IMPACTS OF SELECTED SUSTAINABLE BUILDING COMPONENTS ON CONSTRUCTION WORKER SAFETY

By

BRENT C. OLSON

A THESIS PRESENTED TO THE GRADUATE SCHOOL
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To my mom and step dad – For all the love and support you have provided throughout my life

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I would like to thank my family and friends for always being by my side during tough times. I would also like to thank Dr. Jimmie Hinze and Dr. James Sullivan for their expertise and dedication to allow me to complete this research. These people have made it possible for me to excel in my studies and accomplish my goals.

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Brent C. Olson

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Chair: Jimmie W. Hinze
Co chair: James G. Sullivan
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With any type of construction activity that is performed there are always associated health and safety hazards. Specifically, these safety and health hazards are directly related to constructing specific components of a building. With the built environment becoming sustainable, conventional building components are being substituted with components that are more energy-efficient and have reduced impacts on the environment. There is a limited amount of information available regarding the safety impacts associated with installing specific sustainable building components. This study focused on identifying the safety hazards associated with selected components that are decidedly different in their mode of installation, namely constructing insulated concrete forms (ICF), green roofs, photovoltaic systems, and non-petroleum-based roofing systems. These systems were examined to determine whether there is a negative or positive impact of the sustainable products on worker safety.

Eleven interviews conducted with experts familiar with the selected sustainable building components. The interviews identified the primary health and safety hazards

associated with constructing the sustainable components and conventional components. The results of this study suggest that there is a negative impact on worker safety with regards to photovoltaic system installation and a positive impact with regards to ICF, green roof, and non-petroleum-based roofing construction.

CHAPTER 1
INTRODUCTION

Background

Sustainable construction is on the verge of becoming an industry standard in the commercial and residential markets. With the rapid growth of sustainable technology, newer and more innovative sustainable building products are frequently being introduced into construction. New building technologies come with a learning curve, in the aspect of function, constructability, and especially safety. It is important that safety is always kept a top priority in construction. This study aims to identify the health and safety hazards associated with sustainable construction activities to help devise safer practices in the future.

Statement of Purpose

This research targets the safety hazards associated with constructing sustainable structures in commercial and residential construction. Although sustainable buildings are becoming a larger part of the built environment, certain components of the building are still relatively new technology. Workers who construct these newer building components are subjected to unfamiliar conditions and safety hazards. The safety hazards associated with constructing conventional building components are more familiar to workers because they have been around longer. This study sought to identify the health and safety hazards associated with constructing specific building components of a sustainable structure. They were then compared to the health and safety hazards associated with constructing the conventional building component to finally conclude if worker safety is positively or negatively impacted with regards to sustainable building component construction.

Research Objectives

The objective of this study is to determine if there is a positive or negative impact on worker safety when constructing sustainable building components by identifying the health and safety hazards associated.

CHAPTER 2
LITERATURE REVIEW

Introduction

Whenever any construction activity is performed there is always some level of risk associated with the safety and health hazards. These construction tasks that are particularly hazardous and materials that pose health risks have been researched to devise safer practices. The following sections describe the sustainable and conventional components and the construction processes involved.

Wall Systems

Insulated Concrete Form

Insulated concrete forms are permanent forms consisting of specific types of insulation that act as the forming material for poured-concrete walls. The most common types of insulation material are high-density expanded polystyrene (EPS) foam and extruded polystyrene (XEPS) foam. These foam blocks are stacked together like building blocks without mortar before the concrete is poured. Once the blocks are assembled, reinforced, and braced, concrete is poured into the intermediate cavity to create an integral wall that is structurally sound. This type of wall system provides insulation properties that exceed those of conventionally-built walls utilizing relatively small amounts of concrete.

There are three types of ICF systems: plank, panel, and block systems. These systems vary in sizes and connection methods. Of the three ICF systems, panel is the largest which is usually 4’ by 8’ in size. This type of system allows for more wall area to be erected in less time but may require more cutting. Connection of panels to one another is done with fasteners such as glue, wire, or plastic channel. Plank systems are usually 8 feet long with narrow planks of foam (Miller, 2005). These pieces of foam are separated by steel or plastic ties embedded in the insulation during the manufacturing process. Block systems consist of units ranging from an 8” x 16” block to a 16” high by 4’ long block, which is the typical unit used. The blocks connect with one another by interlocking along the edge with a tongue and groove configuration, and stack together similar to the concept of children’s Lego blocks (Miller, 2005). Block systems are the most common among the three ICF systems. The three types of ICF systems are represented in Figure 2-1.

The process of constructing an ICF wall begins with marking the perimeter of the wall foundation with a chalk line or string to guide the placement of the foam blocks. Another useful technique to guide the placement of the blocks and to prevent movement is to place temporary braces, such as 2 x 4’s, along the foundation. The 2 x 4’s should be secured to the foundation and will act as a track for the first course of ICF blocks. This is shown in Figure 2-2.

Once the perimeter of the foundation is marked, placement of the foam blocks can occur. Placing the foam blocks should start at the corners and work towards the center of the wall. One course of the ICF blocks should be laid around the entire perimeter. Once the first course of ICF blocks is laid, continue laying blocks in a staggered pattern so that the vertical joints of the blocks do not line up from one course to the next. In addition, concurrently place horizontal rebar every one to two feet, or every other course of block, as required (Miller, 2005). As the forms are stacked, temporary bracing of all walls and openings is needed to keep the ICF walls plumb and square during the concrete pour and to support the weight of the concrete until it achieves the desired strength (Toolbase Services, 2001). Bracing is needed at corners, window and door openings, periodically along the length of the wall, and at the top of the forms. Typical vertical bracing should occur at 6-foot intervals along the wall as well at all window and door openings. Vertical bracing is shown in Figure 2-3.

When encountering a door or window, cut the ICF blocks with a hand saw for the openings. A hand saw or hot knife can be used to cut the blocks for electrical conduit and plumbing space. Openings for windows and doors should be blocked with pressure-treated lumber to contain the concrete when it is poured (Miller, 2005). This is shown in Figure 2-4.

After the ICF blocks are stacked to the specified wall height, place 2 x 4 bracing on the top and secure it to the ICF steel furring strips and the side bracing to keep the forms in place during the pouring of concrete. In addition, seal the joints of the ICF blocks with a foam sealant to help secure the blocks until the concrete is poured. It is essential to properly brace the foam walls to prevent a blow-out from occurring because of the lightweight nature of the ICF blocks. The last step in constructing an ICF wall is to pour the concrete. Pouring the walls should be done in 4-foot increments with a chute or a boom pump truck or per manufacturer’s instructions. After the last increment of concrete is poured and is leveled off to the top of the wall, anchor bolts should be set for the top plate for roof construction. The Job Safety Analysis (JSA) report associated with constructing an ICF wall can be found in Appendix A.

CMU

Concrete masonry units are one of the most widely used construction materials (Spence, 1998). They are molded concrete units used in building construction as an integral part of the structure, as facing for or filler panels between structural elements, and to construct partitions (Simmons, 2007). Concrete masonry units are made of mixtures of portland cement, aggregates, water, and sometimes admixtures. The typical block used for CMU wall construction has a nominal size of 8 inches x 8 inches x 16 inches and weighs around 40 pounds.

Constructing a reinforced CMU block wall first begins with locating the corners of the building. Once the corners are identified, place the CMU blocks so that they are spaced out to determine the extent to which the units must be cut to accommodate the horizontal coursing. This is shown in Figure 2-5.

The corner unit is laid first and carefully placed in its correct position (Simmons, 2007). After several units have been laid, it is then necessary to use a straight edge to verify that the units are in correct alignment. All mortar joints should be 3/8 inch thick except for the first course of units, which should be a thick bed of mortar spread out on the foundation to ensure that there will be enough mortar along the bottom edge of the face shells and web of the block (Simmons, 2007). After the first course has been laid, the corners of the wall are built before the rest of the wall is laid. The corners are started by laying up several courses higher than the center of the wall. Each course should be stepped back by one-half unit. Make sure that after every course is laid the alignment is plumb and level. An example of laying the corners is shown in Figure 2-6.

The next step involves laying blocks between the corners. Before lying any blocks between the corners, a line should be stretched from corner to corner for each course. Then lay the top outside edge of the units to this line to ensure additional courses are plumb and true. Continue laying blocks while placing vertical and horizontal rebar at their specified spacing. Typical horizontal rebar spacing is every other course, or every

16 inches, and vertical rebar placement is every 48 inches. Note that additional rebar is required at all corners and openings. In addition to the vertical rebar placed every 48 inches is a column that must be poured. Every 48 inches concrete must be poured down one of the cavities of a CMU block to form an internal solid column. This column serves to add stability to the wall to support loads and resist shear forces. When encountering window and door openings, blocks will have to be sized correctly to create the specified opening and should be cut with a concrete or masonry saw. Window and door openings additionally require CMU lintel blocks which serve as structural support for superior loads. These lintel blocks are a U-shaped block that gets completely filled with concrete and horizontal rebar.

The CMU blocks are typically constructed in 4-foot lifts, or every 6 courses. CMU block walls do not have the capability to be constructed to unlimited heights on a continuous basis because of stability issues. An important issue with regards to constructing a CMU block wall is the relationships between the masons, plumbers, and electricians. All three of these parties must have good communication with each other in order to stay on schedule and construct the wall as specified. Plumbers and electricians have to run conduit and pipe through the wall and must be on site at all times during wall construction in order to do this at the right time. The Job Safety Analysis (JSA) report associated with constructing a CMU wall can be found in Appendix B.

Roof Systems

Single-Ply

Non-petroleum-based roofing is commonly constructed in the form of a single-ply membrane system. Single-ply roof systems consist of four basic components: insulation, single-ply membrane, flashing, and an adhesive. The insulation provides a stable substrate for the single-ply membrane, which makes up the roof system. The adhesive bonds the ply to the substrate and the flashing provides waterproofing around the roof perimeter, equipment, and projections.

Single-ply membranes are either thermoset or thermoplastic materials. Thermoset materials cure during the manufacturing process and can only be bonded to themselves with an adhesive. Thermoplastic materials do not completely cure during manufacturing and can be welded together, usually with a high-temperature air gun (Spence, 1998). The two commonly used thermoset membranes used are chlorosulfated polyethylene (CSPE) and ethylene propylene diene monomer (EPDM). CPSE cures after it is installed and is resistant to ozone, sunlight, and most chemicals. EPDM membrane is an elastomeric compound produced from propylene, ethylene, and diene monomer and has great resistance to weathering, ultraviolet rays, abrasion, and ozone (Spence, 1998). The two common thermoplastic membrane materials used are polyvinyl chloride (PVC) and styrene-butadiene-styrene (SBS). PVC membranes are made by the polymerization of vinyl chloride monomer, stabilizers, and plasticizers. They are easy to bond, have good resistance to most weather conditions and fire. SBS membranes are produced by blending SBS with high-quality asphalt over a fiberglass mat (Spence, 1998). SBS membranes have good fire resistance and can be applied with hot or cold asphalt or be torched.

Single-ply roofing systems can be applied over almost any existing asphalt or built-up roofs. Single-ply roofs are either loose laid, mechanically fastened, or fully adhered systems. Loose laid and ballasted single-ply systems are independent of the roof deck, which allows the structure to move without affecting the roofing. The loose laid membrane is secured to the underlying deck with ballast, which is most commonly large aggregate, to reduce the tendency of the roof to be uplifted from wind. The membrane is covered with insulation and a protective mat and then covered with the ballast. Loose laid roofing is placed over the substrates with only minimal fastening around the edges and at penetrations. Adjoining sheets should be lapped and bonded together using the roofing manufacturer's sealant (Simmons, 2007). An EPDM single-ply system is shown in Figure 2-7.

Mechanically fastened systems are applied using either penetrating or non-penetrating fasteners. The difference between the two is that the penetrating fasteners pass through the membrane in to the underlying roof deck. Non-penetrating fasteners are anchored to the structural deck, and the membrane is fastened to them using clamps or snap-on caps (Simmons, 2007). Another technique used is metal batten bars are placed at intervals on top of the membrane and then screwed to the deck. The metal batten bars are then covered with plastic cover strips by the use of an adhesive (Spence, 1998). Figure 2-8 shows a mechanically fastened single-ply system with batten strips.

Adhered single-ply systems are either fully adhered or partially adhered. In a fully adhered system, the membrane is completely attached to the underlayment using hot- or cold-applied bitumen, cold-applied adhesives, solvents by heating the back of the membrane, or by pressing self-adhering membrane in-place (Simmons, 2007). In a partially adhered system, the roofing membrane is laid into strips of bitumen, adhesive, or solvent and rolled, or is adhered by similar materials placed on the top plates of the fasteners that hold down the insulation (Simmons, 2007). The Job Safety Analysis

(JSA) report associated with installing a single-ply roof system can be found in Appendix C.

Built-Up Roofing

Traditional built-up roofing systems consist of bitumen (asphalt or coal tar) usually applied over hot felts, which may be glass fiber, organic, or polyester, and a finished top surface, such as an aggregate or cap sheet (Spence, 1998). Built-up roofs on nailable roof decks consist of several layers. The first layer is the nailable roof deck, which is either wood, plywood, lightweight insulating concrete, or precast gypsum, with one ply of sheathing paper nailed to it. The next layer consists of three to five layers of and asphalt-coated felt, bonded with coatings of hot mopped bitumen (Spence, 1998). The last layer, which is the top coat, is then covered with roofing asphalt and gravel.

Typical built-up roof construction on non-nailable decks, such as steel, precast concrete, and poured concrete, begins by bonding the insulation with hot bitumen or an approved adhesive. This is followed by layers of asphalt-saturated roofing felt and hot roofing asphalt. The layers of felt are laid in a full bed of hot asphalt and broomed in place. The roofing asphalt is brought to the site in a tank truck and heated in an asphalt kettle. The heated asphalt is pumped to a tank on the roof and moved to the area where workers are applying it. The next paragraph describes a more detailed process of installing a built-up roof.

The process of installing a built-up roofing system first begins with nailing down or mechanically fastening a base sheet to the roof structure. The next step involves placing the first layer of preformed roof insulation board which should be bonded with hot bitumen or an adhesive. Once the insulation is secure to the deck with the base sheathing paper, or vapor retarder, it should then be mopped down with hot asphalt.

The next step is to place a second layer of the preformed roof insulation board down. This second layer of insulation is to then be mopped down with the hot asphalt. After the two insulation layers have been sufficiently mopped down, the next step is to apply an asphalt-coated base sheet. This layer should be mopped down with hot asphalt. The next step involves multiple layers of asphalt glass fiber felt, which is most commonly four plies of #4 felt. The first layer of felt is placed on top of the mopped down base sheet and then mopped down with the hot asphalt. The preceding layers of asphalt fiber felt are applied in the same manner as the first one. After the desired number of felt layers are laid down and mopped with sufficient asphalt, the top should be flood-coated with hot-bitumen, and the aggregate ballast should be laid in it. If aggregate ballast is not specified or desired, other options include aggregate-surface asphalt felt, fiberglass cap sheet, or a glazed top-coat. A built-up roof is shown in Figure 2-9. The Job Safety Analysis (JSA) report associated with installing a built-up roof system can be found in Appendix D.

Modified Bitumen

Modified bitumen membranes combine polymer-modified asphalt and a polyester or fiberglass mat, resulting in a product of exceptional strength The two membranes available are styrene-butadiene-styrene (SBS) and atactic polypropylene (APP). SBS sheets have a reinforcement mat coated with an elastomeric blend of asphalt and SBS rubber. APP membranes have a reinforcement mat coated with a blend of asphalt and APP plastic (Spence, 1998). The major difference between the two is the blended asphalt used. The blends create a product that has greater elongation, strength, and flexibility than traditional roofing asphalts.

The SBS membranes are usually installed using hot asphalt as the bonding material. They are applied as cap sheets over a base of hot asphalt and roofing felts. The cap sheet, or SBS membrane, sometimes has a ceramic granule surface that protects it from the harsh ultraviolet light. It also is sometimes un-surfaced which has to be coated with asphalt and gravel to give it ultraviolet protection (Spence, 1998).

APP products are applied by a method known as "torch-down." The properties of the modified bitumen make this process possible because of the back coating of modified asphalt. The back coating is heated with a propane torch to the point at which it becomes able to bond the sheet to the substrate. These APP products cannot be installed with hot mopped asphalt (Spence, 1998). The torch-down technique is shown in Figure 2-10.

The process of installing a modified bitumen roof system is similar to a roof system except there are fewer layers and a torch is commonly used. The first step of installation involves laying down a preformed roof insulation board and mechanically attaching it or nailing it to the roof deck. The next step is to lay down an asphalt-coated base sheet which may be self-adhering or may constitute the use of an approved adhesive to secure it to the insulation board. The last layer that is laid down is the modified bitumen sheet which has the bitumen substance on the bottom surface. A torch should then be used to heat the modified bitumen sheet so that the bitumen substance can adhere to the base sheet. The roof system is complete after all the modified bitumen sheets have been torched down. Figure 2-11 represents a typical modified bitumen roof system. The Job Safety Analysis (JSA) report associated with installing a modified bitumen roof system can be found in Appendix E.

Green Systems

Green Roof

A green roof is a special roof system consisting of different types of vegetation and living plants. This type of roof is also termed a living or planted roof (Toolbase Services, 2001). A green roof usually acts as a roof system alone, but may also be an addition to an existing roof structure. The concept of a green roof has been around for many years but has not become popular until recently. Since the development of the LEED rating system from the U.S. Green Building Council, green roofs have gained much interest because of their environmentally friendly properties. They help to reduce the heat-island effect, reduce stormwater runoff, and increase energy efficiency of a building.

Green roof systems consist of four basic components: a waterproofing layer, a drainage layer, a growing medium, and vegetation (Toolbase Services, 2001). All green roof systems include these four basic components but some may also include root retention and irrigation systems. A green roof system is represented in Figure 2-12.

There are two types of green roof systems: extensive and intensive. Extensive systems are the smaller of the two and have much less of an impact on the roof structure. They include low-lying plants such as succulents, mosses, and grasses, which usually make up a few inches of foliage, and require relatively thin layers of soil (1-6 inches). A complete extensive green roof system on average weighs in around 10-50 pounds per square foot of roof area. Extensive systems are most commonly used for residential applications. Intensive green roof systems are much larger than extensive systems. They usually feature deeper soil and can support larger plants including crops, shrubs, and trees (Toolbase Services, 2001). These systems weigh in the range of 80 to more than 120 pounds per square foot. Maintenance is generally easier for extensive systems because of less vegetation.

Installing a green roof system typically occurs on top of a single-ply roofing system, such as TPO or EPDM. The process of constructing a green roof system first begins with installing the root barrier. The root barrier is usually in the form of a mat like surface, which may be sheets of rigid insulation or thick plastic, copper foil, or a combination of materials (Wark, 2003). The root barrier serves to reduce the tendency of roots penetrating the membrane which would cause leakage. The next component installed is a rigid insulation board which is secured directly to the root barrier. The insulation is an optional component and is dependent upon certain building codes.

The next part of the green roof is the drainage and water storage layer. This layer typically consists of plastic sheets or synthetic porous mats. This drainage layer serves to prevent plant material from being drained from the system and also to store water to keep the vegetation saturated. The next layer that is installed is the growing medium or soil substrate. This layer is the substrate that the vegetation will be planted in. Intensive systems will have deeper soil thicknesses than extensive systems. Installing this layer may require the use of a crane or some sort of lifting equipment to hoist the materials to the roof depending on the size and type of green roof system. An intensive green roof system would most likely require either a pneumatic boom truck to pump the media to the roof or a crane to hoist the media to the roof in bags. The last step in installing a green roof system is planting the vegetation. Small plants and shrubs will be included in an extensive system, where large plants and trees will be included in an extensive system. The Job Safety Analysis (JSA) report associated with constructing a green roof can be found in Appendix F.

Photovoltaic System

Photovoltaic is a solar energy technology that uses solar cells to directly convert solar radiation into electricity (American Technical Publishers, 2007). A photovoltaic system, commonly termed solar panel, is an electrical system that consists of groups of solar cells which form a PV module. Groups of modules then make up what is known as a PV array. The most common PV system configuration is a utility-connected system on a residential building (American Technical Publishers, 2007). The components of a PV array are represented in Figure 2-13.

The installation of PV systems requires extensive electrical work and should be performed by a qualified person. A qualified person is a person with the skills and knowledge of the construction and operation of electrical equipment and installations and is trained to recognize the safety hazards involved (American Technical Publishers, 2007). Safety is a particular concern as electricity is generated as soon as sunlight exposure occurs; there is no “on-off” switch. Training must include the use and inspection of personal protective equipment (PPE) and use of insulated tools and test equipment. Persons working on or near exposed conductors must be able to identify exposed live parts and their voltage, assess the risks for the type of work to be performed, and determine the appropriate PPE and other safety precautions required during installation of a PV system (American Technical Publishers, 2007).

In most cases, local and state contracting laws and regulations require an electrical contractor to be licensed in order to apply for permits and perform electrical work, including work on PV systems (American Technical Publishers, 2007). A few states, including Florida, California, and Nevada, have a solar contractor license classification that includes PV system installations in their scope of work. However, these licenses are limited to performing only incidental work and require the solar contractor to hire an electrical subcontractor to install any premise wiring or make connections to the utility grid.

Proper safety precautions must be taken during all aspects of PV-system installation. These tasks can expose personnel to electrical, chemical, explosion, fire, exposure, and ergonomic hazards. Certain safety gear, such as special tools and equipment, fall protection, and PPE, may be required depending on the system to be installed (American Technical Publishers, 2007). Proper working space should be reserved around the electrical equipment so that workers can safely and efficiently install and inspect the equipment.

The process of installing a roof-mounted photovoltaic system begins with the solar contractor installing aluminum L-brackets to the roof structure. The aluminum L-brackets are secured to the roof by screwing them into the roof rafters. A polyurethane sealant is applied in the roof penetration right before the L-brackets are screwed in to prevent water from leaking to the interior of the roof. The next step involves installing the aluminum rails for which the PV panels will be mounted on. These rails are bolted directly to the roof mounted aluminum L-brackets with stainless steel bolts. After the aluminum mounting rails are installed, the PV panels are then lifted to the roof and carefully set on the mounting rails. Once the PV panels are centered correctly on the rails, they are secured to the mounting rails with hold-down clamps. These components are shown in Figure 2-14.

The next phase involves installation of the PV combiner, inverter, main service panel, and system wiring. The combiner box strings the series of wires from all the PV panels into one main wire that will run to the inverter, i.e., the combiner box acts as a multiple lane highway that converges into one lane. The inverter is the next part of installation and serves to covert DC power generated from the PV panels into AC power. The main service panel is the last component of the system to be installed before system wiring is run. Proper wiring of the system occurs in the following order: PV panels to the combiner box; combiner box to the inverter; inverter to the main service panel; main service panel to the utility grid and building.

Installation of a PV system involves an electrician and either a solar contractor or a roofing contractor. If a roofing contractor installs the PV system, they are legally bound to only make roof penetrations and PV attachments to the roof. The roofing contractor is considered out of their scope of work if they perform any system wiring. A solar contractor can make roof penetrations, attach the PV system components, and run only the DC system wiring to the inverter. The solar contractor is considered out of their scope of work if they run the AC power from the inverter to the main service panel. The electrician can install the entire PV system wiring and is the only party that can install the AC wiring. The Job Safety Analysis (JSA) report associated with constructing a photovoltaic system can be found in Appendix G.

Warm-Mix Asphalt

The heating of asphalt during roofing and road-building applications results in the release of more than 50 organic compounds to which 350,000 construction workers are routinely exposed (Cervarich, 2009). Over the past two decades, the asphalt pavement industry has been working with NIOSH, other government agencies, and unions to improve working conditions at the paving site, including reducing workers' exposure to asphalt fumes (Harte, 2009). In the late 1990's, an agreement was made to put controls on all U.S. manufactured highway-class pavers to vent fumes away from workers. Although this effort contributed tremendously to keeping fumes away from workers, the industry felt as though it still was not good enough. The ultimate goal was to minimize or eliminate the fumes at their source.

The composition of asphalt pavement material includes asphalt cement, a petroleum product, and an aggregate mix of stone, sand, and gravel. Studies have shown that the temperature of the asphalt cement is proportional to the amount of fumes it produces; therefore, higher asphalt cement temperatures yield higher levels of fumes. To improve paving safety, the task was to produce the asphalt pavement material at lower temperatures to minimize the associated fumes.

In 2002, the National Asphalt Pavement Association (NAPA) sponsored research at the National Center for Asphalt Technology to explore the opportunities of warm-mix asphalt. The first warm-mix technology in the U.S. came about in 2004, and since then, technology innovators have introduced approximately 15 new, warm-mix technologies. Warm-mix asphalt is a term used for different technologies that allow the producers of hot-mix asphalt pavement material to lower the temperatures for its production at the construction stage. Conventional hot-mix asphalt is produced at 280^{o} to 320^{o} F, whereas warm-mix technologies allow production temperatures to be reduced to approximately 215^{o} to 275^{o} F. In addition, the warm-mix asphalt is cooled by another 10^{o} to 20^{o} F during the time it is transported to the paving site (Cervarich, 2009).

Warm-mix technologies bring many benefits to the asphalt pavement industry. The more common benefits include improved working conditions, a reduction in overall fume emissions, and increased fuel savings. Through further research, additional benefits have been discovered for these technologies. These mixes were found to have the potential to extend paving time in cold climates, improve overall pavement quality, and lengthen the lifespan of the pavement. The asphalt industry is considered the number one recycler in the U.S. with over 100 million tons of asphalt pavement being reclaimed each year. Nearly 95 percent of this material is reused or recycled each year (Cervarich, 2009).

Since the temperatures of warm-mix asphalt are significantly reduced when it reaches the paving site, workers experience a more comfortable work area because the paving site is cooler. Also, the fumes and any odor associated with the asphalt paving are virtually gone. Workability of the warm-mix has been reported to be less labor intensive and easier to compact. The introduction of warm-mix asphalt technologies into the U.S. paving industry was an important step in sustainable development. The implementation of these technologies has brought economic, performance, and environmental benefits. Most importantly, there is a reduced impact on worker health and safety.

Green Building Design and Construction

Through the design, construction, and final operation of a green building, the main concern for human safety and health is for the end-user. While the end-user's safety is important, so too is the safety of the worker constructing the building. The issue, which is not addressed in the LEED process, is whether or not construction worker safety and human health are impacted through the implementation of sustainable concepts in the building development process. A pilot study was conducted to determine the relationship between green building practices and construction worker safety and health. The study focused on a project that was to receive LEED Gold certification. The data collected came from project documentation and interviews which included representatives from the general contracting and subcontracting firms working on the college campus project.

Two main questions were asked of the participants regarding green building construction and the safety of the construction workers. The first question was if a safety concern was identified, and if so, was the impact considered positive or negative. The positive impact responses were good housekeeping, low VOC materials, and painting location and timing relative to the location of other workers. The negative impacts included increased material handling, extra dumpsters for material separation, and the design of the atrium. The intent of the atrium design was to increase natural light for the interior of the building, but this design resulted in more scaffolding which increased worker exposure to potential injury.

The second question was how safety on the green building site compared to a conventional building site. The question was part of a survey and included twenty-four participants. Of those interviewed, twelve felt that green building sites were a little safer, seven stated that they were much safer, and five reported that they were the same as conventional building sites (Rajendran, 2006).

The construction industry’s current view on sustainability is based on the principles of resource efficiency and the health and productivity of the building’s occupants. However, if a building is labeled as “sustainable”, it should be sustainable across its entire lifecycle, including construction and design. Rajendran conducted a second and more extensive study to determine the impacts of green building design and construction on the safety and health of construction workers. The focus of the study was to analyze the safety and health performance of 38 green and 48 non-green construction projects to determine if any differences exist between the two. Safety and health performance data were based on the OSHA recordable and lost time injury/illness rates experienced on the projects. Identification of a green and non-green project was based upon whether or not the project was pursuing LEED certification.

There were a total of seven construction firms that provided data from their previous and current projects. The data received from the seven firms included 86 building projects. The approach for obtaining the data from the firms consisted of requesting information on project demographics, safety performance, and LEED. Project demographics included project type, cost, size, and location. Safety performance information included total project man-hours, the number of OSHA recordable injuries and the number of lost time injuries/illnesses on the project (Rajendran, 2006). Information solicited for LEED included the type of certification being sought, the level of certification, the number of points, and if the project was certified or registered.

The research concluded that there appeared to be little to no difference between the green and non-green projects in terms of construction safety and health. The safety performance of green and non-green buildings were the same which raises the question as to whether LEED buildings should be labeled as sustainable buildings. It was concluded that LEED projects are environmentally sustainable but not sustainable in terms of worker safety and health (Rajendran, 2006)

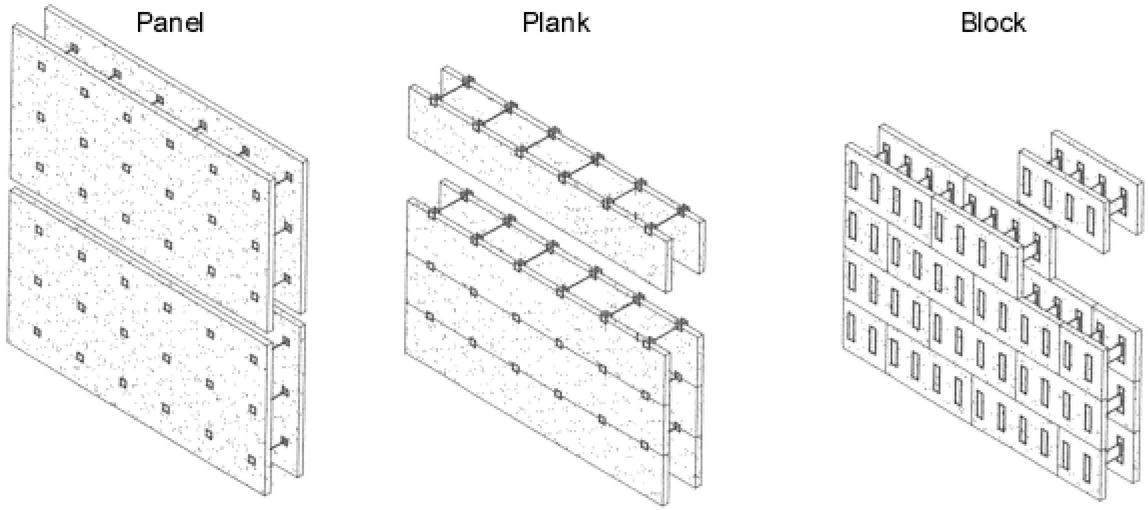

Figure 2-1. Types of ICF systems (BuildCentral, Inc. 2010)

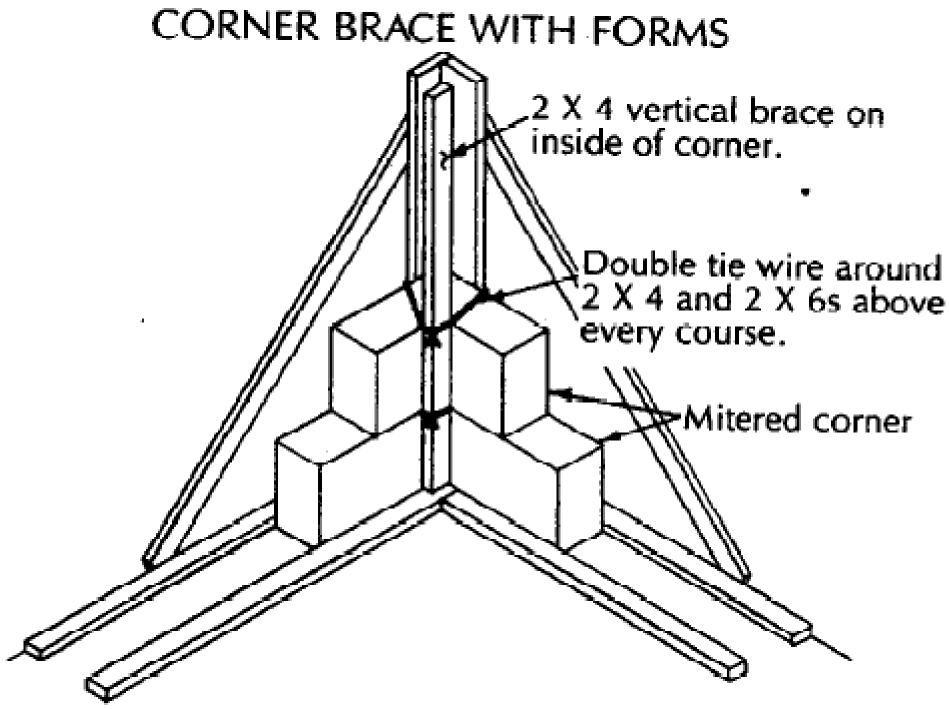

Figure 2-2. Perimeter bracing on foundation for ICF form (Miller, 2005)

Figure 2-3. ICF wall bracing (Miller, 2005)

Figure 2-4. Window blocked in with pressure-treated lumber

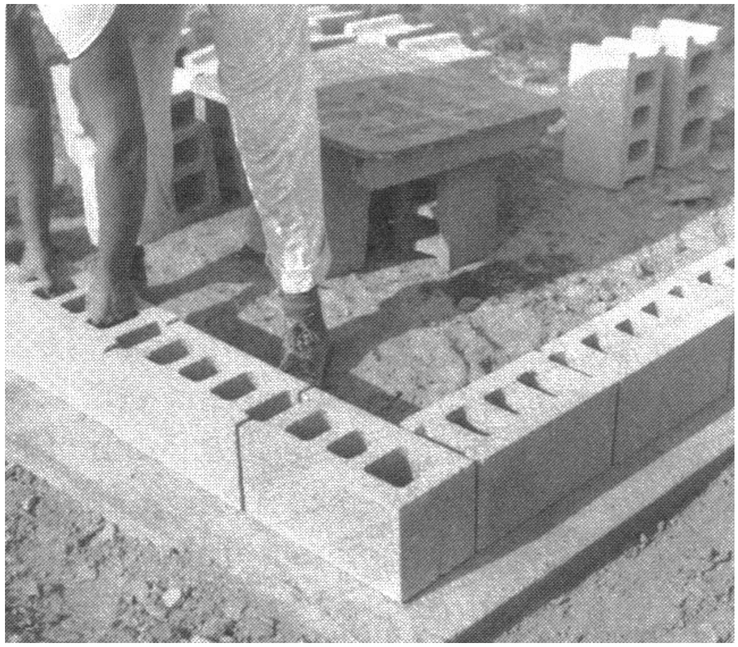

Figure 2-5. Corner CMU units without mortar (Simmons, 2007)

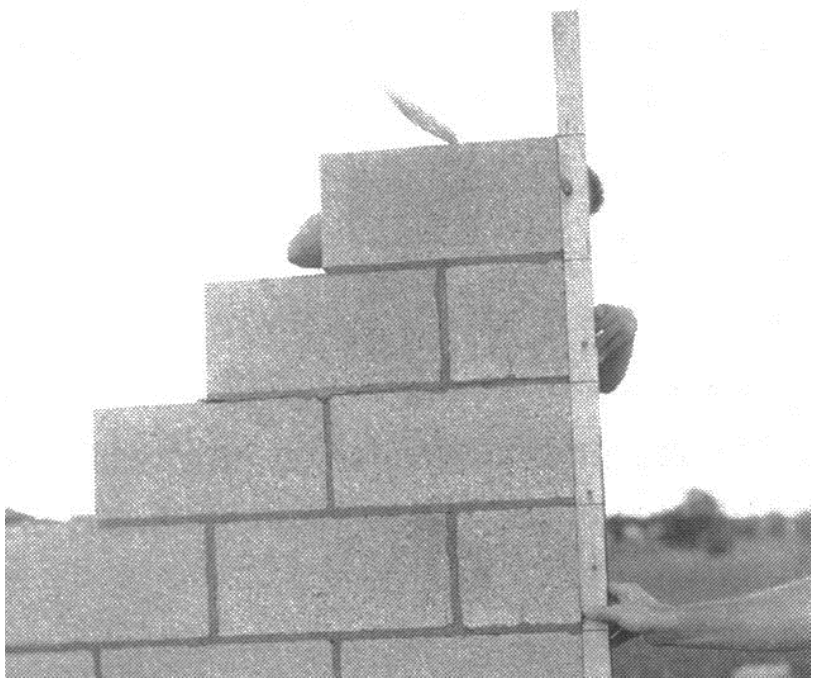

Figure 2-6. Corner CMU units (Simmons, 2007)

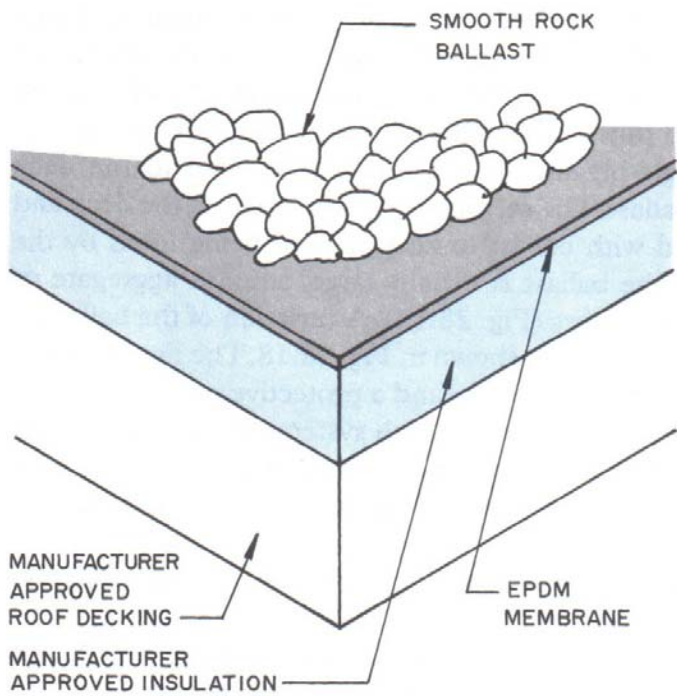

Figure 2-7. EPDM single-ply roof system detail (Spence, 1998)

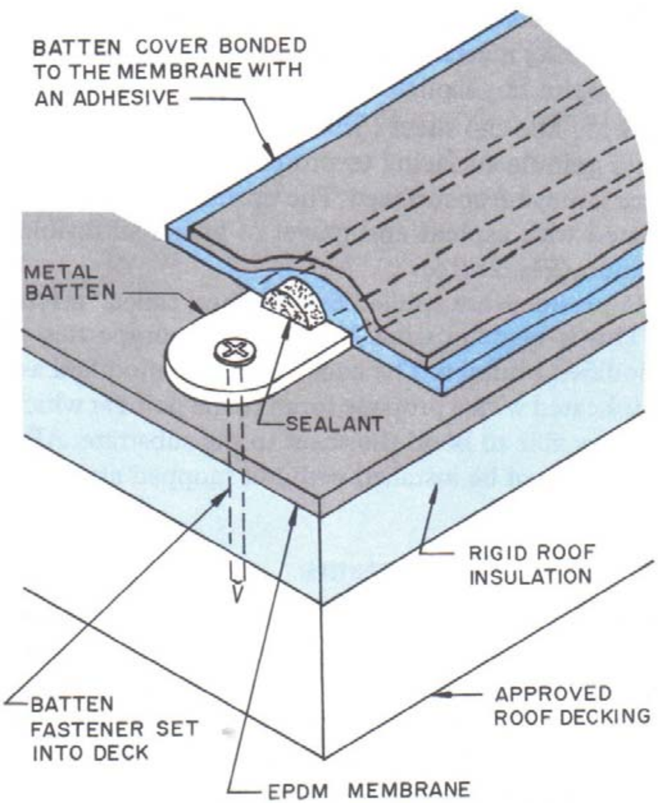

Figure 2-8. Mechanically fastened single-ply roof system detail (Spence, 1998)

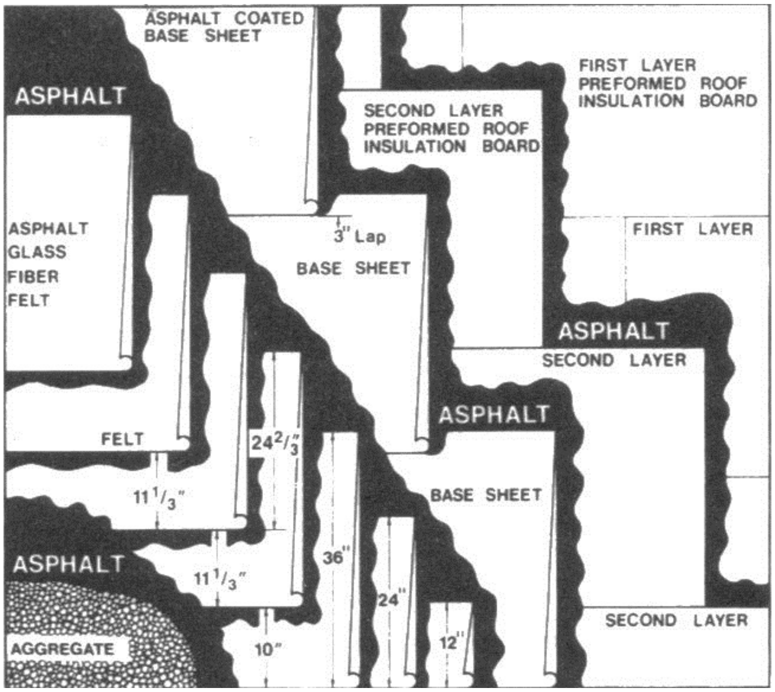

Figure 2-9. Built-up roof detail (Spence, 1998)

Figure 2-10. Torch-down technique

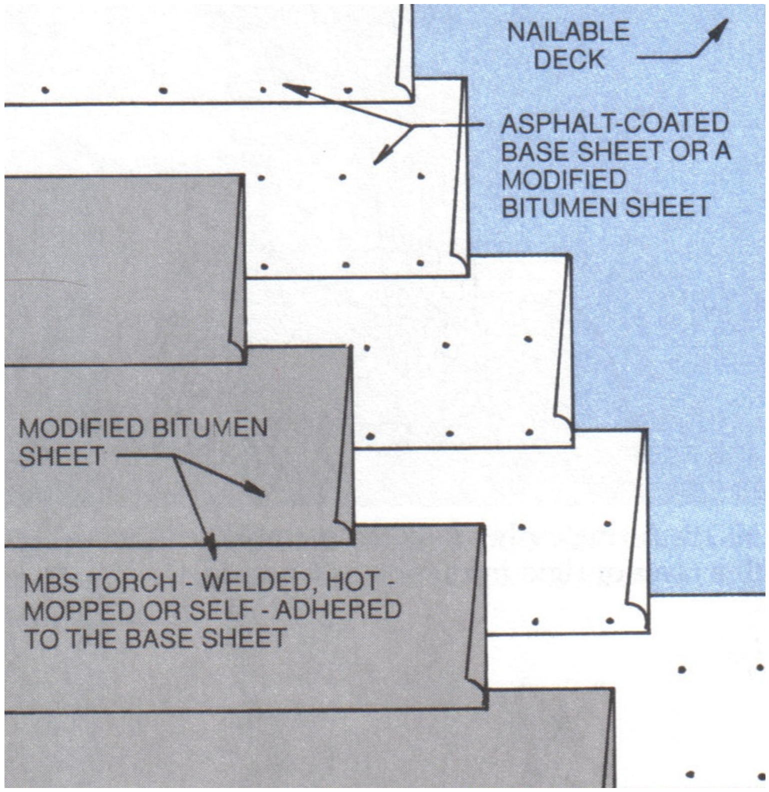

Figure 2-11. Typical modified bitumen roof system detail (Spence, 1998)

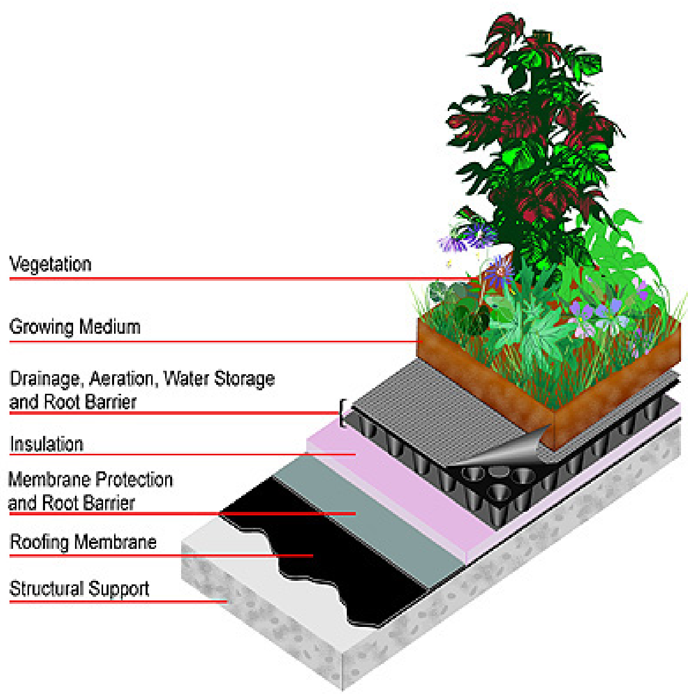

Figure 2-12. Green roof system (American Wick Drain Corp.)

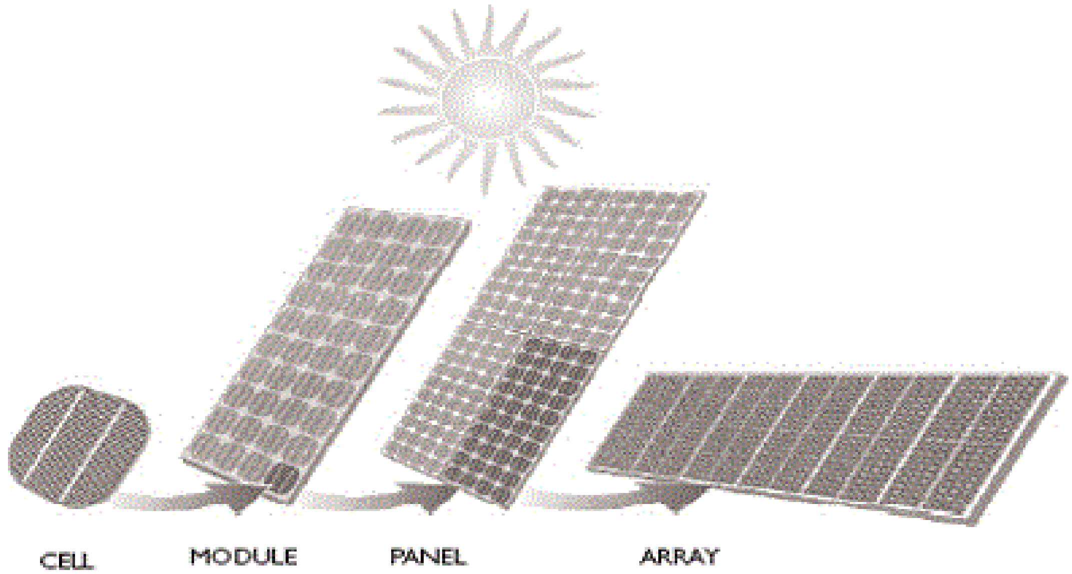

Figure 2-13. Components of a PV array
(http://www.schl.ca/en/co/maho/enefcosa/enefcosa_003.cfm?renderforprint=1
)

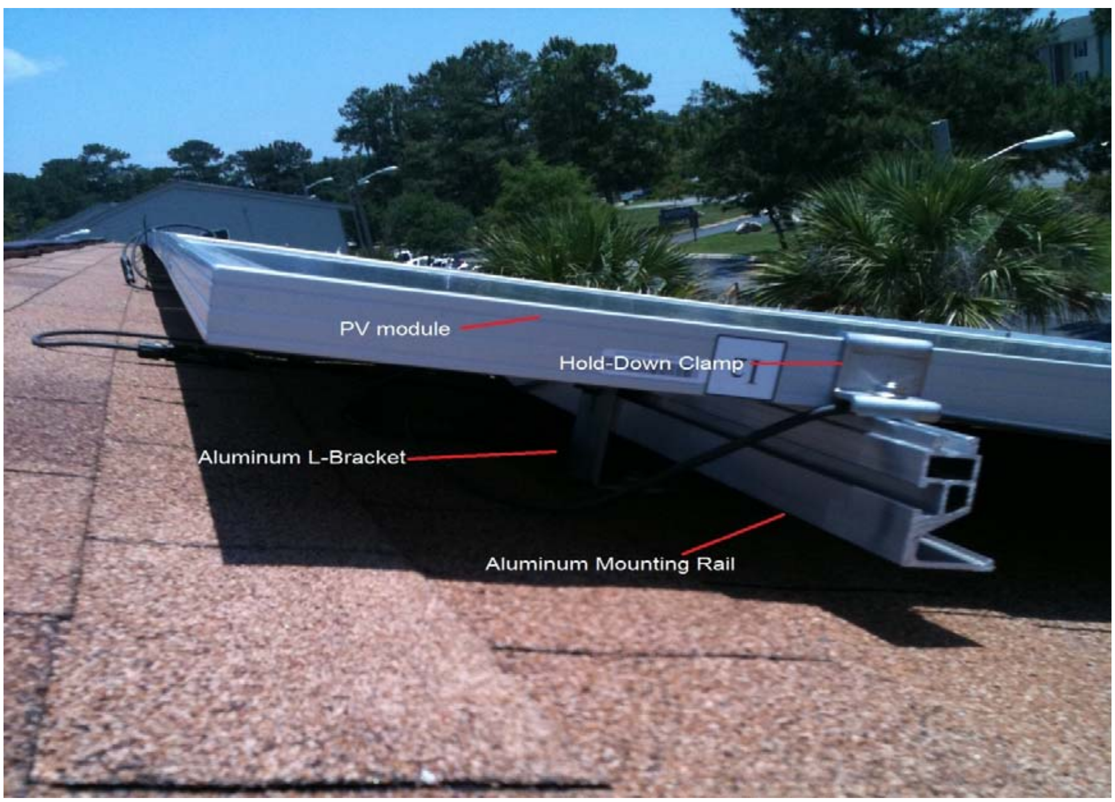

Figure 2-14. Photovoltaic mounting detail

CHAPTER 3
METHODOLOGY

This study was designed to examine the safety hazards associated with selected sustainable building component construction and whether it has a negative or positive impact on worker safety. The sustainable building components analyzed for this research were insulated concrete form (ICF), green roof, photovoltaic system, and non-petroleum-based roofing. The Table 3-1 is not the result of research but a collaborative effort in which safety assessments were made of different building elements encountered in green buildings. Table 3-1 includes 31 design elements which are organized in different categories to show what function the element serves. The categories are air, ecology, energy, toxins, waste, water, and worker productivity. These categories represent the characteristic function of the design element, e.g., high-efficiency air filters are in the air category because the function of the element is to purify air.

The next column, entitled “New Activities?” provides an assessment of whether the design element entails new activities or if the activities are essentially the same for the element being replaced or substituted. The design elements were noted with either an ‘N’ for no or a ‘Y’ for yes, referring to whether or not they were a new construction activity. For example, the use of low energy lights does not introduce a new activity as the same procedures would be used to install the low energy lights or the conventional lights. It was noted that most design elements in Table 3-1 consist of substantially newer, more energy-efficient elements for the older or conventional elements.

The last column represents the impact on safety of constructing the design elements. The elements were marked with either a ‘+’, indicating a positive impact, a ‘-’, indicating a negative impact, or a ‘0’, indicating no impact on safety. Of the 31 elements, eleven were identified as not impacting construction safety, ten were identified as favorably impacting construction safety, and ten were identified as adversely impacting safety.

Of the 31 green design elements, five were identified as being new construction activities. These were photovoltaic, wind energy generators, non-petroleum-based roofing, insulated concrete form (ICF), and green roof. These five design elements were of primary interest in this research. The research objective was to examine the green design elements that entitled new activities to more fully assess the implications on safety and how these issues could be properly addressed.

Table 3-1. Green Elements and Safety (Hinze and Gambatese, unpublished)

Green Design Element	Category	Construction New Activities?	Construction Impact on Safety
High-efficiency air filters	Air	N	0
Air monitors	Air	N	+
Use of indigenous plants	Ecology	N	+
Photovoltaic	Energy	Y	-
Solar collectors	Energy	N	-
High-efficiency HVAC	Energy	N	0
Shading	Energy	N	0
Zoned air conditioning	Energy	N	0
Low energy lights	Energy	N	0
Timed lighting systems	Energy	N	0
Wind energy generators	Energy	Y	-
Insulated curtains	Energy	N	0
Reflective surfaces for roofing and walls	Energy	N	-
High-efficiency windows	Energy	N	0
Use of fly ash in concrete	Energy	N	+
Low cement content materials	Energy	N	+
Use of local materials	Energy	N	+

Table 3-1. Continued.

Green Design Element	Category	Construction New Activities?	Construction Impact on Safety
Geothermal heating system	Energy	N	-
Non-toxic materials (e.g., paints, caulking, sealants, adhesives)	Toxins	N	+
Non-petroleum-based roofing	Toxins	Y	+
Use of recycled materials	Waste	N	-
Material reuse	Waste	N	-
Use of renewable materials	Waste	N	0
ICF	Waste	Y	+
Reuse/recycling of waste products	Waste	N	-
Cut-to-order purchasing	Waste	N	+
Green roof	Water	Y	+
Low water use fixtures	Water	N	0
Greywater use	Water	N	-
Rainwater collection	Water	N	-
Daylighting	Worker productivity	N	0

Upon closer review of the five green design elements that entitled new activities, it was decided not to examine the safety or health impacts associated with wind energy generators. Wind energy generators were excluded from this research because they are not actual components of buildings but rather separate electrical generating units, i.e., there is no parallel conventional component for comparison of safety and health impacts. In addition, the scope of projects to erect wind energy generators is enormous. Wind energy generator installations consist of site development, trenching for utility lines, constructing substantial foundations, erecting the support towers with the generators, attaching the propellers, addressing power distribution, and other major activities. This is a topic for a sole focus for research.

Experts familiar with constructing ICFs, green roofs, photovoltaic systems, and non-petroleum-based roofing were interviewed for data collection. A total of 11 experts were interviewed – three experts for ICFs, three experts for green roofs, three experts for photovoltaic systems, and two experts for non-petroleum-based roofing. Only two experts were interviewed for non-petroleum-based roofing because there was no difference in these observations and opinions. It did not appear worthwhile to conduct a third expert interview.

The experts were chosen on the basis of their knowledge and experience with the components and the associated construction process. The representatives were from large firms in niche areas and were selected in two ways: through the use of a web-based search engine and contacts with professionals personally known by the author. The goal of the interviews was to gather information on the following: 1) the safety hazards associated with constructing the sustainable building component, and 2) the safety hazards associated with constructing the conventional building component. The intent of this study was to determine if constructing sustainable building components has a positive or negative impact on worker safety. The methodology was as follows:

1. Researched companies that specialize in ICF, green roof, photovoltaic system, and non-petroleum-based roofing construction and installation
2. Developed questions for interviews
3. Contacted representatives of companies to arrange interviews
4. Conducted in-person and telephone interviews
5. Organized information gathered from interviews to establish results

CHAPTER 4
RESULTS AND ANALYSIS

The results of this study are presented below in four sections. The sections include the overview of the component and the expert interview results.

1. Insulated Concrete Form
2. Green roof
3. Photovoltaic system
4. Non-petroleum-based roofing

Insulated Concrete Form (ICF)

Expert Interview One

The health and safety concerns associated with constructing an ICF wall were identified by three expert interview participants and will be described. The first safety issue identified by the interviewee involved the amount of time that workers are on the scaffolding, which is required to construct an ICF wall. With regards to the time that workers are on scaffolding, the process of constructing a CMU block wall takes longer than constructing an ICF wall. With an ICF wall, the blocks are much larger than a CMU block so more wall area can be constructed in a shorter amount of time. The amount of time workers are on scaffolding, which is required to build the wall, is in reference to the total time, e.g., two weeks. It is not referring to the daily amount of time workers are on the scaffolding since it would be the same for both a conventional CMU block wall and an ICF wall. The safety hazard associated with workers being on scaffolding is the risk of falling. Less time on scaffolding means there is a reduced risk of a worker falling.

The next safety concern discussed was falling objects during wall construction. The objects of concern pertain to CMU blocks and ICF blocks. CMU blocks are very heavy and if one happens to fall from the scaffolding or during placement on the wall, it can cause serious injury to workers below. In addition, the relatively sharp corners of a

CMU block could contribute additional injury if a worker was struck by one falling. The potential risk of injury caused by a falling ICF block is significantly reduced because the blocks consist of foam insulation and weigh much less than a CMU block.

The next safety concern identified was in regards to pouring concrete columns in a CMU block wall. For a conventional CMU block wall, a column must be poured every 48 inches for structural integrity. During this process, concrete and insulation is poured into the CMU block's cavities to form a solid vertical column. The insulation consists of either vermiculite or perlite and when it is poured or blown in with the concrete it generates dust. This poses a health hazard to workers because of the risk of inhaling the dust particles. This health hazard is not associated with constructing an ICF wall because vermiculite or perlite is not used.

The last safety hazard identified by the interviewee dealt with the use of powder actuated devices. After a CMU block wall is constructed, furrings have to be installed on the wall interior so that drywall can then be attached. Attaching the furrings to the CMU wall requires the use of a powder-actuated device. A worker then becomes at risk to the hazards associated with the use of this device. With an ICF wall system, powder-actuated devices are not used which eliminates the associated risks.

Expert Interview Two

One of the primary safety concerns identified by the interviewee was in regards to the weight of the CMU blocks and the risk of injury to a worker if one falls from a high elevation during conventional CMU block wall construction. The potential for a CMU block falling is during the process of a worker placing the block on the wall, during the process of hoisting additional blocks up to the scaffolding, or when a worker is simply rearranging or organizing the stockpile of CMU blocks on the scaffolding. The CMU blocks are very heavy objects and if one happens to fall and strike a worker below, serious injury can result. The Styrofoam blocks used for ICF wall construction are much lighter than CMU blocks and the potential for injury from a panel falling from a high elevation is significantly reduced.

Another safety concern discussed was ergonomic issues. Workers are at a higher risk of straining muscles when lifting CMU blocks because they are heavy objects. Since ICF blocks are much lighter, the risk of a worker sustaining a back injury or muscle strain is reduced significantly.

Additional safety concerns identified by the interviewee included the use of tools and material characteristics. Both ICF wall construction and CMU block wall construction require the use of power tools. When constructing the wall with either component, certain parts or sections of the wall will require a modified piece, such as a corner or window opening. The power tools used to cut an ICF block to a specific size include a chain saw or a heat gun and the power tools used to cut a CMU block include a concrete saw. In addition, holes have to be drilled for electrical and plumbing work and require the use of a drill. The safety hazards associated with the use of these power tools are relatively the same with regards to cutting and drilling an ICF block or a CMU block. The issue of concern is the dust generated from cutting or drilling a CMU block. Cutting and drilling a CMU block generates a significant amount of dust whereas cutting or drilling an ICF block does not. The health hazard associated is the potential risk of a worker inhaling the dust particles generated. The safety concern associated with material characteristics is the texture of a CMU block. A CMU block has a rough texture and relatively sharp corners which can cause skin abrasions if rubbed against.

However, because an ICF block is composed of Styrofoam the chance of a worker sustaining a cut or abrasion to the skin is unlikely.

The last safety concern identified was in regards to duration of constructing an ICF wall. The process of constructing an ICF wall typically takes 20-30% less time than constructing a conventional CMU block wall similar in size which results in an overall diminished exposure to the safety hazards associated.

Expert Interview Three

The first safety concern that the interviewee identified was in regards to the weight difference between an ICF block and a CMU block. An ICF block is much lighter than a CMU block and is composed of foam like material. With an ICF block, workers are at minimal risk of sustaining injuries from lifting them, injuries from being struck by one falling from scaffolding or any other high elevation, and injuries from abrupt skin contact. Constant lifting of CMU blocks throughout the day can put serious strain on a workers body, especially the back, which can result in muscle strains and back complications. Since a CMU block is made of concrete and has a rough texture, workers are at risk of sustaining cuts, scrapes, and bruises when they are being handled.

The next safety concern identified was the hazards associated with the tools used to cut an ICF block and a CMU block. The tool used to cut an ICF block is a hand saw, similar to a drywall saw, and the tool used to cut a CMU block is a powered concrete saw. A worker using a hand saw to cut an ICF block is at a much less risk of sustaining a bodily injury compared to a worker using a powered concrete saw to cut a CMU block because the powered concrete saw has a high-speed spinning blade. The high speed spinning blade has the potential to cause severe bodily injuries whereas the hand saw only poses minimal threat. Workers are also exposed to dust particles and concrete fragments projected from the spinning blade while cutting. This puts a worker at risk of inhaling the dust particles and sustaining an eye injury from the projected fragments.

Green Roof

Expert Interview One

The health and safety concerns associated with constructing a green roof were identified by three expert interview participants and will be discussed below. The interviewee stated that the typical safety hazards associated with constructing a conventional roof were also present during green roof construction. Three distinct elements were identified that were directly related to green roof construction and safety. These elements are as follows: the construction of a parapet wall, the use of low-VOC materials, and the elimination of asphalt use. The participant stated that the green roofs that they construct integrate a parapet wall into the design. The parapet wall is designed to be 39 inches high to meet OSHA requirements for fall protection so workers do not have to tie-off. By having the parapet wall as part of the green roof structure, workers can construct the green roof without additional fall protection. This provides a barricaded area for the workers and reduces the risk of falling.

The second element was the use of low-VOC materials. The natural root barrier in a green roof is a specific membrane layer applied on top of the insulation board. The root barrier is a PVC or thermoplastic (TPO) membrane which has low-VOC content. The use of this type of membrane reduces worker exposure to VOCs. Conventional roofing membrane materials typically have high-VOC content, resulting in continuous worker exposure throughout the work day.

The third element identified was the use of PVC or thermoplastic materials instead of asphalt. Workers are at risk of burn injuries when working with asphalt because it must be heated to high temperatures for application. Workers are also exposed to the fumes associated with hot asphalt. Inhaling these fumes for extended periods jeopardizes the health of the workers. With the PVC or thermoplastic membrane used for a green roof, the safety and health hazards associated with asphalt are eliminated because it is at ambient temperature and does not expel any fumes.

Expert Interview Two

The interviewee identified that the root barrier installed for the green roof is commonly a 30 mil polyethylene membrane and that the material does not off-gas because it is a low-VOC material. The material does not pose any safety hazards to workers but the process of installing the membrane does. Once the root barrier membrane is laid down on the roof structure the seams are welded together with a hot air gun. The safety hazard associated with the use of a hot air gun is risk for a burn injury. Exposure to a fire hazard is minimal with construction of a green roof because no tools or equipment with an open flame is used. With a conventional built-up or modified bitumen roof system, the use of torches is a common practice.

The next safety hazard identified by the interviewee is in regards to crane logistics. The media, plants, and trees that are hoisted to the roof are somewhat abnormal objects to rig and lift and can pose a challenge to the crane operator and the workers rigging the materials. Since the materials are different than conventional roofing materials, the risk of one of these objects falling caused by the rigging malfunctioning is increased; however the risk is dependent on how well the workers rig the materials. Although the risks associated with hoisting materials to the roof are present with any type of roofing system, the conditions are slightly different with green roof materials. An example identified was the bags of media lifted to the roof are heavy and have the potential to rip open.

Another safety hazard identified dealt with residential green roof construction. The green roof materials are brought up to the roof by hand using a ladder because the most residential roofs are not high enough to require lifting equipment. This technique could cause the worker to fall off the ladder from having undistributed weight, uneven balance, or reduced contact points and cause serious injury. However, the interviewee stated that this unsafe practice is also performed with traditional residential roof construction and the same safety hazards and risk of injuries are present.

The interviewee described that green roof construction is probably safer than conventional roof construction because of the fact that green roofs are relatively new and that this brings an additional amount of attention to the technology. With it being a newer technology, workers pay extra attention while working to make them more aware of the safety hazards present.

Expert Interview Three

The interviewee stated that the typical safety hazards associated with conventional roof construction are also present with green roof construction, which was fall hazards, heat exhaustion, and tripping hazards. The interviewee stated that the material used for the root barrier of a green roof is a low-density polyethylene membrane (LDPM) and does not de-gas or generate fumes that would pose a health hazard to workers because of its low-VOC content. The LPDM also does not require a torch for application so workers are not exposed to a fire hazard and at risk for sustaining a burn injury. This is the case, however, with conventional built-up or modified bitumen roof construction because some of the materials used require a torch to be applied. Workers are also exposed to the hazards associated with hot asphalt. Roofing asphalt is heated to temperatures that would cause serious burn injuries if a worker was to come in contact with it. The roofing asphalt also generates toxic fumes that can be inhaled by workers in close proximity. The plants, trees, shrubs, and media used for a green roof, which are parallel materials to a conventional roof, are safe to with and around and do not pose any significant health or safety hazards to workers.

The next issue was in regards to the duration of constructing a green roof relative to constructing a conventional roof and the exposure to fall hazards. The interviewee stated that the process of constructing a green roof is commonly faster than constructing a conventional roofing system. This means that less time is spent on the roof and reduces the risk of a worker falling from high elevations.

The interviewee identified an issue related to worker safety which did not specifically involve materials, equipment, or practices. The issue was in regards to the experience of a roofing company. A roofing company that previously specialized in constructing conventional roof systems that enters into green roof construction will have a good understanding and background of the general safety hazards associated with roof construction. However, a company that is brand new to roof construction that enters the market specializing in green roof construction is subjected to a learning curve in which the workers could be at higher risk to the safety hazards. This does not constitute that any of the workers are necessarily safer than the other and was just an opinion of the interviewee.

Photovoltaic System

Expert Interview One

The health and safety concerns associated with installing a photovoltaic system were identified by three expert interview participants and will be discussed below. The participant for this interview was a general operation manager for a solar contractor located in Gainesville, Florida and has over twenty years of experience in the solar industry. The interview lasted around 15 minutes and was conducted via telephone. Issues discussed during the interview pertained to the safety hazards associated with installation of a photovoltaic system.

The first safety issue identified by the participant was fall hazards. Installing the PV system components on a sloped roof puts workers at risk of falling; some type of fall protection is required. Other fall hazards are also present during the installation of a PV system, primarily related to tripping hazards. The hazard of electrical shock is also a real concern. Installation of a PV system requires a large amount of wiring to connect the modules. Most of the wires cannot be seen since they are integrated into the PV panels; however, there are some that are elevated a few inches off the roof which run from one set of modules to another. These wires pose a tripping hazard to workers as they walk around the modules and they could also pose an electrical hazard. Once the PV modules are installed they immediately produce DC current and if workers come in contact with loose wires they could get shocked. A worker who experiences an electrical shock may also be at risk of falling off the roof. That is, a worker who is startled by an electrical shock could end up falling off the roof.

Another safety concern that was discussed during the interview involved the process of getting the PV panels from the ground to the roof. The interviewee stated that the way the PV panels get up on the roof is either by handing the panels up to someone on the roof or by using a hoisting mechanism to pull them up, depending on the roof height. This procedure puts workers at risk of injury from falling objects and improper lifting techniques.

Expert Interview Two

The participant for this interview was an installation manager for a solar contractor in Gainesville, Florida and had two years of experience in the solar industry. The participant is a certified licensed general contractor and a certified project manager. The interview with this participant lasted around 30 minutes and was conducted in-person at one of the company's current projects. The project was a 750,000 watt photovoltaic system installation on the roofs of an apartment complex in Gainesville, Florida. The interview allowed this researcher to see firsthand the safety hazards associated with a PV system installation and to obtain additional information about PV systems.

The first safety hazard identified by the interviewee was electrical shock hazard. Once a panel is set and wires are connected, DC current is being generated and any loose wires that a worker contacts result in an electrical shock. The interviewee stated that he had personally been shocked from a loose wire while working on the system, so the exposure to shock hazard is always present during installation.

The next safety hazard identified was heat exhaustion during the summer. When working on a roof during summer days in Florida, workers are exposed to heat exhaustion and dehydration. Between the hours of 1:00 p.m. and 5:00 p.m. workers are subjected to extremely high temperatures and the risk of heat exhaustion becomes significantly increased. The participant stated that during the summer the workers begin work on the roof around 8:00 a.m. and finish around 1:00 p.m. to avoid any heat-related injuries. During the rest of the year, however, the risk of heat exhaustion is diminished.

Another safety hazard discussed was tripping hazards from the PV system wiring. The participant stated that the electrician that does most of their electrical work usually has quality workmanship which results in minimal wiring that could cause a worker to trip. However, some of the electrical work on the project that was examined during the interview revealed wires that increased the risk of a trip hazard. Although the workmanship of the electrical contractor does affect the exposure of workers to tripping over wires, the presence of a trip hazard will always exist. In addition to the PV system wiring posing a trip hazard are the rails that are used to secure the PV modules. The rails protrude about four to six inches which puts a worker at risk of tripping.

Expert Interview Three

The first safety concern that the interviewee identified related to the weight and size of the photovoltaic panels. The panels are 33 inches by 66 inches and weigh approximately 40 to 50 pounds each. Handling these panels is cause for concern for concern for a couple of reasons. The first reason being that at 40 to 50 pounds, lifting these panels can cause back and other muscle strains. In addition, if a panel is dropped from the roof to the ground and strikes a worker, they can sustain serious injury such as broken bones and contusions. The second reason is issues created by the large size of the panels. Workers installing the large panels have to contort themselves to get the panels into position on the roof racks which could place the worker in an unsafe position on the roof. Another issue with the size of the panels is the potential for the panel catching the wind while being moved and throwing the worker off balance. This could cause the worker to fall over onto other objects or push them off the roof.

The next safety concern indentified by the interviewee was the potential for electrical shock. When workers are installing the panels, they are constantly exposed to a shock hazard because the panels are unable to be turned on or off to prevent them from generating current. Each panel generates 48 volts of DC current and once inverted, they generate 120 volts of AC current. The more panels that are connected together will increase the amount of voltage running through the wiring. This elevates the severity of a potential injury occurring from a worker coming in contact with a live wire.

The interviewee stated that for the topic of photovoltaic installation, the main safety concern is fall hazards, especially on sloped roofs. However, anytime someone is working on any type of roofing system, the threat of falling is always present. These hazards can be lessened by the installers using proper fall protection safeguards.

Non-Petroleum-Based Roofing

The health and safety concerns associated with constructing a non-petroleum-based roofing system were identified by two expert interview participants and will be discussed below. There were two telephone interviews conducted for this building component. Both of the interview participants were representatives from large roofing companies that specialize in single-ply, built-up, and modified bitumen roofing systems. The safety concerns identified by the interviewees that were associated with non-petroleum-based roofing were almost identical, so the information obtained from the two interviews was combined to represent one analysis.

The interview participants were asked what roofing system they use that contain non-petroleum-based materials in which they identified as being a single ply system. The single-ply roof consists of either a polyvinyl chloride (PVC) or thermoplastic polyolefin (TPO) membrane, which are both non-petroleum-based. The membrane itself does not pose any health or safety hazards to workers that install it. However, certain adhesives that are used to secure the membrane to the solid underlayment do off-gas, which puts workers at risk of inhaling the fumes. These adhesives are available as either a water-based adhesive, which does not off-gas, or solvent-based adhesive, which does off-gas and is the more popular type used.

The next safety concern identified was exposure to fire hazards with regards to a conventional built-up or modified bitumen roof. Both of these roofing systems require the use of a torch for application of their respective waterproofing material. Workers in the vicinity of the torch are at risk for burn injuries which can occur from an explosion, direct contact with the torch, or materials that catch on fire. With a single-ply roof, the degree to which workers are exposed to fire hazards is significantly less. This is because installation of a single-ply roofing system does not require a torch to apply the waterproofing membrane. It does however require the use of a heat gun to weld together the seams of the membrane. The heat gun does not create an open flame as does a torch which reduces the risk of a worker sustaining a burn injury.

Another safety concern identified was in regards to the use of hot asphalt in a conventional built-up system. The roofing asphalt is at extremely high temperatures when applied and can cause serious burn injuries to workers that come in contact with it. Workers are also exposed to the toxic fumes that the roofing asphalt emits. Hot roofing asphalt is not used in single-ply roofing systems.

The last safety concern stated by the interviewees was in regards to exposure to fall hazards. Workers are always exposed to fall hazards during construction of a roofing system, so the longer the process takes will result in an increased risk of someone falling. The process of constructing a single-ply roofing system takes, on average, 20% to 30% less time than does a conventional built-up or modified bitumen roofing system, which results in less time workers spend on the roof and ultimately reduces the exposure to fall hazards.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

Conclusions

As analyzed in Chapter 4, it was determined from the expert interviews whether the impact on worker safety with regards to constructing ICFs, green roofs, photovoltaic systems, and non-petroleum-based roofing was either negative or positive.

ICF

The safety hazards that were identified through the interviews suggest that the health and safety of workers is positively impacted with regards to ICF construction. With conventional CMU block wall construction, workers are at potential higher risk of sustaining injuries mainly because of the weight difference between a CMU block and an ICF block. The CMU block compared to an ICF block would cause a much more serious injury if one was to fall and strike a worker below because a CMU block is much heavier. In addition, the rough texture and extremely hard composition of a CMU block could cause cuts and bruises from a worker scraping or rubbing against one.

Another assumption as to why there is a positive correlation between worker safety and ICF construction is the reduced exposure to silica dust. Cutting, grinding, and drilling CMU blocks produces dust particles that could pose a respiratory threat if inhaled by a worker. With an ICF block, however, no dust particles are produced from cutting or drilling so the threat of inhaling the harmful dust particles is eliminated.

The next issue that suggests that constructing ICF walls has a positive impact on worker health and safety is in regards to the insulation that is added to the concrete in CMU block wall construction. The vermiculite or perlite insulation that is sometimes added to the concrete for a CMU block wall generates dust particles that put workers at potential risk of inhaling. With an ICF wall, insulation is not added to the concrete which eliminates worker exposure to the dust particles generated from vermiculite or perlite used for a CMU block wall.

Another positive aspect of ICF wall is that it takes less time to construct than a conventional CMU block wall. This results in less man-hours and reduced worker exposure to the safety and health hazards associated with constructing the ICF wall.

One issue that did not necessarily suggest that ICF construction has a positive impact on worker safety was in regards to the tools used. The primary tools targeted with regards to worker safety were tools that are used to cut the CMU blocks and the ICF blocks. The primary tool used to cut a CMU block is a concrete saw and the tools used to cut an ICF block were identified as either a hand saw or a chain saw. The safety hazards associated with using a concrete saw or a chain saw pose similar risks to injuries, which can be significant. The use of a hand saw has a significantly reduced risk for potential injury. This suggests that this aspect of ICF construction is not necessarily safer than conventional CMU construction because a hand saw is not always used to cut the ICF blocks.

Green Roof

The safety hazards that were identified through the interviews suggest that the health and safety of workers is positively impacted with regards to green roof construction. The first issue that supports that green roof construction is safer than conventional roof construction is in regards to the roofing materials used. The root barrier used in a green roof system is a PVC or thermoplastic membrane, which has low-VOC content, and the materials used in a conventional roofing system contain high-VOC content. Since materials with high-VOC content off gas, workers are at an increased risk of inhaling toxic fumes during construction of a conventional roof. Another suggesting issue is the fact that asphalt is not used in green roof construction. Hot roofing asphalt used in conventional roofing not only off gases, but is at very high temperatures during application. Workers in the vicinity of the hot asphalt are at potential risk for sustaining a burn injury.

The next positive aspect of green roof construction is that a torch is not used to install any of the roofing materials. With built-up and modified bitumen roofing systems, a torch is used for material application. By eliminating the use of a torch, workers are removed from the exposure to a fire hazard.

Additional safety hazards that were identified for green roof construction and conventional roof construction were very similar. These cannot be used as evidence to suggest that green roof construction has a positive impact on worker safety. For example, workers are exposed to the same safety hazards associated with lifting either green roof or conventional roof materials to the roof using a crane. Workers are also exposed to relatively the same fall hazards with regards to green roof construction and conventional built-up or modified bitumen roof construction.

Photovoltaic System

The safety hazards that were identified in the interviews suggest that photovoltaic system installation has a negative impact on worker safety. This is because workers are at constant exposure to shock hazards during installation. Once the photovoltaic panels are mounted on the roof and sunlight is present, electrical current is being produced in which workers are at potential risk of getting shocked.

Another negative impact on worker safety was in regards to the weight and shape of the PV panels. The PV panels weigh around 40-50 pounds and can cause back injuries and/or muscle strains when being lifted. In addition, serious injury, such as broken bones and contusions, can occur if a PV panel is dropped onto a worker. The large shape of the PV panel poses the threat of a worker being pushed off balance from the panel catching wind while being moved. This could cause the worker to fall down on the roof or fall off the roof, sustaining a serious or fatal injury.

The last main safety hazard that was directly related to PV system installation that suggests a negative impact on worker safety is exposure to tripping hazards. Sections of the electrical wiring that connect the sets of PV panels that are exposed are elevated just enough off the roof to cause a worker to trip when moving around. In addition to the electrical wiring being a tripping hazard is the railing that the PV panels are mounted to. The rails protrude about four to six inches from the PV panels and could cause a worker to trip if they are walking too close. Since there is limited amount of workspace available on the roof when installing the PV panels, the potential for a worker tripping over electrical wires or the PV mounting rails is increased.

Non-Petroleum-Based Roofing

The information solicited from the interviews suggests that constructing non-petroleum-based roofing has a positive impact on worker safety. Single-ply systems that use PVC or thermoplastic membrane materials were identified as being non-petroleum-based roofing systems. The PVC or thermoplastic membranes have a reduced impact on worker health and safety because they do not off gas and do not require extensive heating measures, such as an open-flame torch, for application to the solid underlayment. Workers are not exposed to toxic inhalants and are not at risk to burn injuries from a torch. With the conventional built-up and modified bitumen roofing systems, which are petroleum-based, the membrane materials emit fumes and require a torch for application. Workers are at potential risk of inhaling the toxic fumes and are exposed to a fire hazard from the torch. Specifically, with a built-up roof, the petroleum-based roofing material used is hot asphalt. Hot asphalt not only off gases, which exposes workers to a toxic inhalant, but also is heated to temperatures high enough to cause severe burn injuries to workers if they come in contact with it.

Future Research Recommendations

This research has revealed primary safety concerns associated with constructing ICFs, green roofs, photovoltaic systems, and non-petroleum-based roofing. In future research, the use of a survey along with the expert interviews is recommended to identify additional safety hazards associated with the selected sustainable building components. The use of a survey would expand the amount of data gathered with regards to safety hazards to make a more accurate assessment as to whether the selected sustainable building components have a negative or positive impact on worker safety. It is also recommended that safety representatives be selected as participants for future expert interviews since this study did not include any safety expert interviewees.

APPENDIX A
ICF WALL CONSTRUCTION JSA

Construction Activity: ICF Wall Construction	**JOB SAFETY ANALYSIS**		
Sequence of Basic Job Tasks	***Tools/Equipment Required***	***Potential Hazards***	***Preventative Action or Procedure***
Mark perimeter of foundation with chalk line, string, or temporary 2x4 bracing on foundation for ICF block alignment	Chalkline reel, 2 x 4 lumber, hacksaw or table saw, concrete screws, elecric drill	Cut injuries from hacksaw or table saw; eye injiuries from saw dust/particles; trip hazards	Make sure to wear proper PPE (safety glasses, gloves; long sleeves if necessary, work boots) when cutting 2x4s; clear work area of any potential trip hazards: keep work area neat and organized; clear scrap pieces of 2x4 bracing
Place ICF blocks at corners, lay first course of blocks around entire perimeter	Hacksaw, heat gun/hot knife	Cut injuries from hacksaw; burn injuries from heat gun/hot knife; trip hazards	Make sure to wear proper PPE (safety glasses, gloves; long sleeves if necessary, work boots) when cutting ICF blocks; keep stockpile of ICF blocks away from immediate work area, only have necessary amount in workspace needed for first course of blocks and at corners to reduce potential for trip hazard
Continue laying additional courses of ICF blocks; Place vertical rebar every 48", place horizontal rebar every one to two feet or as required	Hacksaw, heat gun/hot knife, cutter bender (rebar), wire tie, wire snips, scaffolding	Cut injuries from hacksaw; burn injuries from heat gun/hot knife; trip hazards; fall hazards if scaffolding is used; muscle strains and back injuries when cutting or bending rebar; falling objects	Make sure to wear proper PPE when using cutter bender for rebar and when cutting ICF blocks; position body in proper manner to reduce the potential for muscle injury when bending or cutting rebar; do not pull cutter bender towards body-push away from body to prevent injury; keep heat gun/hot knife away from extremeties; when scaffolding is used make sure to keep work area clear of any trip hazards; inspect scaffolding daily
Install temporary wall bracing with 2x4's on all walls and openings while continuing laying additonal courses	Hacksaw or table saw, heat gun/hot knife, 2x4 lumber, hammer, nails	Cut injuries from hacksaw or table saw; eye injiuries from saw dust/particles; trip hazards; injury from hammer; falling objects	Make sure to wear proper PPE (safety glasses, gloves; long sleeves if necessary, work boots) when cutting 2x4s; When installing the temporarry bracing, make sure that workers around are aware if working above
Block all window and door openings with pressure treated lumber	Hacksaw or table saw, presssure treated lumber	Cut injuries from hacksaw or table saw; falling objects	Make sure to wear proper PPE (safety glasses, gloves; long sleeves if necessary, work boots) when cutting pressure treated lumber
Once wall is at specified hieght, seal joints of ICF blocks with foam sealant to secure blocks until concrete is poured	Foam sealant	Off-gassing from sealant	If foam sealant used generates toxic fumes, make sure to stay in well ventilated area; if working inside with little or no air mvement, use a large shop fan for fresh air
Place 2x4 bracing on top of wall and secure it to the ICF steel furrings and side bracing to help keep forms in place during pouring of concrete	Hacksaw or table saw, 2x4 lumber, ladder	Cut injuries from hacksaw or table saw; eye injiuries from saw dust particles; falling objects; fall hazard	Make sure to wear proper PPE (safety glasses, gloves; long sleeves if necessary, work boots) when cutting 2x4s; If a ladder is required, make sure to securely tie the ladder off to a solid structure; If working at a higher elevation, such as on a ladder, be aware of workers below and concious of the materials and tools you are working with
Pour concrete with chute or boom truck in 4-foot increments	Boom truck or chute	Skin irritation from concrete; harmful inhalants from mixing	Make sure to wear proper PPE (safety glasses, gloves; long sleeves, work boots) when working with concrete; If mixing of concrete is required, make sure to wear some type of respiratory protection
Level off top of wall after top increment is poured with concrete and insert anchor bolts for the top plate for roof construction	Ladder	Falling objects; fall hazards	Keep anchor bolts secure when working on ladder to prevent any from falling below; Make sure to securely tie ladder off if one is needed

APPENDIX B
CMU WALL CONSTRUCTION JSA

Construction Activity: CMU Wall Construction	**JOB SAFETY ANALYSIS**		
Sequence of Basic Job Tasks	***Tools/Equipment Required***	***Potential Hazards***	***Preventative Action or Procedure***
Locate corners of the building; mark perimeter of foundation with string or chakline for alignment of CMU blocks	Chalkline reel, string	Trip hazards	Clear work area of any potential trip hazards: keep work area neat and organized; be aware of alignment stakes (if used) and strings
Place one course of CMU blocks at each corner to determine the extent to which the units have to be cut to accommodate the horizontal coursing; make necessary cuts to fit CMU blocks for the corners	Concrete/masonry saw	Back injuries/muscle strains; severe bodily injury from saw blade; flying objects: dust particles and concrete fragments; eye injuries, inhalation of dust particles	Make sure to wear proper PPE (safety glasses, gloves; long sleeves if necessary, work boots, respiratory gear) when cutting CMU blocks; Use proper lifting techniques when lifting and placing CMU blocks, i.e., lift with legs instead of back; When cutting CMU blocks, make sure to position self in opposite direction of the path of projected fragments and dust from saw blade; keep extremities clear of spinning saw blade
Spread a thick bed of mortar on the foundation for the first course of CMU blocks to ensure enough mortar will be along the bottom edge of the face shells and web of the blocks	Mixer, bucket/wheelbarrow, trowel, concrete/masonry saw	Skin irritation from caustic grout; Inhalation of dust generated from mixing grout; back injuries/muscle strains	Make sure to wear proper PPE (safety glasses, gloves; long sleeves if necessary, work boots, respiratory gear) Use proper lifting techniques when moving and placing CMU blocks
After first course is laid, build up each corner of the wall to the height of the center of the wall specified; Each course shall be stepped back by one-half unit	Mixer, bucket/wheelbarrow, trowel, ladder/scaffolding (if necessary)	Falling objects; fall hazard; back injuries/muscle strains	When laying CMU blocks, make sure that workers around are aware of work above; if scaffolding is erected/necessary make sure to tie-off if required and clear work space of any trip hazards; use proper lifting techniques when laying CMU blocks
Stretch line from corner to corner to ensure additional courses are plumb and true; Start to lay blocks between each corner; Construct wall in 4-foot lifts, or every 6 courses; Mortar joints shall be 3/8" thick;	Scaffolding, bucket, trowel	Falling objects; fall hazard; skin irritation; back injuries/muscle strains; cuts and scrapes from CMU blocks; trip hazard	Make sure to wear proper PPE (safety glasses, gloves; long sleeves if necessary, work boots) when mixing and/or placing grout; keep stockpile of CMU blocks away from immediate work area, only have necessary amount in workspace needed for first course of blocks and at corners to reduce potential for trip hazard; Be aware of potential objects that could fall from scaffolding or elevated position; Contact with CMU blocks can cause skin abrasions: handle CMU blocks properly to avoid injury
Place horizontal and vertical rebar as each course is constructed: horizontal rebar every 16" (every other course), vertical rebar every 48"	Scaffolding, cutter bender (rebar), wire tie, wire snips	Falling objects; fall hazard; back injuries/muscle strains (from bending or cutting rebar); trip hazard	Make sure to wear proper PPE when using cutter bender for rebar and when cutting ICF blocks; position body in proper manner to reduce the potential for muscle injury when bending or cutting rebar; do not pull cutter bender towards body-push away from body to prevent injury; when scaffolding is used make sure to keep work area clear of any trip hazards; inspect scaffolding daily
Place additional vertical rebar at every corner and opening as required; Pour column with concrete every 48"	Scaffolding, cutter bender, chute or boom truck, trowel, wire tie, wire snips	Falling objects; fall hazard; back injuries/muscle strains; skin irritation; inhaltion of dust generated from mixing grout	Make sure to wear proper PPE (safety glasses, gloves; long sleeves if necessary, work boots) when mixing and/or placing grout; position body in proper manner to reduce the potential for muscle injury when bending or cutting rebar; do not pull cutter bender towards body-push away from body to prevent injury; When pouring concrete column in CMU wall, alert any workers below of actions to avoid injury from any falling objects
Cut CMU blocks to size for all window and door openings; Place lintel blocks for window and door openings: place horizontal rebar and fill with concrete	Scaffolding, concrete/masonry saw, cutter bender, bucket, trowel	Falling objects; fall hazard; back injuries/muscle strains; skin irritation; inhaltion of dust generated from mixing grout;severe bodily injury from saw blade; flying objects: concrete fragments causing eye injuries	Make sure to wear proper PPE (safety glasses, gloves; long sleeves if necessary, work boots) when cutting CMU blocks; When cutting CMU blocks, make sure to position self in opposite direction of the path of projected fragments and dust from saw blade; keep extremities clear of spinning saw blade
Place final courses to achieve specified wall height	Scaffolding, concrete/masonry saw, cutter bender, bucket, trowel	Falling objects; fall hazard; back injuries/muscle strains; skin irritation; inhaltion of dust generated from mixing grout	Make sure to wear proper PPE (safety glasses, gloves; long sleeves, work boots) when working with grout; If mixing of grout is required, make sure to wear some type of respiratory protection; clear area of potential falling objects and trip hazards

APPENDIX C
SINGLE-PLY WALL CONSTRUCTION JSA

Construction Activity: Single-Ply Roof Construction	**JOB SAFETY ANALYSIS**		
Job Tasks (Listed in Sequence)	***Tools/Equipment Required***	***Potential Hazards***	***Preventative Action or Procedure***
Mechanically fasten preformed roof insulation board to roof deck	Mechanical fastener power tool, mechanical fasteners, electrical extension cord, ground-fault circuit interrupter (GFCI), utility knife	a. Fall hazards; b. Falling objects; c. Trip hazard; d. Electrical shock; e. Cut injuries from utility knife	a. If no parapet wall is present, make sure follow proper tie-off measures; properly tie ladder off to building structure; b. keep area clean and free of debris to prevent objects from falling off the roof; secure mechanical fastener power tool to roof structure to prevent it from falling off the roof; c. Make sure to keep all electrical cords coiled up if not in use; if the cords are in use keep them as organized as possible to help prevent a worker from tripping; d. Make sure to plug electrical cord into a GFCI before using any power tools to prevent possible electrical shock; e. Make sure to wear durable enough gloves to help reduce risk of being cut; always cut away from body
Lay down single-ply membrane (EPDM, PVC, or TPO) on top of insulation board	Utility knife	a. Cut injuries from knife	a. Make sure to wear proper PPE (safety glasses, gloves, long sleeves and pants, work boots); make sure to wear durable enough gloves to help reduce risk of being cut; always cut away from body
Loose laid system: Lay down smooth aggregate ballast over single-ply membrane	Bucket for ballast	a. Back injuries/muscle strains	a. Make sure to use proper lifting techniques (lift with legs, not with back) when lifting buckets of aggregate and spreading
Bond together adjoining sheets with manufacturer's sealant		a. Off-gassing from solvent-based adhesives (if used)	a. If water-based adhesives are not used and solvent-based adhessives are, wear respiratory protection if fumes are concentrated;
Mechanically fastened system: Mechanically fasten membrane to structural deck; place metal batten bars at specified intervals and screw membrane to the deck	Mechanical fastener power tool, mechanical fasteners, electrical extension cord, ground-fault circuit interrupter (GFCI)	a. Trip hazard; b. Electrical shock	a.Make sure to keep all electrical cords coiled up if not in use; if the cords are in use keep them as organized as possible to help prevent a worker from tripping; b. Make sure to plug electrical cord into a GFCI before using any power tools to prevent possible electrical shock
Adhered system: Apply adhesive/solvent to underside of single-ply membrane and press the membrane down, securing it to the insulation layer		a. Off-gassing from solvent-based adhesives (if used)	a. If water-based adhesives are not used and solvent-based adhessives are, wear respiratory protection if fumes are concentrated;

APPENDIX D
BUILT-UP ROOF CONSTRUCTION JSA

Construction Activity: Built-Up Roof Construction	**JOB SAFETY ANALYSIS**		
Job Tasks (Listed in Sequence)	***Tools/Equipment Required***	***Potential Hazards***	***Preventative Action or Procedure***
Nail down or mechanically fasten base sheet to roof structure	Hammer, nails, mechanical fastener power tool, mechanical fasteners	a. Fall Hazards; b. Falling objects	a. If no parapet wall is present, make sure follow proper tie-off measures; b. Make sure to alert workers below when using a hammer and nail in case either one falls; keep area clean and free of debree to prevent objects from falling off the roof
Place first layer of preformed roof insulation board over roof deck with base sheet and bond it with either hot bitumen or an adhesive	Adhesive, hot-asphalt bucket, mop, utility knife	a. Off-gassing from adhesive or asphalt; b. Burn injuries from hot asphalt; c. Cut injuries from knife	a. If fumes are concentrated, wear some type of respiratory protection; b. Make sure to wear proper PPE (safety glasses, gloves, long sleeves and pants, work boots) when working with the hot ashpalt; keep as much distance as possible from the bucket and when mopping ; c. Make sure to wear durable enough gloves to help reduce risk of being cut; always cut away from body
Mop down the first insulation board layer with hot asphalt	Hot-asphalt bucket, mop, utlity knife	a. Off-gassing from adhesive or asphalt; b. Burn injuries from hot asphalt	a. If fumes are concentrated, wear some type of respiratory protection; b. Make sure to wear proper PPE (safety glasses, gloves, long sleeves and pants, work boots) when working with the hot ashpalt; keep as much distance as possible from the bucket and when mopping
Place second layer of preformed roof insulation board over first insulation board and mop down with hot asphalt	Hot-asphalt bucket, mop, utlity knife	a. Off-gassing from adhesive or asphalt; b. Burn injuries from hot asphalt; c. Cut injuries from knife	a. If fumes are concentrated, wear some type of respiratory protection; b. Make sure to wear proper PPE (safety glasses, gloves, long sleeves and pants, work boots) when working with the hot ashpalt; keep as much distance as possible from the bucket and when mopping ; c. Make sure to wear durable enough gloves to help reduce risk of being cut; always cut away from body
Lay down asphalt-coated base sheet and mop down with hot asphalt	Hot-asphalt bucket, mop, utlity knife	a. Off-gassing from adhesive or asphalt; b. Burn injuries from hot asphalt; c. Cut injuries from knife	a. If fumes are concentrated, wear some type of respiratory protection; b. Make sure to wear proper PPE (safety glasses, gloves, long sleeves and pants, work boots) when working with the hot ashpalt; keep as much distance as possible from the bucket and when mopping ; c. Make sure to wear durable enough gloves to help reduce risk of being cut; always cut away from body
Lay down first layer of #4 asphalt glass fiber felt and mop down with hot asphalt	Hot-asphalt bucket, mop, utlity knife	a. Off-gassing from adhesive or asphalt; b. Burn injuries from hot asphalt; c. Cut injuries from knife	a. If fumes are concentrated, wear some type of respiratory protection; b. Make sure to wear proper PPE (safety glasses, gloves, long sleeves and pants, work boots) when working with the hot ashpalt; keep as much distance as possible from the bucket and when mopping ; c. Make sure to wear durable enough gloves to help reduce risk of being cut; always cut away from body
Lay down second layer of #4 asphalt glass fiber felt and mop down with hot asphalt	Hot-asphalt bucket, mop, utlity knife	a. Off-gassing from adhesive or asphalt; b. Burn injuries from hot asphalt; c. Cut injuries from knife	a. If fumes are concentrated, wear some type of respiratory protection; b. Make sure to wear proper PPE (safety glasses, gloves, long sleeves and pants, work boots) when working with the hot ashpalt; keep as much distance as possible from the bucket and when mopping ; c. Make sure to wear durable enough gloves to help reduce risk of being cut; always cut away from body
Lay down third layer of #4 asphalt glass fiber felt and mop down with hot asphalt	Hot-asphalt bucket, mop, utlity knife	a. Off-gassing from adhesive or asphalt; b. Burn injuries from hot asphalt; c. Cut injuries from knife	a. If fumes are concentrated, wear some type of respiratory protection; b. Make sure to wear proper PPE (safety glasses, gloves, long sleeves and pants, work boots) when working with the hot ashpalt; keep as much distance as possible from the bucket and when mopping ; c. Make sure to wear durable enough gloves to help reduce risk of being cut; always cut away from body
Lay down fourth layer of #4 asphalt glass fiber felt and mop down with hot asphalt	Hot-asphalt bucket, mop, utlity knife	a. Off-gassing from adhesive or asphalt; b. Burn injuries from hot asphalt; c. Cut injuries from knife	a. If fumes are concentrated, wear some type of respiratory protection; b. Make sure to wear proper PPE (safety glasses, gloves, long sleeves and pants, work boots) when working with the hot ashpalt; keep as much distance as possible from the bucket and when mopping ; c. Make sure to wear durable enough gloves to help reduce risk of being cut; always cut away from body
Flood-coat the top of the roof with the hot-bitumen and lay the aggregate ballast in it	Hot-asphalt bucket, mop	a. Off-gassing from adhesive or asphalt; b. Burn injuries from hot asphalt; c. Back injuries/muscle strains	a. If fumes are concentrated, wear some type of respiratory protection; b. Make sure to wear proper PPE (safety glasses, gloves, long sleeves and pants, work boots) when working with the hot ashpalt; keep as much distance as possible from the bucket and when mopping ; c. Use proper lifting techniques when working with bags/buckets of aggregate ballast to place in the hot-bitumen top coat

APPENDIX E
MODIFIED BITUMEN ROOF CONSTRUCTION JSA

Construction Activity: Modified Bitumen Roof Construction	**JOB SAFETY ANALYSIS**		
Job Tasks (Listed in Sequence)	***Tools/Equipment Required***	***Potential Hazards***	***Preventative Action or Procedure***
Mechanically fasten preformed roof insulation board to roof deck	Mechanical fastener power tool, mechanical fasteners, electrical extension cord, ground-fault circuit interrupter (GFCI), utility knife	a. Fall hazards; b. Falling objects; c. Trip hazard; d. Electrical shock; e. Cut injuries from utility knife	a. If no parapet wall is present, make sure follow proper tie-off measures; properly tie ladder off to building structure; b. keep area clean and free of debris to prevent objects from falling off the roof; secure mechanical fastener power tool to roof structure to prevent it from falling off the roof; c. Make sure to keep all electrical cords coiled up if not in use; if the cords are in use keep them as organized as possible to help prevent a worker from tripping; d. Make sure to plug electrical cord into a GFCI before using any power tools to prevent possible electrical shock; e. Make sure to wear durable enough gloves to help reduce risk of being cut; always cut away from body
Lay down asphalt-coated base sheet and secure it to insulation board (may be self-adhering or require use of adhesive)	Adhesive (if not self-adhering sheet), utility knife	a. Off-gassing from adhesive; b. Cut injuries from knife	a. If fumes are concentrated, wear some type of respiratory protection; b. Make sure to wear proper PPE (safety glasses, gloves, long sleeves and pants, work boots); make sure to wear durable enough gloves to help reduce risk of being cut; always cut away from body
Lay down the modified bitumen sheets which has the bitumen susbstance on the bottom surface	Utlity knife	a. Cut injuries from knife	a. Make sure to wear durable enough gloves to help reduce risk of being cut; always cut away from body
Torch down each sheet of modified bitumen ply as it is laid out	Propane torch	a. Off-gassing from bitumen sheet; b. Burn injuries from torch; c. Fire hazard	a. If fumes are concentrated, wear some type of respiratory protection; b. Make sure to wear proper PPE (safety glasses, gloves, long sleeves and pants, work boots) when working with the propane torch; alwyas keep flame directed away from body, especially the feet; c. Keep fire extinguisher within 25 feet of open-flame torch; keep torch flame away from any combustible materials

APPENDIX F
GREEN ROOF CONSTRUCTION JSA

Construction Activity: Green Roof Construction	**JOB SAFETY ANALYSIS**		
Job Tasks (Listed in Sequence)	***Tools/Equipment Required***	***Potential Hazards***	***Preventative Action or Procedure***
Place the root barrier on the waterproof membrane roof	Utility knife	a. Fall Hazards; b. Cut injuries from knife	a. If no parapet wall is present, make sure follow proper tie-off measures; b. Make sure to wear durable enough gloves to help reduce risk of being cut; always cut away from body
Place insulation layer on top of root barrier	Utility knife	a. Cut injuries from knife	a. Make sure to wear durable enough gloves to help reduce risk of being cut; always cut away from body
Lay down the synthetic or natural drainage layer (porous mat)	Utility knife	c. Cut injuries from knife	a. Make sure to wear durable enough gloves to help reduce risk of being cut; always cut away from body
Lay down separation fabric on top of drainage layer	Utility knife	c. Cut injuries from knife	a. Make sure to wear durable enough gloves to help reduce risk of being cut; always cut away from body
Hoist up growing medium/soil substrate to roof	Truck with boom crane or lull	a. Falling objects	a. Make sure to properly rig heavy bags of soil; stay clear of elevated materials when being hoisted to roof- do not stand underneath hoisted materials; always have a tag line attached to hoisted materials to guide it when being set down onto roof
Spread growing medium/soil substrate out evenly among the separation fabric	Shovel, rake, utility knife	a. Back injuries/muscle strains; b. Cut injuries from knife	a.Use proper lifting techniques (lift with legs and not with back) when moving heavy bags of growing media/soil; b. Make sure to wear durable enough gloves to help reduce risk of being cut when opening bags of media; always cut away from body
Hoist up vegetation - Extensive systems: plants, shrubs, grass; Intensive systems: plants, shrubs, grass, trees	Truck with boom crane, lull	a. Falling objects	a. Make sure to properly rig trees and heavy pots with plants; stay clear of elevated materials when being hoisted to roof- do not stand underneath hoisted materials; always have a tag line attached to hoisted materials to guide it when being set down onto roof
Plant vegetation materials in growing medium/soil substrate	Shovel, rake, truck with boom crane or lull	a. Back injuries/muscle strains; b. Bodily injuries from heavy trees and potted plants	a.Use proper lifting techniques (lift with legs and not with back) when moving and planting heavy vegetation materials; b. When large trees and potted plants are being planted/set down into media and have to utilize a crane or lull, make sure to stay clear of the objects when they are still elevated - keep safe distance away in case tree falls over or rigging malfunctions

APPENDIX G
PHOTOVOLTAIC SYSTEM INSTALLATION JSA

Construction Activity: Photovoltaic System Installation

JOB SAFETY ANALYSIS

Job Tasks (Listed in Sequence)	***Tools/Equipment Required***	***Potential Hazards***	***Preventative Action or Procedure***
Make roof penetrations for installation of aluminum L-brakets	Electric drill with bit	a. Fall hazards	a. If no parapet wall is present or on sloped roof, make sure follow proper tie-off measures; properly tie ladder off to building structure; make sure to wear proper PPE (safety glasses, gloves) when drilling into roof
Apply polyurethane sealant to roof penetrations then bolt down aluminum L-brackets	Electric drill	a. Pinch hazards	a. Wear protective gloves and keep clear of pinch points
Bolt aluminum mounting rails to L-brackets	Electric drill/rachet	a. Trip hazards	a. Make sure to identify L-brackets installed to avoid tripping when moving around roof to install mounting rails
Hoist PV panels to roof	Truck with boom crane or lull	a. Falling objects	a. Make sure to properly secure/rig PV panels when lifting them up to roof; stay clear of PV panel when being lifted and do not stand underneath hoisted panel
Set PV panels on mounting rails	None	a. Back injuries/muscle strains; b. Fall hazard; c. Trip hazard	a.Use proper lifting technique (lift with legs, not back) when setting PV panels onto mounting rails; b. Make sure to properly tie-off when handling panels in case of becoming off-balance or strong gusts of wind are present to prevent being thrown off the roof or falling down on the roof; c. Clear area of any loose objects/tools/materials when setting the PV panels to prevent tripping
Secure PV panels to mounting rails with hold-down clamps	Rachet or electric drill	a.Pinch hazards	a. Wear protective gloves and keep clear of pinch points
Install PV combiner boxes and inverter	Electric drill/rachet	None	None
Solar contractor: Install system wiring - ground wiring and DC wiring	None	a. Electrical shock	a. If PV panels are not covered when installed and sunlight is present, make sure to wear protective gloves to prevent electrical shock from the DC current generated
Electrician: Install AC wiring from inverter to main service panel	None	a. Electrical shock	a. If PV panels are not covered when installed and sunlight is present, make sure to wear protective gloves to prevent electrical shock from the ACcurrent generated

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BIOGRAPHICAL SKETCH

Brent Olson was born in Titusville, Florida. He graduated from Astronaut High School in 2003 and then attended Brevard Community College from 2003 until 2005 where he received his Associate of Arts degree. Brent then attended the University of Florida from 2005 until 2008 where he received his Bachelor of Arts degree in Food Science and Human Nutrition. He then began attending the M.E. Rinker, Sr. School of Building Construction in 2008. Brent has worked as an intern for W.W. Gay Mechanical Contractors and TIC – The Industrial Company. Upon receiving his master's degree in building construction, Brent plans to begin his career in the industrial construction industry as an entry level field engineer with TIC – The Industrial Company.