Cold-Formed Steel Wall Panels in a Production Setting: A Case Study of Navy Housing at Radford Terrace on Oahu, Hawaii

Submitted to:

Partnership for Advancing Technology in Housing
U.S. Department of Housing and Urban Development
Washington, DC

And

Steel Framing Alliance
Washington, DC 20005

Steel Framing Alliance™
Steel. The Better Builder.

Prepared by:

Newport Partners, LLC
Davidsonville, MD 21035
www.newportpartnersllc.com

December 26, 2007

Background and Acknowledgements

The objective of this project is to gather state-of-the-art information to enable builders and framers to better integrate steel-framed wall panelization methods and processes into their construction systems, designs and business models. This stage of the project consists of a series of case studies on builders and framers who are successfully using panelized construction in concert with cold-formed steel. This report addresses a case study conducted on the use of cold-formed steel panels in a production setting in Hawaii.

Residential steel framing has been used extensively in Hawaii for at least the past ten years. Builders in Hawaii face many of the same issues as those in the gulf coast region of the United States, especially in regard to termite infestation and climate issues. Thus, the experience gained in Hawaii is important to transfer to other locations to minimize false starts and shorten the learning curve of builders who are looking for sustainable and efficient alternatives to current practices.

Observations and interviews were conducted with personnel from Hunt Building Company (Hunt) and Worthington Military Construction, LLC (Worthington). The builder, Hunt, is using steel panels fabricated and installed by Worthington. The construction site was observed for four consecutive days to document site-specific practices. We also visited the fabrication facility to document their operations. One-on-one interviews were conducted with management representatives from both companies and with construction site workers and sub-contractors regarding their impressions on working with steel in general and steel panels specifically.

This case study and report were prepared by Matt Hawkins and Mark Nowak of Newport Partners LLC. We extend special thanks to Stu Britt of Worthington Military Construction LLC and Ralph Valentino of Hunt Building Company for their assistance throughout the project. Funding for the project was provided through a cooperative agreement between the Steel Framing Alliance and the U.S. Department of Housing and Urban Development, Office of Policy Development and Research.

Section 1 –General site information and participants

Forest City Military Communities was selected by the U.S. Department of the Navy to build and manage Navy Housing in the Hawaii region under the Navy's PPV (Public-Private Venture) program. PPV was initiated by the U.S. Congress and the Department of Defense in response to a need to rapidly increase the quantity and quality of military family housing.

Under this particular PPV project, Forest City retains a 50 year lease on the homes and surrounding property. They assume responsibility for management, construction, renovation, and maintenance of the homes during the lease period. Military personnel rent the units using their housing allowance. The program relies on private sector financing and management to more efficiently do what was formerly the sole responsibility of the government.

This case study was conducted on Navy housing at Radford Terrace, located just outside the Honolulu International Airport. Radford Terrace is a large, multi-year project that consists primarily of the demolition and replacement of homes originally built prior to 1960. The project is situated within an existing urban/suburban neighborhood. In all, 741 new hones will be built over several years time.

Completed homes in Radford Terrace neighborhood

Forrest City manages the homes but they subcontract out all construction. Thus, this case study focuses on the activities and business models of the framer and the builder who are more closely connected to the use of steel framed wall panels at this project.

Forest City has subcontracted the demolition and construction to Hunt Building Company. Hunt has constructed thousands of homes for the U.S military over the years under both conventional turnkey contracts and more recently under the DOD privatization program. Contact information for Hunt is as follows:

Ralph Valentino, Project engineer
Hunt Building Company
5555 Cormorant Ave.
Ewa Beach, HI 96706

Hunt in turn, has entered into a contractual relationship with Worthington Military Construction LLC for the framing operations. The two companies work closely on the design and scheduling of the homes. Worthington is responsible for the entire house framing and also supplies steel-framed wall panels for the project. Contact information for Worthington is as follows:

Stuart C. Britt, vice-president
Worthington Military Construction
94-216 Farrington Hwy B-208
Waipahu, HI 96797

Housing characteristics

The homes under construction at Radford Terrace range between 1,750 and 2,000 square feet. They are all two-story, with three bedrooms and an attached garage. The foundation is a concrete slab. There is a mix of attached and detached units.

Cold-formed steel panels are used for the first and second floor walls. Load bearing walls typically are 43 mil (18 gauge) cold-formed steel. The floor trusses and roof framing are wood.

Formosan termites are a threat to untreated wood throughout Hawaii. Thus, the market and building codes have moved toward building with treated wood, concrete, steel and other termite resistant members.

At Radford Terrace, the HVAC ducts were too large to be run in a floor system framed with steel joists. The builder thus designed the homes with treated wood trusses to provide flexibility in the duct system layout.

Framing innovations

There are two innovative aspects of the production process designed to ensure that steel is used in the most efficient manner on this project. First is the use of a steady and predictable construction process at the housing site. Second is the off-site panelization of walls.

The production process was initially similar to most construction in the United States, with a single crew responsible for framing a home from start to finish

before moving on to the next home. Recently, the framer switched to a process similar to “even-flow” production often used in a manufacturing setting.

Under the even-flow approach, Worthington’s crews are organized according to specific tasks or phases of construction as opposed to one crew doing the entire house frame. The goal is to construct seven homes each week following a predictable schedule for each day for each crew.

The first crew prepares the foundation and stands up the first floor wall panels. Another individual follows them and installs the anchor bolts. A third crew installs the floor joists and support beams. Another crew then installs sheathing on the second floor joists.

Second floor wall panels are sheathed and stood up by one crew while the first floor walls are sheathed by another crew. Next the truss crew installs the main roof trusses. The fascia is then attached by one crew followed by the soffit material. Last, the roof decking is applied by yet another crew. Worthington is also responsible for interior partitions and window installation.

Floor joists supported by steel wall panels. Note that the trusses are each directly located over a stud (inline framing). Further, in order to avoid unusual connection details between the floor trusses and the steel walls, a wood top plate is installed on the panels during fabrication at the panel plant.

Each phase is completed in less than a day but an entire home takes about four weeks from foundation until the framing is complete. A home is finished in roughly sixty days after foundation, including painting and carpeting.


Off-site panel plant

Hunt and Worthington prefer to fabricate panels from pre-cut studs and track sections. Pre-cut studs and tracks reduce fabrication times.

Fabrication at the construction site reduces transportation costs and enables the panels to be stored at their respective building site. However, space constraints at this project required Worthington to build the walls at an off-site plant and transport them to the site for installation.

Employees are paid roughly $20 an hour at an offsite plant while employees in the field are governed by union requirements and received upwards of $50 an hour. In this case, off-site panel production resulted in more use of lower cost labor.

The plant and site framing personnel are different crews – the site crews stay on site and the plant crew works only at the plant. Site crews service multiple builders around Oahu, whereas the specific panel fabrication crew for this project only services the Radford Terrace project.

Surrounding Housing Market

The surrounding area (Aiea and Pearl City) consists of modest-priced homes relative to housing costs in Hawaii. Existing homes in this area range from $500,000 to $650,000 while new construction starts at $600,000 and up. In high cost locations new construction starts around $1 million. The median home price for the island of Oahu is just above $600,000.

Radford Terrace is a not a for-sale project so comparable sales data is not available. Total construction costs of the homes are just above $200,000 per unit not including land and utility costs. As with other homes on the island, land costs are high and lot sizes are small.

Selection factors for steel

Cold-formed steel framing is used in Hawaii primarily due to the aggressiveness of Formosan termites. The termite infestation problem forced the U.S. military services to specify steel or other termite-resistant materials over a decade ago. Building codes that govern the private sector have adopted similar practices.

Summary of process

Hunt was constructing military homes in Hawaii well before steel use was mandated. The conversion process at the design and construction level wasn't difficult compared to finding a business arrangement that worked. Hunt contracts out all panel fabrication and installation to Worthington, who also does the majority of panel design with Hunt oversight. This arrangement provides Hunt with one contractor in charge of the entire structural system. Worthington has an incentive under this system to improve efficiency since they will save money, whereas with multiple contractors the desire to improve efficiency is lessened when the resulting savings go to another contractor.

Worthington employs an even-flow or task construction process. Instead of building a complete home at a time, a crew is dedicated to a specific construction task. This results in multiple homes being constructed at the same time and in different stages of construction. This limits the number of people in a home at a given time. Trades are scheduled to follow each other through the construction site resulting in only one trade contractor in a home at time.

Success to date

The approach used for incorporating steel panels into the homes at Radford Terrace has evolved over time, with efficiencies incorporated along the way. The switch from building one home at a time to building a group of homes at the same time using crews who are dedicated to specific tasks is the latest evolution in the approach.

The task-oriented building approach initially resulted in slower construction times. Over the life of the project the workers become familiar with their tasks and efficiency improved dramatically. The builder recommends this construction process for projects over 100 units.

The approach used by Hunt and Worthington at Radford Terrace has been successful for all parties involved. They have averaged about 150 homes per year over the past three years and have 300 more planned for the next two years. The same arrangement is being planned for a second project on Oahu.

Section 2 - Business model and relationships

Under their agreement with Forest City, Hunt is responsible for design, construction, and selection of all trade contractors. Thus, Forest City is not directly involved in the business relationship relative to how steel is used in the homes. This is primarily between Hunt and the framer, Worthington Military Construction LLC.

A key to the successful relationship between Worthington and Hunt is the comprehensive framing service provided by Worthington. Worthington is responsible for all framing activities including fabricating, designing, and erecting steel wall panels, and installing roof and floor trusses, interior partitions, all sheathing, and windows. They are not responsible for roofing paper, house wrap or siding. Worthington is also the steel stud supplier for partition walls. Worthington is responsible for completing at least seven homes a week to maintain the production schedule.

The steel studs are roll-formed at Worthington's Hawaiian steel processing facility and shipped to the fabrication plant. Wall panels are assembled at the plant and shipped to the job site.

Worthington is responsible for all inventory and supply issues related to fabrication and framing, including purchasing tools, screws and power generators. In the past, the builder purchased screws for the framer but this agreement ended because the framing crew and Worthington had no incentive to reduce lost screws.

Worthington works closely with the designer to create at least one model home. The model home serves as a check against contract requirements and identifies construction issues that could arise.

Unlike most framing operations, Worthington has adopted a production process that brings in components of assembly line methods used in manufacturing. They employ what could be termed an "even-flow" process where a crew or person is responsible for specific tasks rather than one crew framing the entire home. Thus, they have multiple crews who work on different parts of the framing on each home on a predictable schedule.

One major factor in deciding to use the even-flow construction method was the size of the building project. The builder stated that their business model, which includes contracting out the entire design, fabrication, and framing package, works very well for projects over 100 homes.

In the traditional approach with one crew doing the entire home, Worthington and Hunt realized that the tradesmen were interfering with each other, frequently causing delays and cost overruns. The task orientated, even-flow process ensures that only one trade is working inside a home at any given time.

The siding and wrapping crew, who operate outside of the home, are the only crews working on a home while other sub-contractors are present. There was a siding crew working on at least four homes during the framing stage.

Land sharing

Availability of land for a panel fabrication plant is critical to the success of this project. Land is an expensive part of the equation in most locations, but even more so in the Hawaiian Islands where land is at a premium. Hunt has a unique land sharing relationship with Worthington to enable both parties to achieve efficiencies and profits that would be harder to achieve with a conventional contractor-supplier relationship.

Worthington's panel plant is located on land owned by Hunt. The panels are built and stored there until being transported to the construction site. The use of Hunt's land for fabrication and storage is negotiated in the contract between the two parties and reduces the steel panel costs to Hunt. Worthington can offer lower prices to Hunt since they do not have to lease or purchase land for a facility. Hunt and Worthington would prefer to locate the fabrication plant at the construction site to further reduce transportation costs and take advantage of inventory storage. However, land constraints did not allow for on-site location of the plant at Radford Terrace. On their next project, Worthington and Hunt will fabricate panels at the construction site.

Financing

Worthington is responsible for financing and purchasing all equipment, materials and supplies necessary to frame the home. Since homes in this project are constructed by tasks rather than one home at time, the payment schedule is based on these tasks. There are eleven tasks per home (see Section 5 for more detail). The framer submits a bill to the builder detailing how many completed tasks were finished in a one month period.

Insurance

Hunt purchases insurance through Zurich, based out of Europe. They receive a twenty percent discount on builder's risk insurance for each part of the home made from steel. Hunt has explored local insurance companies but the firms are unable to offer similar discounts. The builder attributes this discrepancy to the fact Europeans have used steel for a long time in residential construction and recognize that steel won't burn. The framer and other trade contractors do not receive any insurance reductions or increases when working with steel.

Training

The construction labor market is tight in Hawaii and is union dominated. Workers are compensated according to union pay schedules. Moving from apprentice to journeyman is a four year process, accompanied with eight pay raises and advancements, one every six months. The union program requires training to advance but offers little in way of specific classes besides safety training. Thus, Worthington often trains people on the job.

A benefit of the union presence is that they provide a labor pool from which to draw workers. This helps Worthington find some workers who are already qualified without having to advertise and limits the amount of resources expended on hiring.

Lessons learned form trade contractor experience

Hunt originally adopted a conventional approach to working with steel that included separate bids for the panels, windows and framing. This process resulted in multiple firms involved in the total framing process who didn't talk to or cooperate with each other. When an issue would arise one firm would blame another firm and no real solution was developed to prevent problems from recurring. Under the current arrangement with Worthington, Hunt awards the total framing package to one company in hopes of providing an incentive to the framer to cut costs and look for time-saving strategies.

The approach with other subcontractors is still very traditional. Bids for each trade are on a per house basis. However, Hunt and Worthington have developed a close working relationship with their trade contractors, leading to improvements as everyone has become more experienced with steel. Issues raised by other trades include the following:

The electrician for the Radford Terrace homes has found working with a hybrid frame that includes steel and wood can require extra effort to run wiring. Although steel wall panels have standardized holes punched in the studs, they do not always end up in a location where the electrician needs to run the wiring. The electrician thus has to cut or drill some studs. The electrician needs to drill or cut track sections when wiring runs through the floor. In this wood-steel hybrid situation, electricians need to switch drill bits depending on whether they are drilling through wood, steel, or a combination of the two materials. Besides having to switch drill bits, steel is perceived to be harder to drill than wood. The electrician noted the ease of installation that pre-cut holes provide over wood, but still perceived that steel was more difficult to

drill than wood. This reaction may not be the same on projects where steel floors and walls are used and the need to switch between differing bits is minimized or eliminated.

The extra time and materials (grommets, screws, drill bits) required for the electrician has resulted in an up-charge compared to a home built completely from wood framing. The electrician estimated an 8% to 10% up-charge when working with a steel home over a wood home. The range depends on the configuration and the number of electrical boxes in the home.

The plumber encounters similar problems as the electrician with drill bit changes, but does not charge more to work with steel compared to a wood framed home. The plumber recommended a bi-metal drill bit to avoid time delays associated with changing drill bits. They also use a plasma cutter when cutting steel.

The drywall contractor also claims that working with steel takes longer than with wood because they have to use screws. Screwing into heavy gauge steel is more difficult than wood, especially if it is overhead. The increased application time results in an up-charge in the range of 7% to 15%.

The other trade contractors operate in a very traditional approach. None indicated that working with steel wall panels resulted in increased costs or other changes that impact the way Hunt does business with them. The perceptions of steel, issues they encountered, and solutions they employ in dealing with issues specific to steel are covered in Section 3 of this case study.

Section 3: Starting with Steel

In the mid 1990s, the U.S. military services began specifying cold-formed steel for family housing in Hawaii, with a specific focus on wall construction. The aggressive nature of the Formosan Termite was the primary reason for the shift to termite-resistant construction. Much of the private sector on Oahu has followed suit and is now using steel, treated wood, or a combination of the two. Steel has now become such a commonplace material in Hawaii that there are few significant buyer or market issues.

Builder issues

Hunt began using steel for housing in 1997, well before the start of Radford Terrace. They have used steel floor, wall, and roof framing in the past. At Radford Terrace, Hunt uses open web wood floor trusses instead of steel because openings in steel joists were too small to accommodate the size of the specified ducts. Roof framing members are wood trusses.

Hunt has used steel roof trusses in the past. For simple gable roofs, they prefer a steel panel roof system. However, some of their plans have complex roof lines with dormers, overhangs, ridges, and pop-outs to create some variety. Hunt discovered that as roofs get more complicated, steel losses its advantages over wood. Wood trusses that accommodate these design features can be built faster and at lower cost than steel roof systems. In the residential market, steel framed roof systems can cost 40% more than wood truss systems.

Hunt has tried a variety of approaches to steel framing ranging from traditional methods of subcontracting with multiple contractors for each of the individual trade activities to the current approach of using one company as the supplier, manufacturer and installer of framing materials. Along the way, they also tried a technology where they purchased an onsite roll forming system and rolled their own studs and track and built their own panels at the site. Each of these approaches carries different levels of capital investment.

Under the current approach, Hunt minimized their need for capital investment by using Worthington as a one-stop shop for a series of services that previously were provided by multiple suppliers or contractors. More specifically, by contracting out the panel fabrication and erection, Hunt limited the transition costs commonly associated with switching to steel framing. Thus, the major costs involved in using steel as compared to wood framing are incurred by Worthington on the Radford terrace project.

A disadvantage for steel identified by Hunt is that a steel design needs an engineer's and an architect's seal. Conversely, a wood home two stories and under requires an architect's seal but not the structural engineer's seal. This was attributed by the builder to the longer history of building with wood in Hawaii.

Framer issues

Worthington serves as the framer, panel manufacturer, and steel supplier. They also purchase all tools and miscellaneous supplies related to the steel framing and installation of windows. Since Worthington frames homes for builders other than Hunt, the cost of equipment related to the framing component can be spread out over a larger number of homes.

One of the most significant costs associated with using steel panels is related to the fabrication plant location. Labor and facilities related to fabrication are two other important factors for a builder or framer to consider. These issues were addressed by Worthington in the following sections.

Space for the fabrication plant – Limited space at the construction site required Worthington to set up a panel plant on an off-site parcel of land owned by Hunt. Hunt gets a reduced price for the panels under this arrangement, and Worthington minimizes their need to lease or purchase space for the fabrication plant.

The fabrication area takes up 10,000 square feet, material storage 14,000 square feet, and completed panel storage about one acre. A similar amount of space would be needed if the fabrication was conducted on-site. The builder indicates that they could squeeze the plant into about 1.25 acres if necessary.

Start-up equipment – Worthington uses two framing tables manufactured by TRIAD with double-sided dolly screw guns to eliminate the need to flip the panels to screw studs into tracks from both sides. The tables are located under a tent. Materials and supplies are stored nearby or in an existing building. The facilities fabrication footprint is rather small, with the bulk of the land reserved for storage.

Storage - The necessity for storage makes ample space (land) crucial. Depending on the construction schedule and shipping times, stockpiled panels can take up a vast amount of space. The fabrication plant needs to be ahead of the construction process or else fabrication will slow the construction schedule.

The biggest panels at Worthington's facility ranged between 20' and 22' in width and 10' to 12' tall. Each floor of a home was placed in one stack. Thus each floor required a 22' by 12' space.

Although some storage is required once the panels are delivered to the building site, this is only temporary. The production process allows for some stockpiling

at the home sites, but the panels are erected almost as soon as they are delivered.

Overall, the Worthington plant sits on about 2 acres of land, including parking space for the employees. As mentioned above, the builder has fit similar operations on as little as 1.25 acres.

Labor **-** Labor concerns in Hawaii are similar to other areas of the United States in that there is always an ongoing struggle to find and retain construction workers. At Radford Terrace, labor issues were not necessarily complicated due to the use of steel.

Although there were some labor issues early in the process of transitioning from wood to steel on projects in Hawaii, very few staff members from either Worthington or Hunt were around when the transition began in the 1996-1997 timeframe. The few employees who were on staff at this time were unable to recall specific issues that arose during the transition.

No coordinated effort to train employees was required in the beginning stages at Radford Terrace, since the market had matured enough since the mid 1990s. Framers and sub-trades have come to realize that working with steel is a requirement in Hawaii, especially for military contracts. Further, labor in Hawaii is heavily influenced by labor unions who often supply qualified workers.

When Hunt began building steel homes the contracts were small and didn't draw much union interest. Now that Hunt is involved in large, multi-year projects, they have worked out an agreement with the local construction union. Hunt offers union wage rates and has an open shop policy, meaning workers can join the union if they want to, but all workers have to pay union dues regardless of their membership status.

There is some benefit from a wage standpoint to fabricating panels off site. The crews at the panel plant are not union members nor subject to union dues. Conversely, when panel fabrication occurs at the job site, employers are required to pay union wages because the employees fall under the negotiated union agreement.

Other trade contractor issues

In addition to the issues faced by the framer and builder when deciding to use steel framing, there are some issues that need to be addressed with other trade contractors.

The electrician for the Radford Terrace homes has found working with a hybrid frame that includes steel and wood can require extra effort to run wiring. Although steel wall panels have

standardized holes punched in the studs, they do not always line up with the wiring.

The electrician also needs to drill or cut track sections when wiring runs through the floor. In this situation, they need to switch drill bits depending on whether they are drilling through wood, steel, or a combination of the two materials. Besides having to switch drill bits, steel is perceived to be harder to drill than wood.

The plumber encounters similar problems as the electrician with drill bit changes. The plumber recommended a bi-metal drill bit to avoid time delays associated with changing drill bits. They also use a plasma cutter when cutting steel.

The drywall contractor also claims that working with steel takes longer than with wood because they have to use screws. Additionally screwing into heavy gauge steel is more difficult than wood, especially if it is overhead.

The housewrap contractor also raised some issues that need to be addressed in the early stages of the project. First, the housewrap task has to be integrated into the framer's work flow since the home needs to be wrapped before windows can be installed.

Second, the design of the shear system impacts the housewrap installation. For the homes at Radford Terrace, only shear walls are fully sheathed with plywood. If only a portion of the wall is classified as shear the entire wall is sheathed to prevent siding complications. Typically at least one wall is completely unsheathed. Wrapping a wall without sheathing presented a problem for the crew since it requires a double sided tape that will stick to the steel studs and house wrap. The housewrap crew at Radford Terrace uses ProTrim Constructions' blue Alum-A-Pole tape to adhere the wrap to the studs on walls without sheathing.

The siding installer also noted some differences in working with the homes at Radford Terrace compared to homes with wood framed walls. A fiber-cement product manufactured by James Hardi is the siding product for this project. The siding contractor indicated that he uses screws for fiber cement for wood and steel walls, but the use of screws could result in an upcharge by some contractors who don't commonly use screws with wood framed homes. With the siding at Radford Terrace, the manufacturer provides an innovative screw with wings that cut through the siding. The wings break-off as the screws hit and penetrate the steel studs.

The siding contractor would prefer every wall to be sheathed because they can screw into the side of the home anywhere they want. When a wall is not sheathed (as in the case with some of the walls at Radford Terrace) they need to

screw directly into a stud, which affects the length of the siding product. Locating a stud is usually not hard because you can see the studs through the housewrap.

Worthington straps the panels to facilitate cabinet installation. Cabinets are commonly installed with self drilling screws. Cabinet installers have grown accustomed to working with steel and cited no concerns with working with steel.

Sections 4: Capital Requirements and Inventory

Capital requirements for the use of steel framing vary depending on the business model. Hunt has settled on an approach where they purchase panels from a third party. As the panel provider and framer, Worthington incurs the bulk of the capital costs and inventory costs. The one major exception is that the land for the panel plant is owned by Hunt as part of a land-sharing arrangement negotiated into the cost of the panels and framing package.

The business approach used at Radford Terrace has evolved over time, and some of the changes have impacted the inventory requirements. For example, Hunt used to purchase screws for the framer but has ended this arrangement. Requiring the framer to include the cost of screws in their bids gives the framer more incentive to reduce unnecessary use.

The sections below summarize the capital and working inventory requirements for the plant and framing at Radford Terrace. Except for the land, these items are all the responsibility of the framer. The emphasis is on components that are related to steel. Note that since this is a hybrid house with steel and wood components, the typical tools and fasteners used for wood framing would also be required on the jobsite. Also note that the items addressed in this section are based on production of approximately 28 homes per month.

The prices listed in this report are the prices in Hawaii with bulk purchase discounts. These will vary as market costs rise and fall. Mainland prices would likely be lower.

Tools

Following is a list of tools each crew used for panel fabrication and framing tasks. The first table covers the tools at the off-site fabrication plant. Note that the items in the table represent requirements at start up and for operation of the plant. Periodic replacement and some maintenance would be required

Panel Fabrication

Tool	Application	Average Cost	Quantity
Framing table (manufactured by TRIAD)	Framing wall panels	$38,000	1
Automated Double Screw Gun	Screw studs to tracks on table	$250 per gun	4
Chop Saw	Modify studs/track	$200	2
Skill Saw	Modify studs/track	$180	2
Hand Screw Gun	Attach studs to track, headers, gang studs, attach wood bucks for doors, sills and windows	$100	4
Electric Shears	Modify studs/track	$300	2

The following tables describe tools and equipment needed for each task associated with the even-flow process employed at Radford Terrace (i.e., on-site framing). Note that each task is associated with a specific crew that brings their own tools to the home they are working on at the time. Thus, except where noted, tools and equipment are not shared among the crews.

1st Story Wall Panels

Tool	Application	Average Cost	Quantity
Hand Screw Gun	Attaching panels and braces	$100	4
Powder Actuated Nail Gun	Apply temporary anchoring	$600	1
Skill Saw	Cut steel tracks	$180	2
Gas Powered Electric Generator	Power tools	$1,500	1

Anchoring of Panels to Slab

Tool	Application	Average Cost	Quantity
Hammer Drill (drill and screw bit)	Drill holes for bolts and screwing bolts	$700	1
Gas Powered Air Compressor	Clean bolt holes	$800	1
Gas Powered Electric Generator	Power for the drill	$1,500	1

Floor Framing and Sheathing (Two Tasks)

Tool	Application	Average Cost	Quantity
Screw Gun	Attach brackets to beams	$200	2
Nail Gun	Attach sheathing to floor joists and attach joists to wood plate	$400	3
Gas Powered Air Compressor	Power nail gun	$800	2
Gas Powered Generator	Power screw gun	$1,500	2

2nd Story Wall Panels

Tool	Application	Average Cost	Quantity
Screw Gun	Attach sheathing (plywood) Attach panels to floor and other panels	$200	3
Skill Saw	Cut steel tracks	$180	2
Gas Powered Generator	Power screw gun and saw	$1,500	1

Exterior Wall Sheathing

Tool	Application	Average Cost	Quantity
Screw Gun	Attach sheathing	$200	2
Skill Saw	Cut wood	$180	1
Router Saw	Cut out windows	$350	1
Gas Powered Generator	Power screw gun and saw	$1,500	1

Roof Tasks (Includes truss, soffit, fascia, and sheathing crews)

Tool	Application	Average Cost	Quantity
Nail Gun	Attaching trusses, soffit, fascia and decking	$600	13
Skill Saw	Cut wood	$180	4
Gas Powered Generator	Power saw gun	$1,500	3
Gas Powered Air Compressor	Power nail gun	$800	3

Note: The roof tasks were combined in this table since there was significant tool sharing by the separate crews.

Interior Walls

Tool	Application	Average Cost	Quantity
Screw Gun	Attach studs	$200	2
Skill Saw	Cut Studs	$180	1
Gas Powered Electric Generator	Power screw gun	$1,500	1

The tools in the tables above are all supplied by Worthington in accordance with union rules. Workers purchase their own hammers, tape measures and other common tools. Before the union became involved, workers were responsible for providing their own screw guns and other tools.

The costs in the tables above are estimates that a builder or framer would encounter if purchasing all of the items. However, since Worthington buys large amounts of screws, nails, and tools, they often get screws guns and other tools for free or at a discounted rate from manufacturers.

Supplies

The following section lists the costs for supplies or materials needed on a monthly basis by the framer. Note that the items are specific to the steel components used in the homes. Typical items required to frame the wood components of the framing (i.e., lumber, trusses, plywood, nails, etc) are not addressed here.

Fabrication Plant Supplies

Item	Application	Average Cost
Screws	Attachment	$6,075
2x4 and 2x6 Steel Tracks and Studs	Wall panel fabrication	$120,000

Additional required materials include the top plates for walls (wood 2x4s or 2x6s). These are provided as needed by the builder as part of their lumber package purchase.

On-site Framing Activities

Item	Application	Average Cost per month
Screws	Attaching panels to other panels and attaching braces	$7,425
Powder Actuated Nails	Temporary panel anchoring	$1,200
Caulk	Attaching foam and decking material	$1,200
Foam	Buffer between concrete and steel	$1,000
Sealer/fabric between bottom track and slab	Protection between concrete and steel	$2,000
Steel Braces	Brace wall panels	$5,000
Epoxy and applicator	Secure anchor bolt	$1,000
Anchor Bolts	Secure panels	$1,800
Corner Braces	Use for high load areas	$6,000
Bracket Strips	Connect first story wall sheathing to second story sheathing	$300
Steel Studs and Tracks – Interior	Non-load bearing walls	$14,000

Additional material includes treated plywood for exterior sheathing.

Inventory supplies are maintained by Worthington's supervisor, however this project has been operating for a few years and many of the crew members know the appropriate inventory levels for each item and help with inventory management.

Panels, trusses, joists and beams are delivered a few homes at a time and are stored until needed, preferably at their construction location. Plywood is purchased in bulk and stored on site.

Safety Equipment

Everyone on the job-site is required to wear a hard-hat. Ear and eye protective equipment is common, especially for those tasks involved in cutting. Protective

gloves were worn by some workers. Individuals who work off the ground are required, in most cases, to tie-off with approved equipment.

Machinery

At the panel fabrication facility there is one all-terrain forklift and at the job site there are two all-terrain forklifts. The job-site forklift operators are responsible for prepping workers by placing a stack of panels at their appropriate location, including on top of the first floor. Also, the forklift operators move trusses, joists and plywood around. At night, generators and compressors are loaded onto skids and elevated into the air to prevent theft.

Electric Trailer Generator

The fabrication plant crew uses one diesel electric generator which costs around $15,000. At the construction site there is one diesel electric trailer generator supplied by Worthington that costs approximately $25,000. The majority of the frame crews used their own generator when they are far from the central diesel generator. Other subcontractors are responsible for supplying their own power at the construction site.

Transportation

Flatbed trucks, owned by Worthington, are used to transport panels from the fabrication facility to the construction site, approximately fifteen miles. Worthington engages in many steel production activities. Thus, the transportation trucks are used for a wide variety of other business activities. Had they only been engaged in fabrication for Radford Terrace, renting the transportation trucks would be a viable option.

Permits are not needed to transport the panels. The panels are laid flat on the truck and the width is dictated by the height of the panel. Typically the panels are 9’ to 10’ in height. Stacks are usually between 5’ and 6’ high, consisting of ten to fourteen panels.

Panels can be carried by two people. Machinery is not needed to hoist or lift individual panels during the erection stage, even when the second story panels are sheathed.

Storage

Panels and other materials are stored in uncovered stacks at the job site and plant. Supplies and tools, on the other hand, need a protected storage location. Workers typically take their power tools home while supplies are stored in lock boxes on site. The lock boxes hold screws, nails and brackets that their respective tasks require. There are also freight containers on site to store supplies. Supplies are order to last a month and have approximately a three week delivery time.

Steel panel wall stacks are stored as close to their desired location as possible when they arrive at the construction site. Wood boxes are used to keep the panels off the ground and enable the forklift to easily get under the panels.

Construction Site Storage

There are typically two, 8 feet by 40 feet containers on-site for inventory storage The roofers and erectors have their own storage box to store immediate supplies. Material inventory is also stored in stacks around the job site.

Fabrication Facility Storage

Inventory for panel fabrication predominately consists of screws, wood, steel studs and tracks, and completed panels. Panels are stored in stacks and, due to their size, take up the bulk of the land requirements. Steel studs and tracks arrive cut to length and are stacked near the fabrication tables in piles according to size and gauge. Wood, used for sill plates and door jams, is stored in a similar fashion. Screws are stored in an existing 14,000 square foot building.

All exterior sheathing is done at the construction site and accordingly there is no plywood or OSB inventory at the fabrication facility.

Waste Management

Hunt has noticed significant reductions in waste management fees when building with steel over wood. By using steel panels, a typical home construction job results in approximately one regular garbage can being filled. The majority of the waste consists of wall braces that have outlived their usefulness. Most steel

panel jobs avoid the purchase of a 40 yard or 20 yard dumpster that stick-built wood construction jobs need. Additionally, there are companies who will come and recycle scrap steel, further reducing job site waste. Hunt estimates that their system will reduce waste removal charges by $500 to $600 per month.

Security

Despite the construction site being located in a city environment, the security measures are remarkably low. The site is surrounded by a fence with a screen attached. The screen is primarily intended to keep dust and dirt inside the construction site. The fence gate at the entrance to the construction site is closed during the night hours.

The fabrication facility is uniquely located in a ravine with a guarded entrance. Hunt also uses the fabrication area for other business activities not related to this project.

Panel Costs

A typical steel wall panel home has a one-time $10,000 to $15,000 design cost. This cost is spread across the number of homes using that design. A single panel, 8 feet in length and 9 feet in height, costs between $45 and $65 in material. A panel's maximum dimensions are 22 feet in length and 10 feet in height. Panel sizes and steel gauges vary depending on the layout.

Currently a steel home's design does need a PE stamp but there is indication that in the near future single-story steel homes will not require a PE stamp.

Fabrication at the plant requires a five man crew, including one layout person (supervisor) and four fabricators. The starting pay begins around $15.00 per hour and peaks at $49.00 per hour, including benefits. The pay scale changes if the panel fabrication is conducted at the construction site due to union dues.

The on-site framers operate under a salary schedule that was negotiated with the union. The starting salary is $15.00 per hour and progresses up to $52.00 per hour, with benefits. According to the union's journeyman track, apprentices receive a raise every six months for four years. After four years apprentices become journeyman with the $52.00 wage rate. Radford Terrace is a multi-year project and many of the workers are at or very close to reaching the top of the pay scale.

Overall Costs

According to the framing contractor, they are framing a home, depending on complexity, from $21 to $24 per square foot. The homes when completed will cost the builder about $200,000 not including land preparation. Forest City Military Communities owns the land and they hired another firm for land preparation and installing utilities. The homes would cost about 3% to 10% less to frame if treated wood was used. However this estimate doesn't take into account the reduction of waste material, recycling of scrap steel, reduction of termite treatment in the future and reductions in insurance costs.

Section 5: Crew Requirements

Panel Fabrication

The panel fabrication crew is composed of five workers. The overall requirements to become a panel fabricator are low. There is no formal training for the fabrication crew, solely on-the-job training.

Framing

On-site there is one supervisor and assistant supervisor who oversee construction, maintain supplies, and handle personnel issues. There is another individual on-site who is responsible for safety issues. The framing crew has two leaders, one for walls and one for roofs. The framing crew leaders serve as a liaison between the site supervisor and crew members.

The site supervisor indicated that he tries to place new hires in positions where they feel comfortable. However, the panel erectors, those that stand up panels, are not entry level positions. The first floor wall panel crew has worked together for close to seven years.

The framing crew is broken up into tasks with differing numbers of crew members per task. The following table shows the characteristics of each task.

Task	Time to Complete	Crew Size	Tools	Responsibilities	Preparation Work
First Floor Panels	3 hours	4	Screw Gun Powder Nail Gun Skill Saw Electric Generator	Erect and temporary secure first floor wall panels	Forklift places panels near foundation
Anchors	4 hours	1	Hammer Drill Air Compressor Electric Generator	Install permanent anchor bolts	
Floor Joists	3 to 4 hours	2	Screw Gun Nail Gun Air Compressor Electric Generator	Lay out and secure floor joists and beams	Forklift places joists and beams on walls. Joist brackets attached to beams
Floor Decking	4 hours	2	Nail Gun Air Compressor	Attach second floor decking material	Forklift places plywood on joists
Second Floor Panels	3 to 4 hours	3	Screw Gun Skill Saw Electric Generator	Attach second floor sheathing walls and stand second floor walls	Forklift places panels and sheathing on second floor
Exterior Sheathing	3 to 4 hours	2	Screw Gun Skill Saw Router Saw Electric Generator	Attach first floor sheathing to shear walls	Forklift places sheathing between two homes
Trusses	5 to 6 hours	5	Nail Gun Skill Saw Electric Generator Air Compressor	Install roof trusses	Forklift places trusses on roof
Fascia	5 to 6 hours	2	Nail Gun Skill Saw Electric Generator Air Compressor	Install fascia	Forklift places material in home through second floor window
Soffit	5 to 6 hours	2	Nail Gun Skill Saw Electric Generator Air Compressor	Install “high-grade” perimeter roof sheathing	Forklift places material on trusses
Roof Decking	5 to 6 hours	4	Nail Gun Skill Saw Electric Generator Air Compressor	Securing roof decking	Forklift places material on trusses
Interior Walls	5 to 6 hours	2	Screw Gun Skill Saw Electric Generator	Install interior walls Attach plywood if necessary	
Forklift Operators		2 Forklifts – 1 operator per forklift	All-terrain Forklift	Move supplies	

Skill Level

New hires usually have some home construction experience but individuals are also hired with no experience. Depending on experience level new hires are categorized using the union's apprenticeship/journeyman program.

Shifts

The framing crew has one shift a day, Monday through Friday. The shift starts at 7:00 a.m. and ends at 3:30 pm. The workers are entitled to two fifteen-minute breaks and one thirty-minute lunch break.

Section 6: Cycle Time, Crews, and Onsite Construction Issues

Cycle Time for Framing Operations

The cycle time to complete the framing phase of a home at Radford Terrace typically took 5 to 7 days under the old approach where one framing crew started a home and stuck with it through completion of the framing and installation of the windows. However the even-flow work schedule now being employed was developed to avoid down times and to absorb construction delays. The current work flow process has a cycle time from foundation to finish framing, including installation of windows, of 30 days. During a typical 30 day period, Worthington will frame 28 homes.

Under the old approach, a crew could do between 4 to 5 homes per month. Thus it would take slightly over six crews of five workers (30 to 35 workers) to frame the same 28 homes currently completed each month with about 22 full time equivalent employees under the task oriented approach.

The time to complete homes is based on the crews operating a single shift each day, starting at 7:00 am and ending at 3:30. A thirty-minute lunch break and two fifteen-minute breaks are required under the terms of the agreement between Hunt and the local union. More detailed information on the tasks and responsibilities of those involved in the process are contained in the following sections.

Framing Crew Work Task Format

This section addresses the tasks that make up the framing process at Radford Terrace, the crew size and time required for each task, and provides a description of the work each crew conducts for the task.

First Story Wall Panels

Crew size	Four
Completion time per home	Three hours

The first floor framing crew is responsible for installing and bracing the first floor wall panels. The crew initially applies the foam and protective barrier (sill sealer) to separate the concrete slab from the steel panels. After this process is completed, two of the crew members unscrew the connecting straps needed for transportation and begin laying out the panels in their correct area. Then they stand up the first floor panels and connect them together. The other two crew members apply the support bracing and temporary foundation connections using power-driven nails. Pictured here are panels laid out ready to be stood up.

This crew works at other construction sites as needed, so they are not on the Radford Terrace job full time. The crew leader also works on exterior sheathing when the rest of the crew goes to another job site.

Anchoring

Crew Size	One
Completion time per home	Four hours

The anchoring task involves installing the permanent foundation tie downs and brackets for high wind resistance and traditional anchor bolts for the first floor wall panels. The crew first attaches brackets to the wall panels. Then they drill holes through the steel panels into the concrete slab. Next air is blown into the holes to remove dust so the epoxy will adhere to the slab and bolt. The bolt and bracket connections are used at critical locations as dictated by the structural design.

Anchor bolts are drilled directly into the foundation through the steel. Pictured above is a bracket bolt with epoxy at a corner stud.

Floor Joist and Beams

Crew Size	Two
Completion time per home	Two to three hours

This two-person crew is responsible for installing the floor joists and their supporting beams in preparation for the second floor decking. Brackets are applied to the support beams prior to being lifted on top of the first floor wall panels. Beams and joists are set on the wall panels by an all-terrain forklift. During down time the crew preps beams for future installation and helps other crews as needed. Pictured to the left is a beam with brackets waiting for the forklift to place it on the wall panels and a forklift (above) placing floor joists on wall panels. Notice the placement of the beam on wood blocks to facilitate use of the forklift.

Second Floor Decking

Crew Size	Two
Completion time per home	Four hours

The main responsibility of the decking crew is to apply the second story floor sheathing. Plywood stacks are placed on the joists by a forklift. Once the decking is applied a forklift will drop off the second floor panels for the next crew. This crew requires tie-off training. Pictured here is a crew member carrying floor sheathing.

Second Story Wall Panels

Crew Size	Three
Completion time per home	Three to four hours

This crew is responsible for applying the sheathing to second floor shear walls and erecting and bracing them with the non-sheathed second story walls. Just like the first floor panel crew, they place the panels in their appropriate locations first. Then they apply the exterior sheathing on the necessary panels. The panels are then stood up, attached to the decking, and braced. This crew requires tie-off training. Pictured (above-left) is a completed second floor wall panel job and (right) a worker screwing sheathing onto a wall panel before tilting it up. Notice the extension attachment on the screw gun to facilitate screwing into a wall panel from the standing position.

First Floor Exterior Sheathing

Crew Size	Two
Completion time per home	Three to four hours

The exterior sheathing installers are responsible for affixing sheathing to the first story exterior walls. The crew also applies brackets to connect first story wall sheathing to second story wall sheathing. Walls that don't require shear resistance are left open. Pictured here is a completed sheathing job.

Trusses

Crew Size	Five
Completion time per home	Five to six hours

The truss crew is the biggest crew at the job site. Longer trusses are placed on top of the second floor by a forklift. Smaller trusses and pieces are inserted through a window on the second floor. The crew then begins spacing out the trusses and standing them up. As a home approaches completion, some of the truss crew moves over to the next house and begins prep work. This crew requires tie-off training. Pictured here are trusses being installed on a home.

Fascia

Crew Size	Two
Completion time per home	Five to six hours

This crew is responsible for attaching the fascia board to the end of trusses. Most of the fascia arrives pre-cut but some modifications are necessary on site. This crew requires tie-off training. Pictured here is the fascia on the truss tails.

Soffit (perimeter roof sheathing)

Crew Size	Two
Completion time per home	Five to six hours

Soffits in Hawaii are different than in many other parts of the United States. It is common practice to have an open soffit where the roof sheathing and truss tails are visible from the underside of the roof overhang. Therefore the soffit material is not a traditional soffit designed to cover the trusses and roof sheathing, but rather it is a special section of plywood that covers the roof at the overhang. The soffit, or perimeter sheathing, is a high end, paintable plywood instead of traditional plywood. The plywood is installed around the perimeter of the building and then painted so it can remain exposed. Standard roof sheathing is then applied (by a different crew) to the rest of the roof.

The soffit material (plywood) arrives in sheets and is cut to size onsite. This crew requires tie-off training.

Roofing

Crew Size	Four
Completion time per home	Five to six hours

The roofing crew installs the roof sheathing (plywood) after the soffit previously discussed. The crew places a few sheets of plywood that serves as a stand for the rest

of plywood to be dropped off. This crew requires tie-off training. Pictured above is the roofing crew installing plywood. Notice the plywood stand and different shade of the soffit perimeter plywood in the photograph.

Interior Partitions

Crew Size	Two
Completion time per home	Five to six hours

The interior partition crew is responsible for constructing and installing the interior partitions. These walls are stick built in much the same way as in commercial buildings. The studs arrive in a standard length but the crew does have to cut some studs and almost all the track to length in the field. Also, they only need to screw one-side of non-load bearing walls to the track, whereas load bearing walls need both sides of the stud attached to the track. When the drywall crew comes through, they secure the second side as they attach the drywall.

Supervisors

There is one site supervisor and assistant supervisor on site who oversee the process. The assistant is basically on site full time and the supervisor about half time.

Safety Supervisor

There is one safety supervisor on site who monitors the construction process and handles safety related incidents. This person is responsible for tie off training of specific crews.

Forklift Operators

There are two forklift operators at the job-site. They are responsible for prepping the construction crews by placing heavy materials in the appropriate locations. The forklift operators are critical in maintaining the work flow.

Transportation

The trucks used to transport the panels from the fabrication plant to the construction site are owned and operated by Worthington. Worthington Industries gains efficiencies and a cost advantage by owning trucks because of the all the activities they are engaged in. If Worthington was a smaller company focused solely on panel fabrication, leasing or renting flatbed trucks would most likely be more cost effective.

Call Backs

Hunt reports a steep reduction in call backs, especially related to framing members, when using steel. They attribute this reduction to the uniform quality found in steel studs and tracks, and to steel's ability not to pop nails and twist with moisture changes. The majority of their stud replacement is a consequence of transportation damage. Hunt estimates that over 20% of the studs in a wood home need to be replaced or repaired. Only one wall panel needed repair and two studs were twisted in the 15 homes observed during this study.

Site Issues

Over the weekend prior to our observations, high winds racked one home's first floor wall panels. The panels had been left unbraced on the previous Friday because the panel erection crew had run out of bracing material. On their return to the site the following week, the crew straightened the panels. This took about an hour before the crew was able to move on to other work. No other on-site modifications were required.

Efficiency Improvements

The main efficiency improvement reported by the framer was the implementation of the task orientated even-flow construction schedule. After a home has been built four or five times the framing crew begins to demonstrate real efficiency and reduce construction time. Over time, each crew began to understand the amount of supplies and inventories they need and they helped the site supervisor maintain adequate supplies.

In addition, the framer noted two other improvements they have adopted over time. The exterior sheathing crew screws plywood to the steel panels and then goes back and cuts out the window openings. This process eliminates the need to pre-measure the window and cut-out the openings in hopes they line up correctly. Also the exterior sheathing for the second floor is attached to the panel before being erected. This prevents sheathing damage that can occur during transportation and limits the amount of work done and waste generated at the fabrication facility. Scaffolding is also unnecessary if this sheathing strategy is employed. The second floor panels are laid out in their place on the second floor and the sheathing is attached by the crew before raising them.

The electrician also noted two products that have improved their efficiency in preventing wires from being damaged as they pull them through steel members. The first one is a plastic grommet that snaps together around the openings in steel studs. These grommets are hard to move and take little time to install. The second product is a thin plastic strip with adhesive inside. The plastic is cut to length, usually enough to cover the bottom of the hole in the stud.