |
| 6  | -0.45 |
| 1E | 0.69  |
| 2E | 0.27  |
| 3E | -0.53 |
| 4E | -0.48 |

Wall = 12'

Roof =  $\frac{6.667}{18.667}$ 

\* 16.44' to mean roof height

• LOW-RISE BLDG.

 $K_{zt} = 1.0$ 

ASSUME FLEXIBLE

$$G_f = 0.925 \left( \frac{1 + 1.7 I_z \sqrt{g_a^2 Q^2 + g_v^2 P^2}}{1 + 1.7 g_v I_z} \right)$$

$$I_z = \left( \frac{33}{2} \right)^{1/4} \quad \bar{z} = z_{min} = 30' \quad C = 0.3 \quad I_z = 0.30480356$$

$$T_a = C_t h_n^x \quad h_n = 20.667' \quad x = 0.75 \quad C_t = 0.02 \quad T_a = 0.19386$$

$$\text{Frequency} = 1/T_a = 5.2 = n, \quad g_a = g_v = 3.4$$

$$g_R = \sqrt{2 \ln(3600 n_s)} + \frac{0.577}{\sqrt{2 \ln(3600 n_s)}} = 4.5657$$

$$\bar{V}_z = \left( \frac{\bar{z}}{30} \right)^{\alpha} V \left( \frac{88}{60} \right) = 0.45 \left( \frac{30}{30} \right)^{1/4} (90) \left( \frac{88}{60} \right) = 58$$

$$B = 30' \quad L = 20'$$

$$R_h (\eta = 1.4628) = 0.4625 \quad R_B (\eta = 12.3724) = 0.07156$$

$$R_L (\eta = 27.6138) = 0.03556$$

$$L_z = L \left( \frac{\bar{z}}{30} \right)^{\frac{1}{3}} = 320 \left( \frac{30}{30} \right)^{\frac{1}{3}} = 309.99$$

$$N_1 = \frac{n_1 L_z}{\bar{z}} = \frac{(5.2)(309.99)}{30} = 53.73$$

$$R_n = \frac{7.47(N_1)}{(1 + 10.3N_1)^{\frac{1}{10}}} = 0.01073$$

$$R =$$

### RIGID STRUCTURE

$$G = 0.925 \left( \frac{(1 + 1.7g_a I_z Q)}{1 + 1.7g_v I_z} \right) \quad g_a = g_v = 3.4 \quad I_z = 0.3048$$

$$L_z = 309.99 \quad B = 20' \quad h = 20.667' \quad 18.667'$$

$$Q = \sqrt{\frac{1}{1 + 0.63 \left( \frac{B+h}{L_z} \right)^{0.63}}} = 0.91239 \quad 0.9143$$

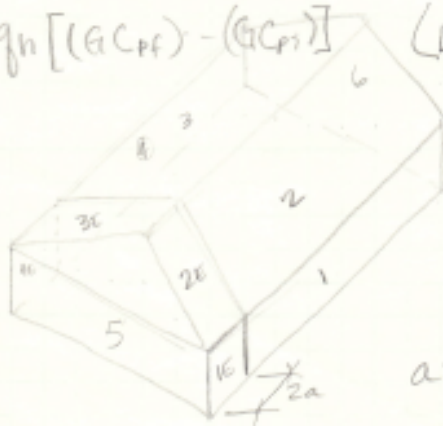
$$G = 0.925 \left( \frac{[1 + (1.7)(3.4)(0.3048)(0.91239)]}{[1 + (1.7)(3.4)(0.3048)]} \right) = 0.87444$$

$$g_z = 0.00256 K_z K_{zt} K_d V^2 I \quad K_z = 0.7$$

$$g_h = 0.00256 (1.7)(1)(1.85)(90)^2(1) = 12.338 \text{ psf}$$

$$GC_{pi} = \pm 0.18$$

$$P = q_h [(GC_{pf}) - (GC_{pi})] \quad (\text{Low-Rise})$$



TRANSVERSE

$$a = (1.1)(20') = 2'$$

$$(1.4)(18.444') = 7.3778'$$

$$(1.04)(20') = 0.8'$$

$$\textcircled{3''} \quad 2a = 6'$$

$$1: p = 12.34(0.56 + 0.18) = 9.1316 \text{ psf}$$

$$w = \left(\frac{12'}{34'}\right)(9.1316 \text{ psf}) = 310.5 \text{ plf} \Rightarrow 109.6 \text{ plf}$$

$$F_1 = (310.5 \text{ plf})(12') = 3726 \text{ lbs}$$

$$2: p = 12.34(0.21 + 0.18) = 4.8126 \text{ psf}$$

$$w = (4.8126 \text{ psf})(12.0185') = 57.84 \text{ plf}$$



$$w_x = \left(\frac{12}{14.4222}\right)(57.84) = 48.126 \text{ plf}$$

$$w_y = \left(\frac{8}{14.4222}\right)(57.84) = 32.084 \text{ plf}$$

$$3: p = 12.34(-0.43 - 0.18) = -7.5274 \text{ psf}$$

$$w = (-7.5274 \text{ psf})(12.0185') = -90.468 \text{ plf}$$

$$w_x = -75.274 \text{ plf} \quad w_y = 50.183 \text{ plf} \uparrow$$

$$4: p = 12.34(-0.31 - 0.18) = -6.787 \text{ psf}$$

$$w = (12')(-6.787 \text{ psf}) = -81.444 \text{ plf}$$

$$5: p = 12.34(-0.45 - 0.18) = -7.7742 \text{ psf}$$

$$w = (16.444')(-7.7742 \text{ psf}) = -127.8424 \text{ plf}$$

$$6: \text{ same as } (5) \quad p = -7.7742 \text{ psf} \quad w = -127.8424 \text{ plf}$$

$$1E: p = 12.34(0.69 + 0.18) = 10.7358 \text{ psf}$$

$$w = (12')(-10.7358 \text{ psf}) = 128.8296 \text{ plf}$$

$$2E: p = 12.34(0.27 + 0.18) = 5.553 \text{ psf}$$

$$w = (5.553 \text{ psf})(12.0185') = 66.74 \text{ plf}$$

$$w_x = 55.53 \text{ plf} \quad w_y = 37.02 \text{ plf}$$

$$3E: p = 12.34(-0.53 - 0.18) = -8.7614 \text{ psf}$$

$$w = -105.3 \text{ plf} \quad w_x = -87.614 \text{ plf} \quad w_y = -58.41 \text{ plf} \uparrow$$

$$4E: p = 12.34(-0.48 - 0.18) = -8.1444 \text{ psf}$$

$$W = (12')(-8.1444 \text{ psf}) = -97.7328 \text{ plf}$$

LONGITUDINAL:

$$1: p = 9.1316 \text{ psf}$$

$$W = (9.1316 \text{ psf})(17') = 155.24 \text{ plf}$$

$$2: p = 4.8126 \text{ psf}$$

$$W = (20')(4.8126 \text{ psf}) = 96.252 \text{ plf}$$

$$W_x = 80.0865 \text{ plf} \quad W_y = 53.4 \text{ plf}$$

$$3: p = -7.5274 \text{ psf}$$

$$W = -150.548$$

$$W_x = -125.26 \text{ plf} \quad W_y = 83.51 \text{ plf}$$

$$4: p = -6.781 \text{ psf}$$

$$W = -115.38 \text{ plf}$$

$$5: p = -7.7742 \text{ psf}$$

$$W = (12')(-7.7742) = -93.3 \text{ plf}$$

$$6: \text{ same as } (5) \quad p = -7.7742 \text{ psf} \quad W = -93.3 \text{ plf}$$

$$1E: p = 10.7358 \text{ psf}$$

$$W = 161.037 \text{ plf}$$

$$2E: p = 5.553 \text{ psf}$$

$$W = (6')(5.553 \text{ psf}) = 33.318 \text{ plf}$$

$$W_x = 27.72 \text{ plf} \quad W_y = 18.48 \text{ plf}$$

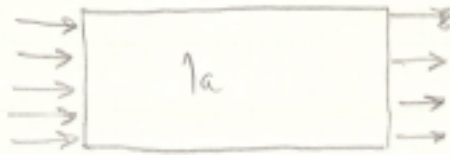
$$3E: p = -8.7614 \text{ psf}$$

$$W = -52.5684 \text{ plf} \quad W_x = -43.74 \text{ plf} \quad W_y = -29.16 \text{ plf}$$

$$4E: p = -8.1444 \text{ psf}$$

$$W = (-8.1444 \text{ psf})(15') = 122.166 \text{ plf}$$

CASE 1:



1a:

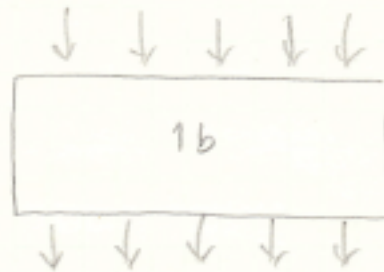
$$(155.24 \text{ ptf})(14') = 2173.36$$

$$(161.037 \text{ ptf})(6') = 966.222$$

$$(115.38 \text{ ptf})(14') = 1615.32$$

$$(122.146 \text{ ptf})(6') = \underline{732.996}$$

$$\text{TOT} = 5487.896 \text{ lbs}$$



$$1b: (109.6 \text{ ptf})(24') = 2629.7$$

$$(48.126 \text{ ptf})(24') = 1155.024$$

$$(75.274 \text{ ptf})(24') = 1806.576$$

$$(81.444 \text{ ptf})(24') = 1954.656$$

$$(128.8296)(6') = 772.98$$

$$(55.53)(6') = 333.18$$

$$(87.614)(6') = 525.684$$

$$(97.7328)(6') = \underline{586.3968}$$

$$9764.3968$$

SHEAR WALLS:

$\approx 5000 \text{ lbs per side}$

$$w = 5000 \text{ lbs} / 12' = 416.667 \text{ ptf}$$

$$M = \frac{wl^2}{8} = \frac{(416.667)(12')^2}{8} = 7500 \text{ lb-ft} = 90,000 \text{ lb-in}$$

### Components $\geq$ Cladding

$$p = q_h [(GC_p) - (GC_{pi})]$$

$$GC_{pi} = \pm 0.18$$

$$a = 3'$$

$$\text{Zone } 5_L: (9')(3') = 27 \text{ ft}^2$$

$$-1.3 \text{ } \pm \text{ } +.95$$

$$5_T: (12')(3') = 36 \text{ ft}^2$$

$$-1.2 \text{ } \pm \text{ } +.9$$

$$\text{Zone } 4_L: (24')(9') = 216 \text{ ft}^2$$

$$-0.86 \text{ } \pm \text{ } +0.78$$

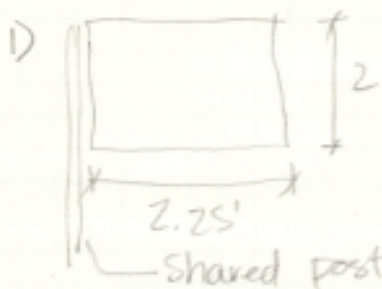
$$4_T: (14')(18') = 252 \text{ ft}^2$$

$$-0.85 \text{ } \pm \text{ } +0.78$$

$$q_h = 12.338 \text{ psf} (-1.3 - 0.18) = 18.26 \text{ (USE FOR ZONE 5)}$$

$$q_h = 12.338 \text{ psf} (-0.86 - 0.18) = 12.83 \text{ (USE FOR ZONE 4)}$$

HEADERS:



$$w_y = (18.26 \text{ psf})(2) = 36.52 \text{ plf}$$

$$w_x = \overset{\text{wall}}{(12 \text{ psf})(4')} = 48 \text{ plf}$$

$$M_x = 364.5 \text{ lb}\cdot\text{in}$$

$$M_y = 277.32 \text{ lb}\cdot\text{in}$$

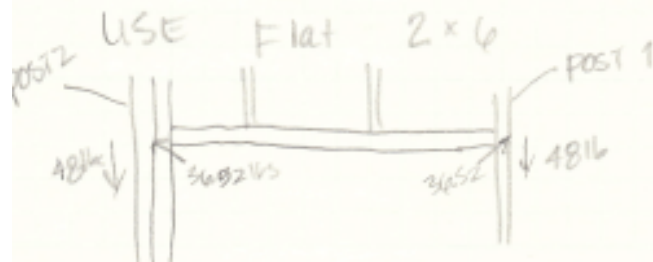
TRY (2) 2x6

$$- 2 \times 6 \quad S_x = 7.563 \quad S_y = 2.063$$

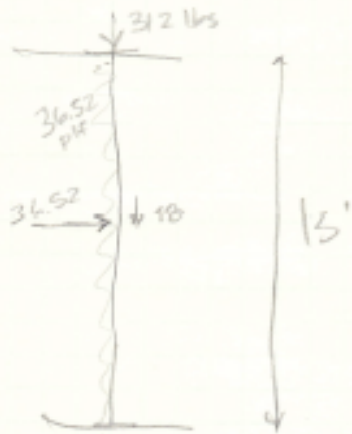
$$I_x = 20.8 \quad I_y = 1.547$$

$$M_{x_{all}} = (1250)(7.563) = 9453.75 \text{ lb}\cdot\text{in}$$

$$M_{y_{all}} = (1250)(1.1)(2.063) = 2836.125 \text{ lb}\cdot\text{in}$$



POST 1:  $l = 13'$



$$P_{\text{TOT}} = 360$$

$$M = 9257.82 + 1424.28 = 10682.1 \text{ lb}\cdot\text{ft}$$

## **Appendix C: Integrated Design Team Survey Results**

Nick

Pg 1/2

## Survey for New Norris House

### 1. What is your discipline?

My discipline is Architecture and Interior Design.

### 2. What were your responsibilities this semester?

My responsibilities to the Norris House team during the Fall '09 semester were to research and implement the LEED for Homes rating system into the Norris House project. It was my responsibility to see that the sustainable features developed by the design team were in compliance with accepted LEED strategies and to coordinate a LEED plan that would earn the project as many points as possible. Our goal was to be the first LEED Platinum home in East Tennessee. After evaluating the home's features at the beginning of the semester, the project was soundly in the LEED Silver category. I worked with the various disciplines—Architecture, Structural Engineering, Civil/Waste-water, MEP, and Landscape Architecture—throughout the semester to develop additional strategies that would result in a higher LEED rating.

### 3. As an integrated design team, please describe how you felt your responsibilities differed from what they would have been in a traditional design setting (not an integrated design team).

Decisions were made faster among the integrated team. Communication was streamlined, and the possibility of innovation through our collaborative efforts was greatly enhanced. Regular meetings with the whole group allowed us to brainstorm together, and to keep the common goal of building an innovative and efficient demonstration house in mind at all times. From my experiences of working on projects as a part of a firm that provides architectural services only, the integrated design team for the Norris House project resulted in a more innovative project—questioning the limitations of traditional design and construction, including construction techniques and the use of materials. My responsibilities as member of the integrated team were less focused on a preconceived result.

### 3. Describe your design process

I try to begin the design process by identifying a set of contextual issues that affect the site, and ultimately the design. When looking at architecture, I find most compelling buildings that are a response to a set of factors that are operating at the site. These factors can be historical/cultural, climatic, ecological, and also economic in origin.

### 4. What have you learned from the course (and what was the most important thing you learned)?

I learned more about framing techniques, about MEP issues, and thoroughly detailing out a residential wood framed project. I also learned more about all the parties involved in the realization of a project—from the integrated design team, contractors, material suppliers, codes/ regulatory officials. The work to cost and budget the materials, and the formation of the spec binder was more labor intensive than I realized it would be for such a small home.

### 5. What have you learned about other disciplines and what more would you like to have learned or understood about what the other disciplines do?

pg 2/2

I learned more about the civil/wastewater strategies and the way civil engineers approach a project as compared to the Architects.

I would like to have learned more about the Landscape Architectural component of the design. During the Fall 09 term, many of our landscape features were determined by our rainwater harvesting and civil/wastewater treatment strategies, and the design of the landscape seemed to be secondary to many of the systems inside the home. Decisions about specific plants, trees, grasses were not discussed during Fall 09, and were postponed until the Spring '10 semester after the home's design was finalized.

6. Do you feel the class has more of a practical benefit or an academic benefit? Why?

The project lent more of an academic benefit, than a practical. Although there is, for sure, a practical benefit since the collaborative effort resulted in an innovative and more sustainable home for the area. The academic benefit was stronger since the integrated design team is more similar to professional practice.

7. Would you take another integrated design course and would you suggest others take it? Why or why not?

If I were not graduating, I would for sure take another integrated design course, because I think it more adequately prepares students for professional practice. It also helps to develop better communication skills since each discipline seems to have its own vocabulary—verbally and visually.

8. What improvements can be made to the course?

It would have been nice to have a bit more studio space last term to pin up and to have a large table where we could all sit and collaborate during team meetings.

9. Do you feel that integrated design teams are an efficient way to go about the design process especially as it pertains to sustainable/green design (despite the fact it took us 6 weeks to start working together- imagine we had a quicker start)? Why and how does working together make sustainability more of a reality (more attainable)?

The integrated team is critical to the proliferation of sustainability in the built environment, I believe. Sustainable strategies are not applied, they are integral themselves—so a project must begin with all the disciplines coming together at the start of the project. Integrated design teams are more efficient at producing sustainable architecture.

10. Any other comments or suggestions.....

Thank you everyone for taking a chance on this course and helping me with my thesis by completing this survey.

Survey for New Norris House

Hanya  
Senno

pg 1/2

1. What is your discipline?

Civil Engineering (most interested in Environmental)

2. What were your responsibilities this semester?

Look into waste water pretreatment options and design plan

Help with rainwater collection system

Greywater discharge: design plan for use as irrigation system

3. As an integrated design team, please describe how you felt your responsibilities differed from what they would have been in a traditional design setting (not an integrated design team).

Communication amongst the different disciplines was the biggest difference. This project required constant updating, feedback, and input from all the disciplines.

4. Describe your design process.

My design process first started with background research on waste water pretreatment and greywater discharge. From there, LEED criteria was also taken into consideration along with site constraints. Finally, the greywater discharge system was designed and load calculations were used to verify design parameters. The pretreatment for waste water was only taken to a conceptual level as it did not seem feasible for our project.

5. What have you learned from the course (and what was the most important thing you learned)?

I've learned more on rainwater recycling, LEED for Homes accreditation, and waste water pretreatment and overall treatment through ecological engineering.

The most important thing I learned however was time management and more about the group dynamic of different disciplines and personalities.

10/12

6. What have you learned about other disciplines and what more would you like to have learned or understood about what the other disciplines do?

I've learned that the architect's role is much more involved than I originally thought and that the structural's role requires a lot of communication with the architects and several runs of calculations for stability. I would have liked to learn all of this on a more detailed level.

7. Do you feel the class has more of a practical benefit or an academic benefit? Why?

I personally feel like this class was a practical benefit because it presented a huge scheduling challenge and therefore required me to balance my time better and learn as much as possible in a condensed amount of time.

8. Would you take another integrated design course and would you suggest others take it? Why or why not?

Probably not because of my future schedule.

I would suggest it to other people only if they had time and were interested in design work for their career.

9. What improvements can be made to the course?

More structured deadlines and class meeting times.

10. Do you feel that integrated design teams are an efficient way to go about the design process especially as it pertains to sustainable/green design (despite the fact it took us 6 weeks to start working together- imagine we had a quicker start)? Why and how does working together make sustainability more of a reality (more attainable)?

It makes it more attainable because sustainability encompasses several aspects that fit into multiple disciplines. Working with architects, engineers, and environmental science majors helps to figure out different parts of sustainability so that the total design can incorporate the whole aspect of sustainable/green design.

11. Any other comments or suggestions.....

Survey for New Norris House

Andy  
Pg 1/2

1. What is your discipline?

Architecture

2. What were your responsibilities this semester?

Specifications, Research, Detailing, Communication with Permit Office

3. As an integrated design team, please describe how you felt your responsibilities differed from what they would have been in a traditional design setting (not an integrated design team).

I was given a more precise role in the group, which allowed me to focus on a few specific topics. However, because the responsibilities of the various participants overlapped to a degree, it allowed for the opportunity to become involved in processes and decisions that I would not have been exposed to otherwise.

4. Describe your design process

My design process focused on the application of significant amounts of research to inform decisions that would allow the house to succeed on a very pragmatic and culturally relevant scale. The design of the various integrated systems was a collaborative process that allowed all the members of the team to integrate themselves into the final solution.

5. What have you learned from the course (and what was the most important thing you learned)?

I've learned the multiplicity of scales and topics one must work at within a group in order for the project to be integrated, well designed, and successful.

6. What have you learned about other disciplines and what more would you like to have learned or understood about what the other disciplines do?

I have learned an incredible amount regarding the responsibilities, processes, and skill sets of engineers, environmentalists, and even architects. I would have liked to have sat in on some discussions concerning contracts, permits, and other legal issues.

pg 2/2

7. Do you feel the class has more of a practical benefit or an academic benefit? Why?

This class absolutely has more practical benefit than a standard academic course, given the fact that the goal of the project was to cross the chasm from academia to professional work. At the end of the semester, we were able to work within an academic framework and design a house that meets or exceeds the requirements of practical realization.

8. Would you take another integrated design course and would you suggest others take it? Why or why not?

I would absolutely take another course in integrated design, and would almost wonder why more of our classes are not arranged in this manner. This is one of the best experiences I've had, including professional internships, to prepare me for a successful career in the design and construction industry.

9. What improvements can be made to the course?

A greater transparency between disciplines should be emphasized, so that each team member has a greater understanding of not only the responsibility of their fellow teammates, but also the process and theory that accompanied their tasks.

10. Do you feel that integrated design teams are an efficient way to go about the design process especially as it pertains to sustainable/green design (despite the fact it took us 6 weeks to start working together- imagine we had a quicker start)? Why and how does working together make sustainability more of a reality (more attainable)?

The integrated design team is an extremely efficient approach to the design process, in that it enhanced the communication, integration, and overall design of the project. It also seemed to eliminate much of the confusion and delays normally experienced with a project of this type. As for the reality of sustainability, an integrated design will inherently focus on aspects that traverse the continuum of a design project, creating opportunities for efficiency and precision.

11. Any other comments or suggestions.....

Survey for New Norris House

Lew;

pg 1/2

1. What is your discipline?

architecture

2. What were your responsibilities this semester?

schematic design, design development, energy analysis, presentation

3. As an integrated design team, please describe how you felt your responsibilities differed from what they would have been in a traditional design setting (not an integrated design team).

My responsibilities increased as I had to provide answers to students from other disciplines. In order to allow them to complete their tasks, they needed information from me. So while completing tasks that were normal in my process, I also had to communicate these decisions to others in order to confirm their practicality. This does, however, make the entire process more fluent.

4. Describe your design process

In this project, the design process was very much about defining the word "normal." Based on found writings, our project sought to integrate itself within a very vernacular and powerful community through the process of becoming "normal." My literal process includes sketching, modeling, explaining conceptual ideas, computer aided drafting, and many presentations.

5. What have you learned from the course (and what was the most important thing you learned)?

I have learned much about the integrated experience of multiple disciplines, the pressures of team projects increase one's efficiency. I have also learned much about sustainable practices and methods (passive and active) and how these approaches are achieved in the combination of multiple disciplines.

6. What have you learned about other disciplines and what more would you like to have learned or understood about what the other disciplines do?

While I am somewhat familiar with the tasks that engineers do, I was somewhat unfamiliar with environmental science. This project allowed me to understand how they can improve the design process.

7. Do you feel the class has more of a practical benefit or an academic benefit? Why?

I think that it is a balance. I think as students of design, it is a more practical exercise. Given the real constraints of Norris, it was necessary to understand out limitations and achieve a design that took advantage of those limitations. However, it is also important to realize the greater implications of the project. Our concept, titled UPLoad, could inform future design projects and their understanding of sustainability.

Pg 2 1/2

8. Would you take another integrated design course and would you suggest others take it? Why or why not?

I feel that the opportunity to work with engineers and environmental science students at this level gives me a head start in understanding how "building" really works. Others who have the opportunity will most likely find the same results.

9. What improvements can be made to the course?

As this course and similar future courses progress, it will be necessary to improve communication techniques so that communication is more efficient.

10. Do you feel that integrated design teams are an efficient way to go about the design process especially as it pertains to sustainable/green design (despite the fact it took us 6 weeks to start working together- imagine we had a quicker start)? Why and how does working together make sustainability more of a reality (more attainable)?

Sustainability's greatest challenge is within the communication of the multiple disciplines within building and construction. While it may not always be efficient due to the differences of communication among the different disciplines, it is important to design with an integrated process. Sustainability is only possible through the communication as a result of the integrated design process.

11. Any other comments or suggestions.....

none.

Thank you everyone for taking a chance on this course and helping me with my thesis by completing this survey.

Daniel

pg 1/2

1. What is your discipline? Architecture
2. What were your responsibilities this semester? Designer, coordinator, detailed drawings, cross discipline integration
3. As an integrated design team, please describe how you felt your responsibilities differed from what they would have been in a traditional design setting (not an integrated design team).

Generally more time was spent in design sessions with team members from various disciplines that allowed for more overlap and a smoother process with less back tracking.

4. Describe your design process

Worked with architecture students daily and met with environmental science and engineering two to three times a week on average. A give and take of drawing and going back and forth discussing issues that effected various parts of the project.

5. What have you learned from the course (and what was the most important thing you learned)?

I learned most about the pragmatic issues involved in integrated sustainable design and the need for a close working relationship between various disciplines involved in LEED projects in order to secure a positive outcome to a project.

6. What have you learned about other disciplines and what more would you like to have learned or understood about what the other disciplines do?

How they work, medium of expression ie. Drawing, modeling and way by which processes can be integrated more effectively

7. Do you feel the class has more of a practical benefit or an academic benefit? Why?

I think both. Practical for obvious reasons in that it is in line with the realities of achieving a LEED accredited project in the "real world" and academically because it brings together colleges that are typically at odds with one another

(architecture and engineering) and creates an environment in which collaboration can happen.

pg 2/2

8. Would you take another integrated design course and would you suggest others take it? Why or why not?

Yes. It is beneficially for one's career and personal development

9. What improvements can be made to the course?

More involvement from other disciplines, wider range of input and more drawing and modeling and design awareness from engineering

10. Do you feel that integrated design teams are an efficient way to go about the design process especially as it pertains to sustainable/green design (despite the fact it took us 6 weeks to start working together- imagine we had a quicker start)? Why and how does working together make sustainability more of a reality (more attainable)?

Generally yes. Its like anything though there is always a balance between working on your own and working in groups. Groups reach a critical mass beyond which they are ineffective. So it is a game of doing working and knowing when its time to speak with others and having the platform for that to happen quickly and spontaneously.

11. Any other comments or suggestions.....

It seems that it was a successful endeavor and lead to a better outcome than if architecture would have worked alone on the project.

Thank you everyone for taking a chance on this course and helping me with my thesis by completing this survey.

Survey for New Norris House

Matt

pg 1/2

1. What is your discipline?

*Civil Engineering*

2. What were your responsibilities this semester?

*Site Planning, Water Reuse and Treatment, Surveying and Permitting*

3. As an integrated design team, please describe how you felt your responsibilities differed from what they would have been in a traditional design setting (not an integrated design team).

*I was asked questions about plumbing which usually do not fall upon the civil engineer.*

4. Describe your design process.

*Find out codes and meet them. Be as efficient as possible. Visit other examples if applicable. Site visits and surveys. Brainstorm and then preliminary design. Synthesis and rework conflicts. Boil down final results.*

5. What have you learned from the course (and what was the most important thing you learned)?

*LEED Criteria*

6. What have you learned about other disciplines and what more would you like to have learned or understood about what the other disciplines do?

*Architecture – the Jeff Christian Zero Energy Concept*

7. Do you feel the class has more of a practical benefit or an academic benefit? Why?

*Practical because of real world experience and application.*

8. Would you take another integrated design course and would you suggest others take it? Why or why not?

*Yes. Experience is important. 75% of your working career will be spent networking, and collaborating with business associates and coworkers. School does not prepare you for the bulk of what you will be doing when you get out there.*

pg 2/2

9. What improvements can be made to the course?

*The course needs to be better marketed to engineering students by engineering professors/faculty. This project would make a great senior thesis class.*

10. Do you feel that integrated design teams are an efficient way to go about the design process especially as it pertains to sustainable/green design (despite the fact it took us 6 weeks to start working together- imagine we had a quicker start)? Why and how does working together make sustainability more of a reality (more attainable)?

*That is just a level of experience and maturity that comes with age and has nothing to do with the fact that the teams were integrated. If money and jobs were at stake instead of grades, it would have been taken more seriously by most.*

11. Any other comments or suggestions.....

Thank you everyone for taking a chance on this course and helping me with my thesis by completing this survey.

Survey for New Norris House

Ryan  
pg 1/2

1. What is your discipline? Environmental Studies
2. What were your responsibilities this semester? I was assigned the task, along with Nick Richardson, of navigating the LEED for homes manual to figure out which credits we could earn for our project, and to work with each of the teams to assure the implementation of the strategies described in the LEED manual.
3. As an integrated design team, please describe how you felt your responsibilities differed from what they would have been in a traditional design setting (not an integrated design team). Not being in an architecture-related field, I am not sure exactly what occurs in "traditional design settings." Also, given my position in environmental studies, it seems likely to me that my only possible role in the project would have involved making sure the LEED manual was followed either at certain key increments throughout the project or upon the completion of the project. It doesn't seem realistic that an architecture firm employing a more traditional style of work would involve (pay) someone with my background for the entire length of the project. However, I would imagine that trying to keep up with all of the LEED credits would be incredibly difficult without someone there throughout the process to monitor progress as decisions are made by the building designers.
4. Describe your design process- NA
5. What have you learned from the course (and what was the most important thing you learned)? In addition to learning a great deal about the LEED certification system and process, this project also introduced me to several new strategies for making a home more sustainable of which I was not previously aware (storm water garden, ecomachines for sewage, etc.). I also learned a lot about working in a design process and the necessity of communication amongst team members when working on a project of this degree of complexity.
6. What have you learned about other disciplines and what more would you like to have learned or understood about what the other disciplines do? Before working on this project, I had no clue how architects and engineers go about building a structure. Obviously I knew they used drawings and things to plan it out carefully but I was very impressed by all the ways of modeling a house and even a neighborhood. I also didn't know the degree to which calculations must be made for every square inch of the house. I would have liked to learn more about the specific plants that were chosen to go on the site, especially in the rain garden.

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7. Do you feel the class has more of a practical benefit or an academic benefit? Why? I felt like the knowledge I gained from working on this project was more of the practical type. Going through the process of designing and ultimately building a real house was much more in depth of a learning experience than simply studying green design would have been.
8. Would you take another integrated design course and would you suggest others take it? Why or why not? Yes, I enjoyed my experience in this class and would recommend others to take an integrated design course. Taking a class that involves so many disciplines is guaranteed to be a beneficial experience for all involved, regardless of their background.
9. What improvements can be made to the course? I'm not sure exactly how to go about it, but integrating the process more would be beneficial to all. I guess that effort would be aided by putting peoples work online and making every drawing, calculation, etc available to everyone as soon as they are performed.
10. Do you feel that integrated design teams are an efficient way to go about the design process especially as it pertains to sustainable/green design (despite the fact it took us 6 weeks to start working together- imagine we had a quicker start)? Why and how does working together make sustainability more of a reality (more attainable)? Yes, working with a group in an integrated way seems to me to be the only way to design something that is remotely complex without a huge number of setbacks. Working together makes sustainability more attainable by integrating all of the systems within the project (necessary for energy and water efficiency), as well as making sure the project meets the needs of a variety of people (based on many people having their own ideas about the project).
11. Any other comments or suggestions.....

Thank you everyone for taking a chance on this course and helping me with my thesis by completing this survey.

## **Vita**

Mary Elizabeth French was born March 25, 1979, in Knoxville, TN. She and her older brother Martin Blake were raised in Knoxville by their two parents Elizabeth Jane and Robert Clayton French. She graduated from Knoxville Central High School in May of 1997 after which she began attending The University of Tennessee, Knoxville, (UTK), majoring in pre-veterinarian studies. After two years studying animal sciences, her love for mathematics and structures eventually led her to civil engineering. She worked for a structural engineering firm, attended school, and graduated in civil engineering from the University of Tennessee, Knoxville in December of 2008. Her graduate career in civil engineering with a concentration in structural engineering began immediately after at UTK, where she will be graduating in May of 2010.