Faster, safer, lower cost

PANELIZED ROOF SYSTEMS

All-wood and hybrid panelized roof systems make good sense for commercial buildings.

Cost-effective materials, speedy erection and improved worker safety make panelized wood roof systems a good choice for commercial buildings, particularly low-slope roof structures such as big box stores and warehouses.

Panelizing, the process of assembling roof sections on the ground and then lifting them into place, allows contractors to reduce labor and material costs. Typical savings in markets along the west coast range from $1.25 to $1.50 per square foot over conventional steel joist metal deck systems.

"With a panelized wood roof system, you get lower cost, faster construction and a safer work site," said Darrell Marchell, PE, with Panelized Structures, Inc. "A panelized roof system gives you the economies of efficient erection coupled with cost-effective materials and design versatility for a structure that can be engineered to resist the required loads."

Panelized Basics

The two most common types of panelized wood roof systems used in North America are all-wood systems and hybrid systems.

- An all-wood system consists of glued laminated (glulam) beam girders with wood purlins (glulam, I-joists or open web wood trusses), wood sub-purlins and a wood structural panel deck. Commonly seen in buildings with spans of less than 40 feet, the all-wood system is particularly well suited for applications where conveyor equipment is hung from the roof structure or in food-processing facilities that need to minimize dust from overhead joists. It is also a good choice for developers and designers who want to take advantage of wood's aesthetic benefits for an exposed roof structure, such as for retail or school applications.
- The hybrid system uses steel purlin and girder trusses together with wood sub-purlins and a wood structural panel deck. The long-span capability of steel framing makes this system particularly economical when spans range from 32 to 60 feet, but much larger spans can be accommodated. Wood decking allows better economy than steel, both in terms of material and installation cost. This is usually the system of choice for large warehouse and industrial structures requiring long spans.

While market share fluctuates with commodity steel and wood prices, Marchell said about 70 percent of new low-slope, commercial roof projects in California are built with hybrid systems, 10 percent are all-wood and the remaining 20 percent are built using all steel. "Steel is used where the owners are not familiar with wood or in applications with special occupancy requirements, such as hazardous storage," he said. "Otherwise, most developers and owners understand and appreciate the value of a panelized wood roof system."

Assembly and Installation

The process for assembling and installing a panelized roof structure actually starts with the walls. Concrete tilt-up walls are most common, although masonry is often used for smaller projects.

Column installation varies by region. The general contractor typically installs columns in California, while the roof erector/framer tends to handle installation in the Pacific Northwest.

"There are several reasons for this," explained John Mandere with Mandere Construction of Idaho. "In the Pacific Northwest, we use wedge anchors, which allow us to reposition the column if the slab and walls are not perfect. But California seismic conditions require that they cast everything in place, so the general contractor typically installs the columns there."

One of the reasons construction of panelized roof systems is so safe is that much of the work is done on the ground. In one method, the crew nails the wood structural sheathing to the sub-purlins, sometimes called stiffeners, which are typically spaced 24-inches on center. This is done either off site or at the job site.

Using a fabrication table or jig, crews then fasten the panel/sub-purlin assembly to the purlins with joist hangers. In the other method, workers attach the sub-purlins to the purlin and then nail the sheathing into place over the top.

The roof erector then lifts the pre-fabricated panel into place and connects it to the joists and girders to form the roof structure.

Designers have flexibility in choosing components. Wood structural panels can be oriented strand board (OSB) or plywood, in 4x8 or 4x10 sheets, even 8x8 jumbo panels. Framers attach these panels to 2x4, 2x6, 3x4 or 3x6 sub-purlins. Common purlins for an all-wood system include I-joists and open-web trusses, or 2½-inch glulam in certain circumstances. Hybrid systems use K-Series open-web steel joists for short-span purlins (less than 48 feet) and

LH-Series long-span steel purlins for applications with spans greater than 48 feet. G-Series steel girders can span up to 120 feet but are more commonly used for 50-to 60-foot spacing.

A typical 50-foot panel takes five to 10 minutes to assemble on the ground. Panels are most often lifted into place by forklifts and reach machines, though cranes are used about 10 percent of the time. Two or three people work on the roof deck to land the panels and weld them into place (for hybrid systems). The diaphragm nailing takes place once the panels have acclimated.

Significant Cost Savings

With cost savings of up to $1.50 per square foot, contractors, developers and owners are increasingly turning to panelized wood roof systems. "When we take advantage of all the efficiencies of this type of

Highland Fairview Corporate Park / Skechers Distribution Center / Moreno Valley, CA

DESIGN:	Highland Fairview
EXECUTIVE ARCHITECT:	HPA Inc. • Irvine, CA
ENGINEER:	Kramer Engineering Inc. (formerly Kramer and Lawson Inc.) • Tustin CA
GENERAL CONTRACTOR:	Highland Fairview Construction Inc. Moreno Valley, CA
ROOF ERECTOR:	Beven-Herron, Inc. • La Mirada, CA

Nowhere are the benefits of speedy panelized roof erection more noticeable than on a project like this. At over half a mile long—1.8 million square feet—the sheer size of the Highland Fairview Corporate Park project made it uniquely qualified for a hybrid panelized wood roof system. "It was a job of a magnitude we had never seen before," said JD Herron from Beven-Herron. "Speed was critical. We started work on September 29, 2010 and were substantially complete on January 21, 2011, using a crew of about 50."

With more than 53,750 sheets of OSB, 45 miles of steel trusses and girders (240 truckloads), 1.63 million board feet of lumber (20 rail car loads) and 14 million nails (four truckloads), it was also an immense job in terms of material acquisition and staging.

"Sixty percent of the roof was prefabricated in our La Mirada facility," said Ed Pitts, also from Beven-Herron. "We nailed the OSB to the sub-purlins there, and trucked everything 59 miles to the job site, which allowed us to use our labor more efficiently. It also provided significant cost savings. Plus, the panel-building machine has very precise nailing, so we got better quality in terms of nail spacing."

Several factors led to unique loading criteria for the project:

- The building is located in an area with a higher seismic load than normal—a 33 percent increase above normal California requirements.
- The building had a 40-foot clear height, which increased diaphragm loads.
- The project team designed the building to accommodate future solar installation. The building initially had about 200,000 square feet of solar panels installed; the developer will eventually cover the entire roof.

"All of these things led to a more expensive roof structure than is typical for a hybrid system," said Herron. Under normal loading conditions, he said this project would have cost about $3.25 per square foot but additional loading criteria increased the final cost. "We don't see many projects this size," he added, "But when we do, a hybrid panelized wood roof system is the only way to go."

construction, a typical hybrid panelized system for a large project under normal loading runs about $3.25 per square foot," said JD Herron with Beven-Herron, a California-based roof erector. Savings can be attributed to material costs, speed of installation, safety on the job site, and insulation.

"Even considering price fluctuations of both materials, wood is consistently more economical than steel for most low-slope commercial roof projects," said Lisa Podesto, MS, PE, Senior Technical Director and Building Systems Lead for WoodWorks.

Speed of installation also adds to the cost effectiveness of the system, and savings for the owner and developer because they can occupy or lease the building sooner. An accomplished roof erector with just one crew can erect more than 100,000 square feet of roof panels per week. Tim Lessard from Panelized Structures said, "We can install a hybrid roof in half the time that someone else can put in a metal deck roof."

A safe work environment also adds untold cost savings to a project. Because the panels are assembled on the ground, a roof erector needs only two or three people on the roof at a time. "Fewer man-hours on the roof directly translates to a safer work site," said Marchell.

Differences in insulation requirements also add to cost savings. Contractors can install roofing membranes directly to the wood structural panels, eliminating the need for rigid insulation or barrier board on top of the deck. In a metal deck system, rigid insulation is required, even in mild climates, because it provides the substrate for roofing attachments.

If insulation is needed, inexpensive batt insulation can be installed below the deck of a panelized wood roof system, saving $0.50 to $.75 per square foot over the cost of rigid insulation. However, rigid insulation may be required in regions with cold exterior temperatures, applications with high indoor humidity, or situations where single-ply roofing is desired and a Class A roof is required. OSB radiant barrier panels offer another option. They cost about $0.05 to $0.10 per square foot more than regular OSB, but their reflective backing blocks up to 97 percent of radiant heat, which helps reduce cooling costs.

Diaphragm Design

High-load diaphragm capacities and collective chord design are useful tools for designing panelized wood roof diaphragms.

"The high-load diaphragm capacities are needed for any large building that uses a wood diaphragm," said John Whiteman, a structural engineer with Kramer Engineering. "Table 2306.3.2 in the 2009 IBC provides high-load

Freedom Truck Center / Spokane, WA

ARCHITECT:	ALSC Architects • Spokane, WA
ENGINEER:	DCI Engineers • Spokane, WA
GENERAL CONTRACTOR:	Lydig Construction • Spokane, WA
ROOF ERECTOR:	Mandere Construction • Rathdrum, ID

Freedom Truck Center is a full-service Freightliner and Western Star truck dealership. The 45,000-square-foot building houses a showroom, offices and maintenance shop. Owners wanted the most cost-effective roof system; they also had an aggressive construction schedule. Both requirements led the design team to choose an open-web panelized wood roof system instead of an all-steel structure.

Mandere Construction's John Mandere said steel was at a premium at the time of design, making wood even more cost effective. "The roof joists were $2.45 per square foot; glulam beams, sheathing and framing materials were $1.38 per square foot; and labor and equipment cost $1.66 per square foot, including column erection. That put our total installed cost at $5.49 per square foot, where a similar steel system would have been $6.00 to $7.25."

Justin Cook, PE, with DCI Engineers, said, "We do cost comparisons on a normal basis and cost was definitely a big part of the reason why this project was built with wood instead of steel. When we factored in depth, spacing, fire ratings and other considerations, we knew wood would be the less expensive option. We just had to go through the exercise of proving it."

Cost-effective installation also added to the value. Mandere assembled the roof panels on site and lifted them into place by crane. "The open-web wood trusses were 45 to 50 feet long, spaced 48-inches on center," said Mandere. "Fortunately, we had a job site big enough to accommodate our panelization, so we started assembling the panels about six days before we began erection. We ran our installation crew for five days but then had to leave because we were too fast and caught the masons. Altogether, the roof took just about 14 days to install."

Rivergate Corporate Center III / Portland, OR

ARCHITECT: Group Mackenzie • Portland, OR
ENGINEER: Group Mackenzie • Portland, OR
GENERAL CONTRACTOR: Howard S. Wright Constructors • Portland, OR
ROOF ERECTOR: Panelized Structures Inc. • Modesto, CA

Sometimes, a building is the perfect candidate for a hybrid panelized roof system. Subaru's Distribution Center at Rivergate Corporate Center III is one example. Designed and built to meet Subaru's specific distribution needs, the LEED-rated facility is 413,700 square feet.

Tim Lessard from Panelized Structures said the project team designed the building as a hybrid roof from the outset. "They knew going in that a hybrid system would be the most economical roof structure; the engineer from Group Mackenzie had experience with these systems. Plus, the developer knew (as do many on the West Coast) that the hybrid system would come in at $1.25 to $1.50 per square foot less than a metal roof system."

Final cost for the hybrid wood roof system was $3.40 per square foot, not including the cost of the columns but including cost of their installation. The developer saved more than $500,000 by using a wood hybrid system instead of steel while meeting all performance criteria.

This 35-foot-high facility has 50-foot bays throughout most of the building, with 60-foot joists in the truck bays. The roof erector used 15⁄32-inch, 10-foot-long OSB panels to minimize waste and maximize installation efficiency. Panelized Structures spent a week setting the steel columns and hanging the steel joists and girders, and erected the rest of the roof structure in just under three weeks.

"Our role was to install the steel columns, wide flange beams and joist seats that were furnished by the general contractor," said Lessard. "Then we furnished and installed the joists and girders, sub-purlins, straps and roof sheathing, and did all field welding and nailing. It was a very straightforward job—perfectly suited for a hybrid panelized roof system."

diaphragm values for nailing in multiple rows. It would not be possible to design some of these large warehouses with heavy pre-cast concrete walls without that high-load diaphragm nailing."

Collective chord is a design method that uses the repetitive wood or steel members that are already tied together for the chord. "This is particularly beneficial for large warehouse projects, especially in loading direction perpendicular to the purlins," Whiteman added. "Collective chord design uses an equation to determine the moment of inertia and chord forces in the repetitive members. The resulting forces in the members are often less than the cross-tie forces required by the anchorage design."

Sub-diaphragm design is another efficient design tool. "The sub-diaphragm analysis makes sure that we develop higher wall anchorage loads into the building to ensure that the walls won't pull away," said Whiteman. "Over the years, the required anchorage load has gone up significantly, to the point where we're now at 80 percent of the seismic acceleration."

Effective Design, Smart Results

Panelized roof assemblies meet Underwriters Laboratories (UL) and Factory Mutual (FM) wind uplift ratings to comply with insurance requirements. "Over time, wind uplift loads have increased," said Whiteman. "Uplift around the perimeters and corners of buildings are more involved and higher with the IBC wind calculations, but it is something that can easily be designed into the project."

Wood roof decks also accommodate compound slopes and abrupt slope changes for roof drainage, thus eliminating the need for costly crickets and sloped insulation. Per Section 1611.2 in IBC 2009, designers should use a slope of ¼-inch per 1 foot to eliminate the need for ponding calculations.

Roof penetrations for skylights and downspouts are more easily flashed with a wood roof system than with steel since all openings are framed with wood. This means skylight installation can cost up to 33 percent less for hybrid and all-wood roofs than for steel roofs. In addition, structural expansion joints are not required with wood roof decks as they are with metal decks.

"Even with all the advantages, the number one reason we like using panelized wood roof systems is safety," said Mandere. "Our business lives and dies by our people, so our biggest goal is to keep employees safe. We also value the fact that panelizing allows us to provide speed and quality. All of that translates into cost savings for the owner."

SIPs Offer Versatility for Panelized Wood Roof Systems

The Jacob E. Manch Elementary School in Clark County, Nevada provides a good example of how Structural Insulated Panels (SIPs) added value in a panelized wood roof application. Framing crews were able to dry-in the 68,000-square-foot building in just 47 days, which was 60 to 80 percent faster than the school district's typical construction schedule. SIPs will also reduce the building's energy use by at least 50 percent.

Because of its construction, with rigid foam insulation sandwiched between two OSB panels, a SIP panel provides both structure and insulation. Panels are available in sizes up to 8 x 24-foot dimensions, which also speeds installation.

Kailua Town Center / Whole Foods / Kailua, HI

ARCHITECT: MC Architects • Honolulu, HI
ENGINEER: KAI Hawaii • Honolulu, HI
GENERAL CONTRACTOR: Gateside, Inc. • Honolulu, HI
ROOF ERECTOR: La'au Structures • Honolulu, HI

An all-wood panelized roof was the system of choice for the Kailua Town Center Phase III. Kaneohe Ranch Management Limited developed the 41,000-square-foot facility as part of their revitalization of downtown Kailua. Whole Foods will occupy 32,000 square feet, Executive Chef will take 8,000 square feet and additional businesses will occupy the remaining space. La'au Structures installed the all-wood panelized roof system for the entire building.

As is typical for all-wood systems, bay sizes were shorter—around 35 feet. The 40-foot-long main-span beams cantilever over the columns, and 3 1/8-inch glulam purlins span 35 feet at 8-foot centers.

Total cost for the roof structure was $9.50 per square foot, approximately $1.10 of which was for the connectors. Greg Boyd from La'au Structures is quick to point out that $9.50 may seem high to those on the mainland. "In Hawaii, the cost of an all-wood system is usually around $10.00 per square foot. A hybrid system generally costs $10.00 to $11.50 and an all-steel roof system will be $15.00 to $16.00 per square foot."

He added, "An all-wood panelized roof is very cost effective on buildings of this size in Hawaii, particularly compared with steel. We used pressure treated lumber, since structures here are subject to termite issues. Pressure treating increased the glulam cost by about 35 percent, and increased lumber costs by 15 percent. But the all-wood option was still significantly less than a steel system."

Boyd said that an all-wood system was also easier to work with because the structure was not a square. "In fact, where there are irregular point loads, either from mechanical units on the roof or hanging machinery, an all-wood system can be an even more cost-effective option," he said. "Otherwise, each steel bar joist would need to be designed uniquely for the specific loading scenario. Plus, when we need to make modifications, wood gives me more flexibility. Steel's long lead times make it difficult for me to make changes in the field."

ADDITIONAL RESOURCES

WoodWorks offers free technical support and resources related to the use of wood in non-residential and multi-family building types.

Visit woodworks.org for:

- One-on-one project support
- Online training
- CAD/REVIT details
- Span tables
- Cost and carbon calculators
- Technical materials
- Workshops/lunch and learns
- Wood Solutions Fairs

Resources related to the design of all-wood and hybrid panelized wood roof systems are available at www.woodworks.org/design-with-wood/building-systems.

woodworks.org

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