

Putting the Pieces Together



On the right projects, prefabrication and modular construction can increase speed and lower cost



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For a growing number of contractors and developers, it's the answer to a million dollar question: how to build faster, safer and better—and do it for less.

Although the choice to use on-site wood framing versus some level of prefabrication depends on many factors, prefabricated and modular construction can offer a number of benefits, including faster construction, improved material efficiency and worker safety, enhanced quality assurance, and reduced material, labor and interest costs.

Options range from prefabricated components and panelized assemblies to full modular units. All can be used for a wide variety of applications, including Type III or V structures up to

five stories for education, commercial, multi-family, healthcare and other occupancies. Prefabricated and modular designs can accommodate architectural aesthetics such as building offsets, angled walls, balconies, pitched roofs, and more. In fact, in a well-designed structure, it can be impossible to tell that any level of prefabrication was used at all.

Wood is well-suited for prefabricated and modular construction because it is lightweight and easily transported, strong, straightforward to engineer, energy efficient, durable and cost effective.¹

Benefits of Prefabrication

Prefabrication can offer a variety of benefits, especially when it comes to prefabricated systems and modular construction.

Speed – Prefabrication may allow simultaneous instead of linear construction, which shortens on-site erection time. As foundation work is being done on site, fabricators and manufacturers can be building prefabricated components, panelized systems or modules at the same time, speeding construction. This can also lessen the impact of weather disruptions because workers have a protected work environment for fabrication, which helps ensure on-time delivery of components to the jobsite.

Once on site, erection is also faster both with panelized and modular systems. According to Harold Marek, Director of Modular Design for Clayton Building Solutions, contractors can set anywhere from eight to twelve modules a day. Using typical 16-foot x 60-foot modules, this can translate into 12,000 square feet of completed structure daily.

Traditional to Modular Construction—a Continuum

TRADITIONAL	PREFABRICATED COMPONENTS	PANELIZED SYSTEMS	MODULAR CONSTRUCTION
<ul style="list-style-type: none"> • Conventional wood-frame construction using dimension lumber • Structural systems are constructed entirely or largely on site • Linear construction; requires each step to be completed before the next can begin 	<ul style="list-style-type: none"> • Wood products such as dimension lumber and structural wood panels are used to form pre-assembled components for walls, floors and roof systems • Examples include trusses, I-joists, Structural Insulated Panels (SIPs) and others • Constructed at off-site facilities • Recognized via code evaluation reports; production facilities utilize factory inspection for quality assurance 	<ul style="list-style-type: none"> • Method in which prefabricated components are assembled into larger panels or complete assemblies before being shipped to a building site • Can be delivered as complete exterior and interior wall panels or structural roof and floor systems • Systems can be panelized at an off-site facility, or assembled adjacent to the jobsite if space allows • Can be assembled while other work is done on site • Engineered for specific job applications 	<ul style="list-style-type: none"> • Components are assembled at an off-site location and built into modular structures, which are then transported to the jobsite and set into final position to form a completed building • Two types of modular construction: temporary and permanent (this document focuses only on permanent) • Modules include interior and exterior finishes as well as mechanical, electrical and plumbing (MEP) • Typically 80 to 95 percent complete before being shipped to the jobsite • Modules are inspected at the factory but the completed structure must meet the same local code requirements as traditional types of construction • Can be up to 50 percent faster than traditional construction²





The Woodlands at Harvest Hill Senior Housing • Prefabricated Construction

LOCATION:	Lebanon, NH
OWNER:	Alice Peck Day Memorial Hospital
SUPPLIER:	Wallace Building Products Corporation
GENERAL CONTRACTOR:	Trumbull-Nelson Construction Company
SIZE:	167,230 square feet
TYPE:	Four stories, Type V Construction

Trumbull-Nelson hired Wallace Building Products to panelize the floor and wall systems of The Woodlands at Harvest Hill, a senior housing project, primarily because their construction schedule did not allow enough time for traditional framing. The project started in December 2009 and was completed just a few months later, in late spring 2010, which meant they had to work through winter in New Hampshire. “We had days where we had to shovel snow off the decks before we could erect walls,” said Doug Hounsell of Wallace Building Products. “This project would have taken at least one-third longer if it had been traditionally framed.”

Wallace provided all materials and labor to erect the completed shell. “We’re different than many panel manufacturers in that we can build long panels, up to 80 feet in length, although the wall panels in this project were closer to 50 feet long,” he added.

The Woodlands used typical wall construction, 2x6 studs with bottom and top plate. But Wallace doesn’t add the very top of the double top plate until they’re in the field. “Doing so helps us tie everything together on site and allows easy installation,” said Hounsell. To lift the big wall panels, a jig is used that requires holes to be drilled through the top plate. To meet fire blocking requirements, those holes need to be covered. So, adding the top plate in the field has a twofold benefit: it provides improved rigidity—walls end up being straighter and more square—and it gives us the ability to cover those holes easily in the field.

To form the panelized floor systems for The Woodlands, Wallace preassembled the trusses, sheathed the assembly, and then divided the floor structure into sections that could be transported by taking out wood structural panels to be laced in later. They then stacked these floor sections on top of one another and trucked them to the site. “We’ll do floor panels in 14 x 60 foot sections, which provides structure for two units and a hallway in one piece,” Hounsell said.

Added Value / Lower Cost – Many factors can lead to lower cost. Prefabricated components, systems and modular units are assembled under controlled conditions using materials which are often ordered from the supplier cut to exact lengths. This results in more efficient material utilization. Consistent conditions may also help improve labor productivity. Fabricators and manufacturers often pre-buy materials, which can lead to more predictable profits for developers and contractors. Speed of construction leads to earlier completion and faster occupancy, resulting in quicker revenue and less interest paid on construction loans.

Quality Assurance – The controlled fabrication and manufacturing environment is easy to monitor and inspect; depending on the level of prefabrication, multiple inspections may take place throughout the process to ensure a high quality assembly. Because components and systems are built in a climate-controlled environment, there is less weather-related damage to materials and fewer potential moisture issues. Prefabrication facilities use tables and jigs for walls, ceilings and floor systems, which helps ensure consistent results.

Reduced Risk / Improved Safety – For panelized and modular construction, the chance of injuries on the jobsite is reduced because assembly takes place on the ground in a familiar, monitored environment without hazards caused by bad weather. There is also less risk to materials at the jobsite because prefabricated components, systems and modules are typically delivered and installed within a day or two.

Environmental Benefits – Because components and systems are prefabricated, on-site waste is reduced. Less than five percent scrap is typical for modular construction, which means less material going to landfills.³ Prefabrication also results in less site disturbance and thus lower environmental impact at the jobsite, while tighter tolerances may create fewer gaps between assemblies, resulting in improved energy efficiency.

Building Codes and Inspection

All prefabricated building materials—regardless of whether they are components, assemblies or modular structures—must be designed to current *International Building Code* (IBC) requirements applicable at the jobsite location.

Inspection requirements, on the other hand, depend on the type of component. Wallace Building Products specializes in prefabricated wall, floor and roof systems. “We build open-wall construction, so there’s no inspection process in our facility,” said Doug Hounsell, Wallace’s Sales Manager. “All the inspections and certifications are done on site by the engineer and building inspector during their walk-through, just like they would for a traditionally-framed job.”

Inspections for modular construction are different. “Each modular manufacturing facility uses third-party inspectors that work for the state,” explained Howard Koenig, CEO of Zeta

Design+Build. “When we ship modules to a jobsite, our modular units must meet local ordinances, so building inspectors from the local jurisdiction make sure that anything delivered on site meets the code requirements of that city or county.”

Third-party inspectors do their work from the Zeta Design+Build factory, inspecting modules as they move down the assembly line. “When a module is approved, it gets an insignia fixed on the exterior,” said Taeko Takagi, Zeta’s Vice President of Product Development. “The module is then closed up so local inspectors don’t have to worry about what’s behind the walls; they’re only looking at the connections made on site. It’s really quite easy.”

“Like other modular manufacturers, we also have our own quality control program where we inspect everything as it is being built,” added Clayton Building Solutions’ Marek. “For some projects, the owner will also have an inspector in the plant as the individual components are built. The key to success is to have the local authorities or inspectors available; we invite them to our facility to show them the assembly line before we go into production. We also meet with the fire inspectors before we begin assembly, to make sure that the completed module will meet all their requirements before we begin.”

38 Harriet Apartments • *Modular Construction*

LOCATION:	San Francisco, CA
DEVELOPER:	Panoramic Interests
SUPPLIER:	Zeta Design+Build
GENERAL CONTRACTOR:	Charles Pankow Builders, Ltd.
SIZE:	11,740 square feet
TYPE:	Four stories, Type V Construction
UNIQUE:	LEED Platinum

Much has already been written about 38 Harriet, one of the first prefab micro housing projects in the U.S., and for good reason. Modular construction was critically important to the project’s speed of construction—a blazing six months from ground breaking to completion. The developer secured permits in January 2013; Zeta Design+Build built the prototype model units in its factory for preapproval and then built the actual units between March and May. Installation took just one week and the entire project was completed in June 2013.

Zeta used wood structural panel sheathing and dimension lumber for the modules, with 2x10 floor framing and 2x6 ceilings. Each module had a double LVL rim. Because acoustics are important in all multi-family housing but particularly so in micro units, exterior walls were 2x6 and interior walls and party walls were 2x4 with a 1-inch space between units. In fact, the assembly has a higher-than-required STC rating because the floors and ceilings are separated by a 3-inch gap between the modules. This gap can be filled with insulation for added energy efficiency; it also provides a plenum for the sprinkler system.

The contractor added tapered rigid insulation to the flat modules on site to form the desired roof slope. “The roofer wouldn’t have known whether this project used modular construction or not,” said Taeko Takagi of Zeta Design+Build. “He just saw a wood structural panel deck.”



When it came to setting the modules, Zeta used specific details designed for rapid installation. First, they installed clips from the floor rim to the plates below. Next, they installed hold-downs and straps at the ceiling mate lines and made sure the modules were level. They also connected the pre-installed tie-down rods, installed wood structural panels across the horizontal and vertical mate lines for shear, installed straps between the modules and the podium, and then installed the wood structural panel bands and straps across the mate lines at the roof.

From a design perspective, 38 Harriet posed a number of challenges because the objective was to create efficient units in a small space. “The design and production needed to be highly coordinated,” said Takagi. “Everything, including structural hardware like tie-downs as well as mechanical, electrical and plumbing systems had to be micro-engineered to optimize the unit’s interior space. Modular construction was well-suited to this job.”

Panelized Construction

Panelized construction, where prefabricated building components are assembled into larger panels before being shipped to a building site, is efficient, fast and cost effective.

When wall, floor and roof components are pre-assembled in a climate-controlled environment, builders and developers can save time and money with improved speed and ensured quality. Fabrication capabilities vary, but firms that target commercial construction can typically fabricate wall panels up to 60 feet long (or more) and up to 16 feet tall that include window and door openings and sheathing on the exterior face. Roof and floor systems can also be panelized in similar-sized sections using dimension lumber, trusses or I-joists. Panels are sheathed to allow for staggered installation of wood structural panels between sections on site.

Quality is a key benefit of panelized construction. “Our factory guys are not factory workers,” said Wallace’s Hounsell. “They’re framers who frame inside. We frame everything and nail it all with a nail gun on tables; it’s all hand-done.”

Since fabricators often buy material on contract and can produce components and systems year-round, this can help them reduce the impact of price fluctuation during the year. “Panelizing simplifies the construction process,” Hounsell added. “Contractors come to us because we give them a fixed price contract for an erected package. We provide the trucking, lumber, field labor, hangers and other hardware—all for a fixed price.

“The multi-family market is very strong right now. Developers want to shorten the timeframe between when they begin construction and when the project is complete, because that’s when their cash flow turns positive. Panelized construction helps them do that.”



Modular Construction

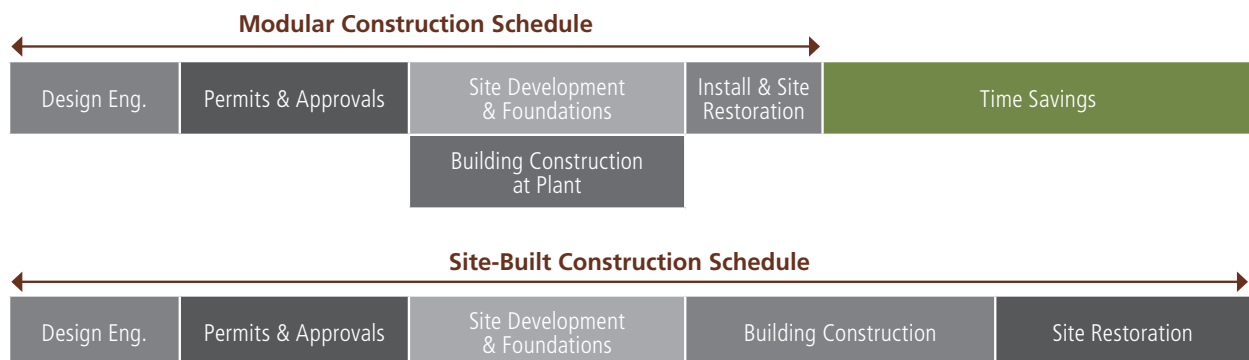
Most agree that the modular construction industry is and will continue to grow,⁴ in large part because owners and developers want their projects completed fast and cost-effectively.

Companies fabricate complete modules with finished exteriors and interiors, and complete MEP systems installed. Modules can arrive at the jobsite up to 95 percent complete.

Built in a controlled environment by skilled workers, modules are inspected multiple times by independent inspectors and approved before being transported to the jobsite. Once there, they are lifted into place by crane and then all modules and MEP systems are connected together. A qualified general contractor then finishes the exterior of the building and turns over a completed project. Once erected, modern modular buildings are essentially indistinguishable from typical site-built structures.

Modular construction differentiates itself from manufactured housing or mobile homes because modules are always installed on a foundation, slab or podium, and are under the jurisdiction of the local building department (IBC instead of HUD/Housing and Urban Development) for permits and inspection.

Time Savings Add Up to Cost Savings



Source: Modular Building Institute, <http://www.modular.org/documents/2012-PMC-Annual-Report.pdf>

Projects can also be built using a hybrid of modular and traditional or panelized construction, since not every design is suitable for just one method. For example, a student or senior housing project may consist of a central space flanked on either side by rooms. The architect may want to feature long spans and exposed framing members in the central area, which is better suited to traditional framing, whereas the other areas may be built using modular construction, which is most cost-effective when the module design can be repeated.

Challenges, Opportunities

Opportunities for both panelized and modular construction are growing as architects, general contractors and developers become more familiar with their benefits. But with growth comes both challenge and opportunity.

Historically, modular construction was used when the structure was a simple box, but current construction capabilities allow more creative designs. "Our industry will continue to grow

and improve as we work together to build attractive modular structures," said Marek. "But these can be more complicated to build. We will also be challenged by the fact that we need to have all the answers up front before modules go into production; that's one of the biggest challenges for modular manufacturers."

Modular construction is also opening doors to projects that weren't previously possible. "A lot of developers who never even thought about modular construction are now considering it because of speed," said Koenig. "We are also seeing a lot of interest in modular because some think this type of construction holds the key for below-market-rate and affordable housing."

Marek added, "Some people think that the main benefit of what we do is that it's less expensive. That's not always true. But it *is* more efficient. You certainly will save time with modular construction, and the process will result in a very high quality building."

Appalachian State University, Mountaineer Hall Student Housing • *Modular Construction*

LOCATION:	Boone, NC
OWNER:	Appalachian State University
SUPPLIER:	Clayton Building Solutions
GENERAL CONTRACTOR:	John S. Clark Construction Company
SIZE:	124,186 square feet
TYPE:	Three and four stories, Type V Construction
UNIQUE:	LEED Gold

As is often the case with education projects, Appalachian State University had a strict deadline. Their first construction meeting was in mid-summer of 2010, and they needed the new student housing building open and ready for use the following fall. The university already knew that, in order to tear down the existing structure and build the new one within a year, the project had to be built using modular construction.

Harold Marek of Clayton Building Solutions said the project was originally designed to optimize the modular spacing, which made things easier. "The modules were approximately 12 x 60 feet, which is a good size for us." They used LVL for the first floor perimeter beams to optimize spans, which helped them increase spacing for the piers underneath. Clayton also used some LVL headers in the modular units.

He added that everything was pre-cut to exact lengths for Clayton by the lumber producer. "We don't have any waste in the plant; we buy exactly what we need, and that's just part of what makes modular efficient."



The bottom level of the four-story portion, where it was inset into the hillside, was traditionally framed on site, and three stories of modular units were then placed on top. The three-story portion of the project was entirely modular. All plumbing and drain lines were installed underneath the building before the modules were set. In fact, everything had to be ready at the site, because the modules took only 30 days to lift into place.

By using modular construction, Appalachian State students were able to use the residence hall much earlier than another building, which was started at the same time using traditional construction. Mountaineer Hall, with 460 beds, was finished in just nine months and was ready for students a full year earlier than the other dorm, which had just 333 beds. "Modular construction is just that fast," Marek said.



¹ Details on wood's characteristics, including durability, energy efficiency and cost effectiveness, can be found at www.woodworks.org.

² http://www.modular.org/HtmlPage.aspx?name=why_modular

³ http://www.modular.org/htmlPage.aspx?name=Green_Modular_TownHomes; http://www.modularsolutionsltd.com/reasons-choose-modular-construction_01.php

⁴ *FMI Survey Shows Modular as Growth Opportunity for Construction Industry*, Building Design+Construction, December 22, 2010; Haas, Carl T., James T. O'Connor, Richard L. Tucker, Jason A. Eickmann, and Walter R. Fagerland. 2000. *Prefabrication and Preassembly Trends and Effects on the Construction Workforce*, Austin, Texas: Center for Construction Industry Studies

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