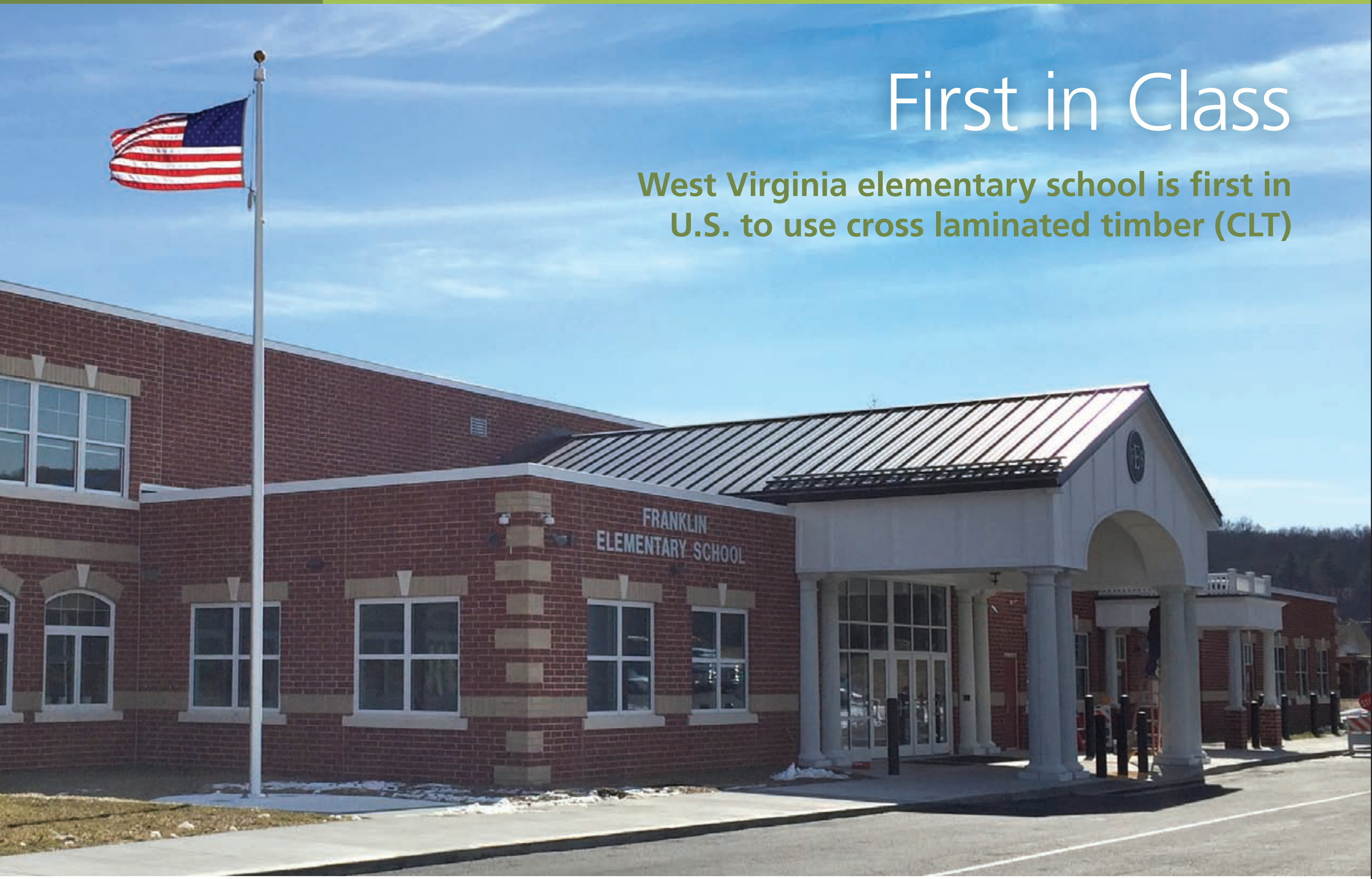
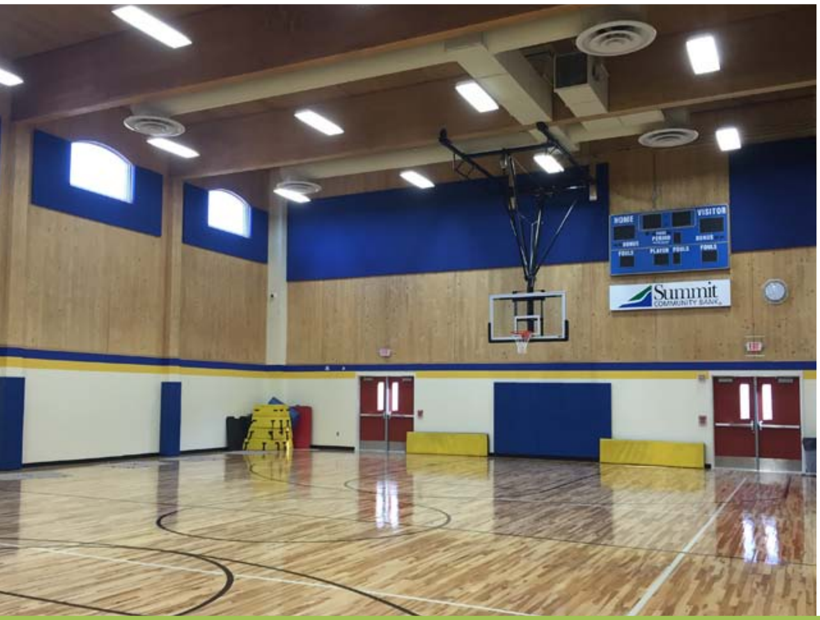
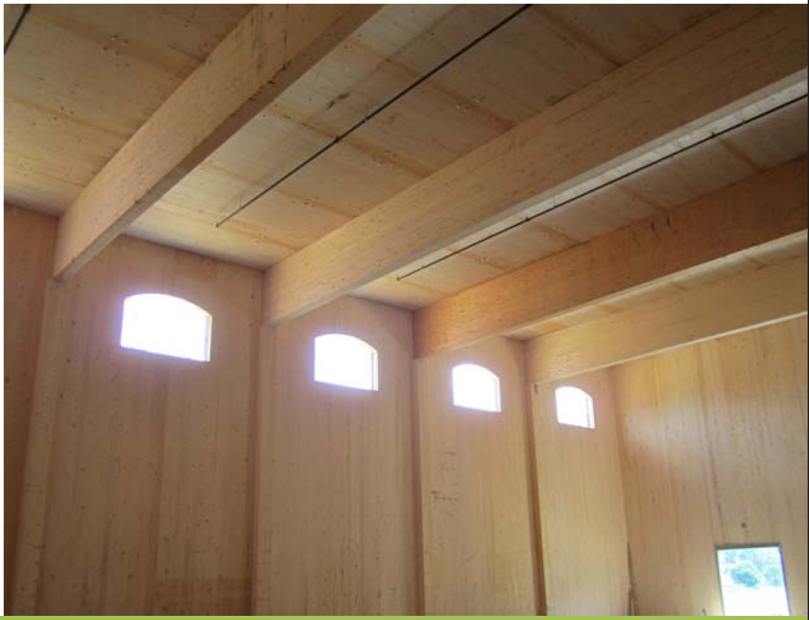
First in Class

West Virginia elementary school is first in U.S. to use cross laminated timber (CLT)







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WOOD PRODUCTS COUNCIL

They set out to build a school that would last; they ended up achieving two significant firsts.

The town of Franklin, West Virginia needed a new elementary school—quickly and on budget. Some might have expected this small, rural community to take a conventional approach. But area leaders wanted more for their students. So they did two things no one else had done: Franklin Elementary is the first design-build school project for the state of West Virginia, and the first school in the U.S. to be built using cross laminated timber (CLT).

Fixed Cost, Speedy Construction

Franklin's school district needed the predictability of a fixed-cost project for the 45,200-square-foot elementary school, which the design-build contract provided. They also had a short construction window. That's why CLT was chosen for the structural framing over concrete masonry units (CMU) and insulated concrete forms (ICF), which are more commonly used for school construction in West Virginia.

"Franklin is a very tight-knit community," said Pam Wean, Senior Project Architect and Project Manager, MSES Architects. "It's a small town with literally one stoplight, so this project was very important to them. In fact, the groundbreaking ceremony was attended by hundreds of people, yet Franklin itself has a population of less than 1,000. It is significant that they were willing to try a new wood building product."

The fact that the school was constructed through a harsh West Virginia winter was testament to CLT's quick installation. The CLT structure was erected quickly enough to allow students to move into the new school in January 2015, just in time for second semester.

Innovation at Work

West Virginia's School Building Authority (SBA) is responsible for assisting school districts in the bidding process for capitol building projects. The SBA had been planning to build Franklin Elementary out of steel, concrete or CMU—just like every other school in the state.

But Bud Henderson, president of City Construction Company, was familiar with CLT through another project and saw the opportunities for Franklin Elementary. "We're proud of the fact that City Construction is the biggest school builder in West Virginia," he said. "When the SBA decided they wanted to be more innovative and allow for a design-build concept delivery, I knew it was also a good time to introduce CLT."

Henderson said that CLT was not initially listed in the building formats allowed by the SBA, so they first had to go through an approval process. "We weren't sure if CLT would be approved and we had an extremely short time window, so we initially had multiple sets of foundation drawings allowing for a CMU, ICF or CLT building system."

To learn more about CLT's capabilities, SBA met with WoodWorks-The Wood Products Council, which has expertise on the use of all wood products in non-residential and multi-family projects. Approximately 30 people attended the meeting, including representatives from the SBA and project team. Discussions, which included CLT as well as general wood-frame construction, covered (among other things) safety and durability. With WoodWorks' support, the SBA added CLT to the list of materials approved for use in school construction in West Virginia.

Wean added that they also had to seek approval from West Virginia state fire marshals, who govern construction of all of the state's schools. "The fire marshal for Pendleton County schools has been heavily involved and very supportive of the CLT system," she said. "Now that CLT has been approved, it can be used for other schools in the state of West Virginia."

Once the wood system was approved, the design and construction team placed the material order. Although CLT can now be sourced in North America, the material for Franklin Elementary was engineered by Timber Concept in Germany, and the panels were manufactured and shipped from Europe. Timber Concept designed panel specs and layout as well as shear walls, openings and other details; they also coordinated pricing and delivery of the panels to the job site. Because the CLT system was new, Timber Concept provided these value-added services to provide a link between the manufacturer and the project team.

The decision to use CLT brought many structural advantages, said Bernd Gusinde, a Director at Timber Concepts. "CLT provided high axial load capacity for the walls of Franklin Elementary and a floor span-to-depth ratio of 20:1 to 30:1. Apart from that, the speed of installation and quick turnaround time from planning to start on site was a big benefit to the community. Finally, CLT is much more effective in terms of sustainability and building physics performance."

Franklin Elementary School

LOCATION: Franklin, WV

OWNER: Pendleton County School District

ARCHITECT: MSES Architects • Fairmont, WV

PROJECT ENGINEERS: MSES Consultants, Inc. • Clarksburg, WV and Clayton L. Carter Professional Engineer, Inc. (CLCPE) • Elkins, WV

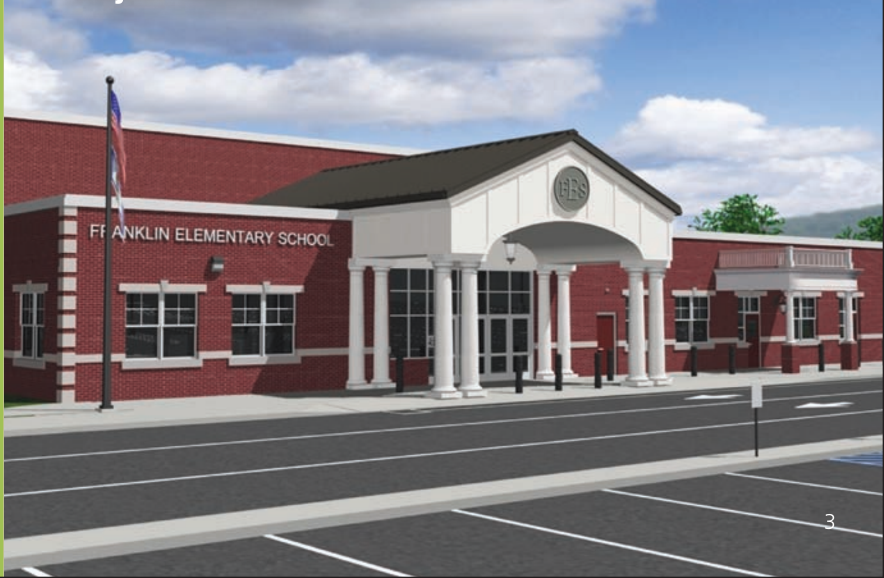
TIMBER ENGINEERS: Timber Concept GmbH • Weißensberg, Germany and Ingenieurbüro von Fragstein • Landau in der Pfalz, Germany

GENERAL CONTRACTOR: City Construction Company • Clarksburg, WV

CLT BROKER: LignaTerra Global, LLCl • Charlotte, NC

COMPLETED: January 2015

Project Overview



CLT Panel Thickness Adjusts to Accommodate Span

As is typical with a design-build approach, the initial building specifications were developed by the criteria developer, another architectural firm that worked with the district to determine their needs for the school. MSES Architects then stepped in to design the structure. The resulting school houses about 300 students in pre-kindergarten through grade six, with two classrooms per grade.

The administrative suite is located in the center of the school at the front entrance, adjacent to classrooms for pre-K through first grade. Another wing houses the second grade classrooms as well as a computer lab and media center. The gym, cafeteria and music room, which opens on both sides to highlight the stage, are located in the back. The second floor houses classrooms for grades three to six.

While it is relatively easy to increase the thickness of a CLT panel to allow for longer spans requiring fewer interior support elements, the design team had to limit panel length to a size that would fit in an ocean-going shipping container. "Other than that, the general approach for Franklin Elementary was the same as we use for every CLT building we engineer, and very straight-forward," said Gusinde. "The resulting impact of slightly shorter panels on building physics was minor."

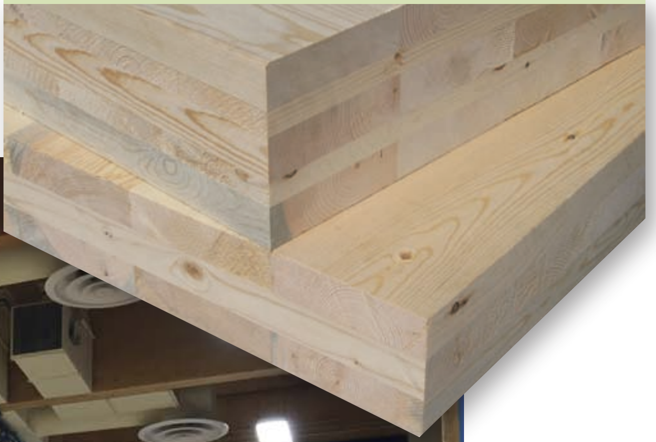
The slab-on-grade design uses CLT for the roof and above-grade floor structures as well as all bearing walls. Interior partition walls were framed in light gauge metal, though Wean agrees they could easily have used dimension lumber. "The CLT bearing walls, which include all the exterior walls, corridor walls, shear walls and gymnasium walls, were approximately 5 inches thick," she said.

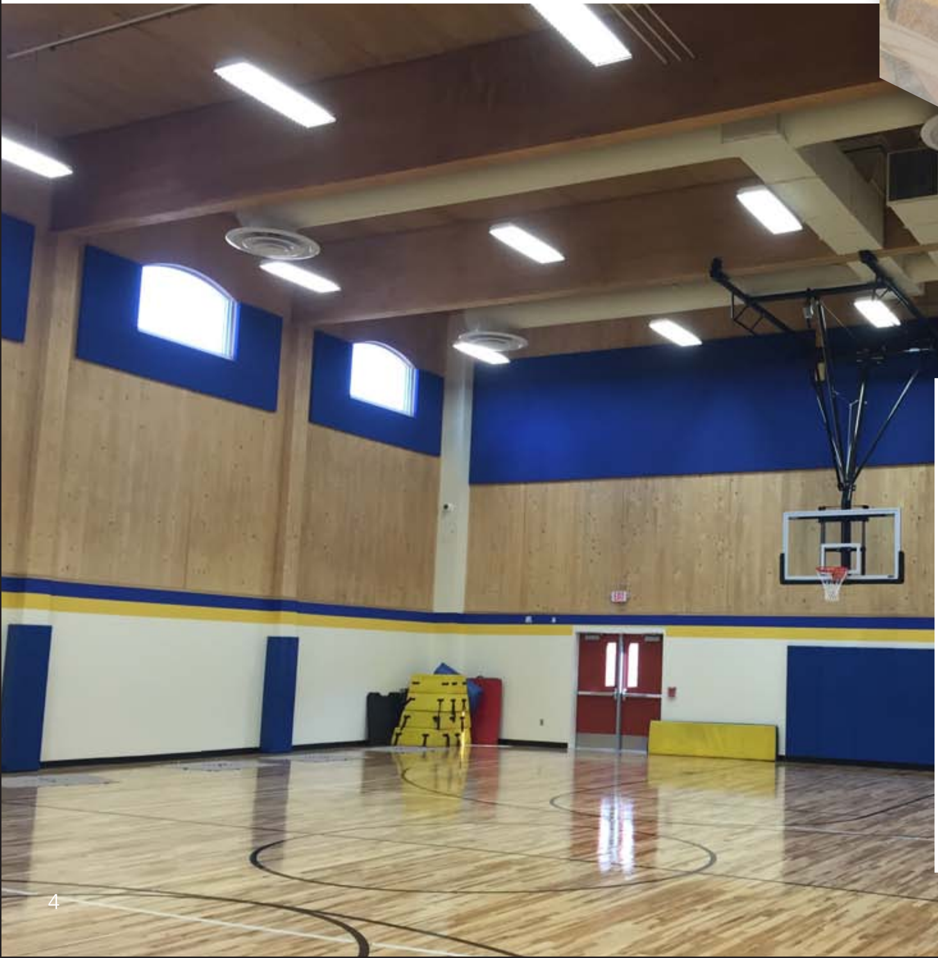
What is CLT

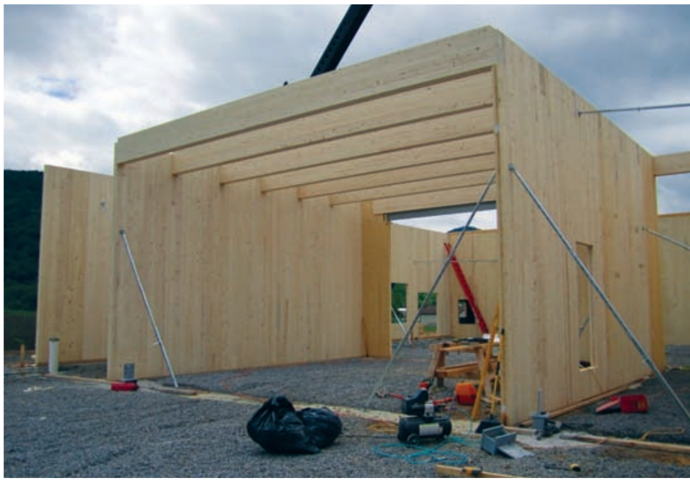
Widely used in Europe for more than 20 years, CLT is a prefabricated engineered wood panel typically consisting of three, five, seven or more layers of dimension lumber or structural composite lumber. Kiln-dried boards are cross-oriented and bonded with structural adhesive to form a solid wood panel. This cross lamination provides dimensional strength, stability and rigidity. Most CLT is made with pine, spruce or fir; the panels used for Franklin Elementary were made with a mix of spruce and European Whitewood.

LCA studies show time and time again that wood offers a lighter environmental footprint than concrete or steel. CLT benefits can also include quicker installation, less on-site waste, lighter weight, improved thermal performance and energy efficiency, and design versatility. CLT panels can be used for interior and exterior applications with proper finishes and protection.

Changes in the 2015 *International Building Code* (IBC) allow the use of CLT manufactured according to ANSI/APA PRG 320, *Standard for Performance-Rated Cross-Laminated Timber.* CLT walls, roofs and floors are permitted in all types of combustible construction, including Type IV (Heavy Timber) buildings.







"CLT panel thickness is dependent on span and loads, so when we needed to avoid columns, we just increased the thickness of the CLT floor panels to increase the allowable spans," said Wean. "We did the same for the CLT roof panels, which ranged in thickness from about 5 to 9-9/16 inches, and were nearly 8 feet wide and 40 feet long."

While CLT panels act as two-way slabs, the stronger direction follows the grain of the outer layers. For example, Franklin's CLT wall panels were engineered and installed so the boards on the outer layers have their grain running vertically. The panels used in the school's floor and roof applications were installed so the boards on the outer layers run parallel to the span direction.

Design Challenges, Opportunities

Franklin students aren't the only ones who are learning. Because this design-build project had so many 'firsts,' the team opted for a mixed solution. But Wean and Henderson agreed they may do things differently with future projects.

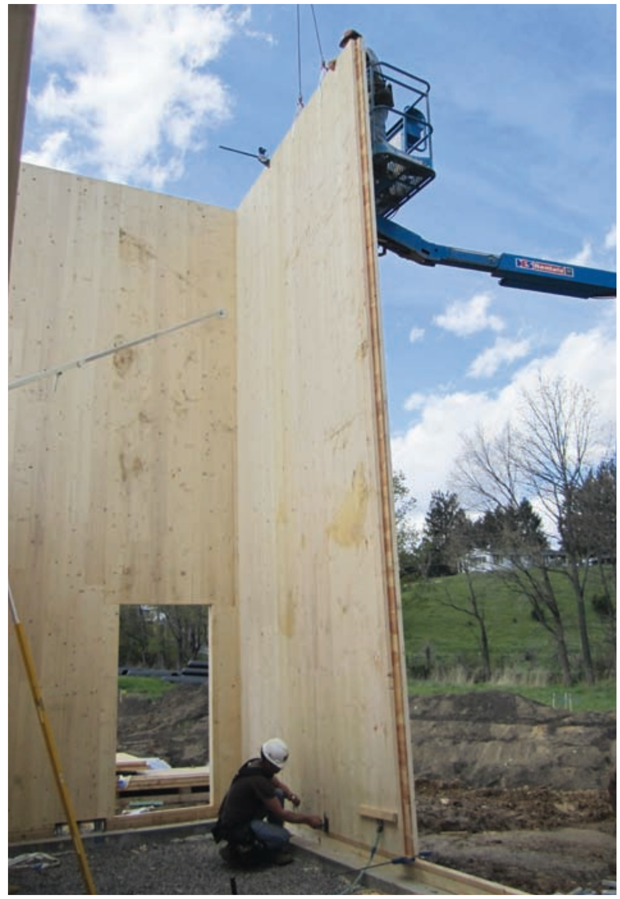
"When we initially laid out the school, we designed it generically, knowing it could either be built from CLT, CMU block or ICF," explained Wean. "We're not used to designing schools using wood, and we were certainly not familiar with CLT, so this was all new to us. We'll do things a bit differently with the next project to take full advantage of the CLT."

One challenge came from some data regarding snow loads. "Criteria for snow loads in this part of West Virginia falls under the 'case study' approach, which means there's no set snow load in the code; you have to go on a city-by-city basis," said Stacey Bowers, Project Architect, MSES Architects. "Once we were in design phase, we discovered the snow loads were higher than originally thought; 43 psf instead of 30. Since we were already far into design, we solved the problem in two ways. We added steel in part of the building, and we increased the thickness of some of the CLT panels in other areas."

The team also worked to balance cost versus span. "We weighed the cost of adding columns against the cost of thicker panels needed for some of the spans," said Bowers. "In some places, it was less expensive to order thicker CLT panels; in other places, we simply added a column." They also used glulam beams for the long spans in the cafeteria and the gym because of the limited panel sizes that could be shipped by container.

In West Virginia, all schools must be sprinklered. "Initially, the fire marshal didn't think they would require sprinklers above the drop ceilings, so that's the way the project was bid," said Wean. "However, that changed, so we ended up installing sprinklers everywhere with exposed CLT, which meant both above and below the drop ceilings." Fire officials agreed that the CLT walls needed to be one-hour rated, so MSES added a layer of drywall on each side of the bearing walls.

Architect, engineer, contractor and manufacturer coordination is critical in CLT construction. "Thanks to straightforward and practical architecture, there were no big challenges to overcome with this project," said Gusinde. "We introduced CLT shear walls to brace the structure in one area; the other areas were



unproblematic. Some of the specific details were new to us, such as the way the foundations and the finished floor layer are carried out. We had to react to them but in the end it was very easy, also due to the great cooperation between the architects and local parties."

Speed of Construction

One of the greatest advantages CLT brought to the project was speed of installation. The schedule for Franklin Elementary is even more amazing when you consider the weather in which City Construction's crews worked.

"We started installing the foundations in late November 2013, in the dead of winter," Henderson said. "In fact, that winter was so bad we had to pour concrete with an excavator because our trucks couldn't get around. We finished the foundation at the end of March 2014, started setting CLT panels in April, and set the last panel mid-June."

Chuck Pickens is Project Superintendent for City Construction. "On our best day, we set 33 panels with four guys and a crane operator," he said. "That's roughly 10,000 square feet of building surface put up in just one day. It would have taken 29 masons to cover that same area in a day with CMU, so the labor savings with CLT were huge. When I compare speed of construction against CMU and ICF, the CLT is definitely fastest. And as we get more familiar with the CLT, it will go even quicker."

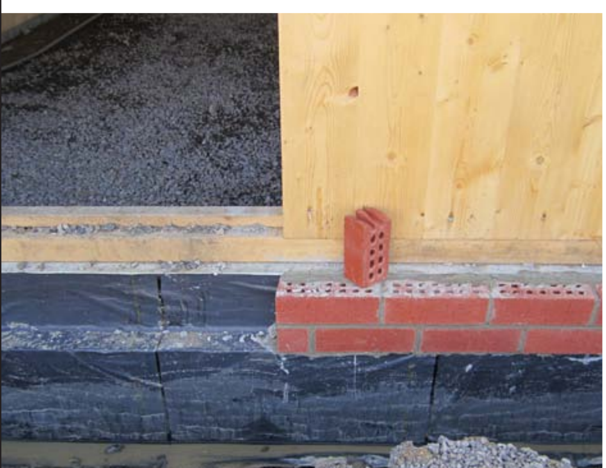
"With a school, you can't slide opening day, so speed of construction was a huge benefit," said Wean. "We were at the job site many times when the snow was one or two feet deep, yet crews were still able to lift and place CLT panels. There's no way they could have worked through the winter we had last year in West Virginia with another material. They would have had to shut the site down."

Connections

CLT erection for Franklin Elementary had many similarities and a few differences from other framing systems.

Initial construction progressed similarly to that of block construction; they erected the walls first and then poured the slabs. This left crews free to route conduit up into the walls. CLT wall panels were attached to the foundation using sill plates, which were anchored to the foundation using 10-inch anchor bolts. CLT panels were notched to match the sill plate configuration and screwed into the sill plate from the side using 9-inch long fasteners. Since the sill plate is exposed on the inside of the structure, they did not want to use treated wood, so they applied a silicone product to protect the lower portions of the CLT from termites and pests; the product provided a barrier while leaving diffusion open.

Vertical CLT panels were anchored to each other using a shiplap connection detail, which allowed them to make minor adjustments to keep everything plumb and true. For the second floor slabs, CLT panel edges arrived with a pre-cut recess and, once the panels were connected, they covered the recess with wood closure strips to fill the gaps. The school had brick exterior siding, and they used a vapor barrier similar to that used on any other wood-frame structure with a brick façade.



Sequential Installation

Installation of CLT panels is sequential, so site management was important for Franklin Elementary. Altogether, more than 700 panels arrived in 32 shipping containers.

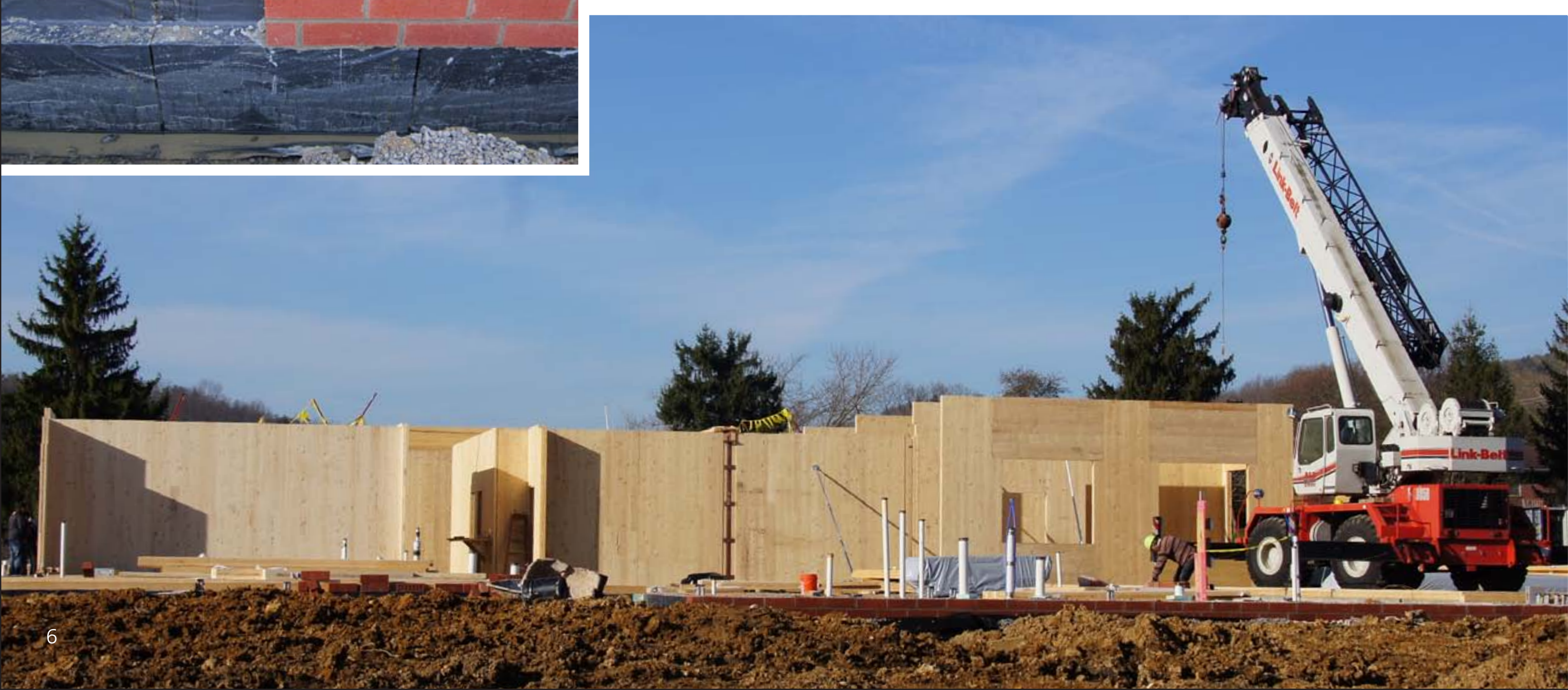
Panels were pre-cut by the manufacturer with openings and utility chases routed into the surfaces for plumbing and HVAC penetrations, and labeled for positioning. They arrived wrapped in bundles on sleds in shipping containers. The large site at Franklin allowed crews to stage containers and materials so panels could be moved by crane and with forklifts, and accessed in the needed order.

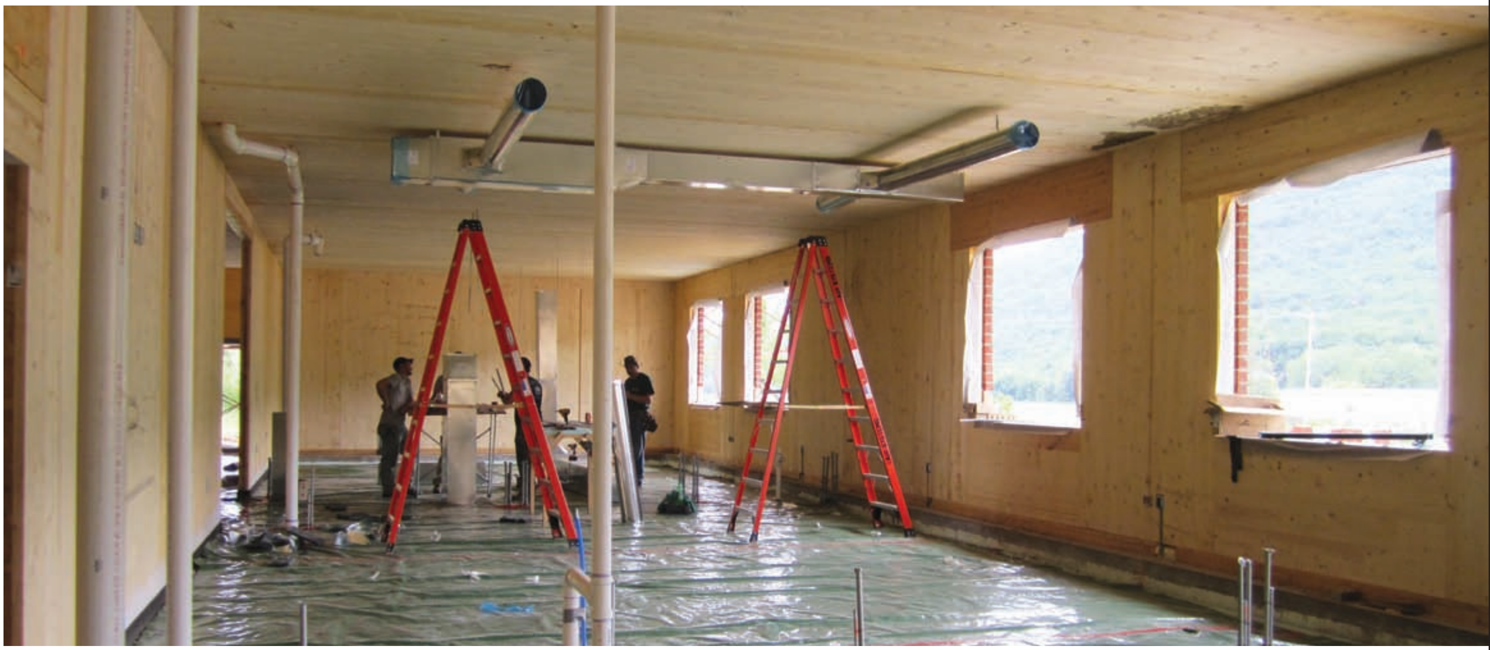
Rigging was also important; the CLT manufacturer pre-installed holes in the panels for lifting straps, pre-set for balance, so crews just needed to attach and lift the panels, which weighed upwards of 3,000 lbs. Once in place, the panels were screwed together. Crews used more than 25,000 screws—with different screw lengths and spacing for varying penetrations—so it was important to keep workers informed.

Installers were particularly careful to avoid kick-out at the base of the multi-story structure, so they used a stepped sill plate with a notched base on the panels for indexing; this helped speed construction and ensure accuracy of the installation. To make sure walls stayed true, crews started by checking the walls for plumb every four panels. Eventually they moved to every eight panels and finally they felt comfortable enough that they only checked every 15 panels. In the end, when crews placed the final CLT wall panel, it was just 1/16-inch out of true—perhaps because the sill itself was out of square instead of the panels.

Crews also routed some conduit chases for panels on site. When panel aesthetics were important, they installed the route on the exterior side and then penetrated through to the panel to install the box. Most plumbing stub-ups were installed exterior to the wall.

The investment in accurate design, engineering and planning paid off with smooth installation. In fact, out of more than 700 panels, crews only had to modify four panels on site, mostly due to service stub-ups being installed slightly out of plan in the concrete slabs.





Learning Curve

As with anything done for the first time, there are a few things the team will do differently with their next CLT project.

"If we could start over again and have the school designed with CLT in the first place, it would have made it much simpler," said Henderson. "We learned everything on the fly." Pickens agreed, adding, "We constructed the building in phases, and would have liked to start in the back and build forward to work our way out of the site rather than having to go around the construction. But our CLT panels arrived for the opposite progression; we made it work. It's a simple thing, but we'll do that differently next time."

Although the majority of the gym walls and ceiling were left as natural CLT, Bowers says they would have liked more of the wood exposed. "CLT allows for a warm, pleasing environment on the interior, especially compared to more traditional materials like CMU. Teachers I know complain about their classrooms built with CMU as being cold. We love the look of the CLT; it's beautiful."

Wean agreed, adding "The most important thing for a future project will be to get everyone on board as soon as we decide we're going to build using CLT, so that we can take advantage of everything it offers. We definitely want to use CLT again. Schools have a very finite open date; speed and reliability of CLT construction, where contractors can work through rain, sleet and snow, offers so many benefits."

First in Class

CLT has been used to build schools across Europe for many years, and Gusinde sees opportunity for increased use in North America—partly because of wood's environmental attributes. Franklin Elementary School includes approximately 818,736 board feet (equivalent) of CLT and glulam, which has a significant carbon benefit—because wood products continue to store carbon absorbed by the trees while growing, and because wood requires less energy to manufacture than fossil fuel-intensive building materials. For Franklin, this equates to 1,014 metric tons of CO_2 (equivalent) stored in the wood, and 2,155 metric tons of avoided CO_2 emissions. (See chart on page 8.)

Wean reiterated the benefits of speedy construction. "CLT was a good fit for this project because of the weather constraints; it allowed construction to proceed in all types of weather. Could another product have been used? Yes, but they might have had to shut down for the winter, which happens here. CLT was safe, fast and effective, and it can be installed year round, even in West Virginia's harsh winters. My advice to other building professionals is to certainly consider CLT."

Henderson agreed, adding "This product seems to make sense for so many applications. In West Virginia, we've become used to being last in so many things, so I guess that was another motivation for me. We wanted City Construction Company to be first in the nation to build a CLT school."

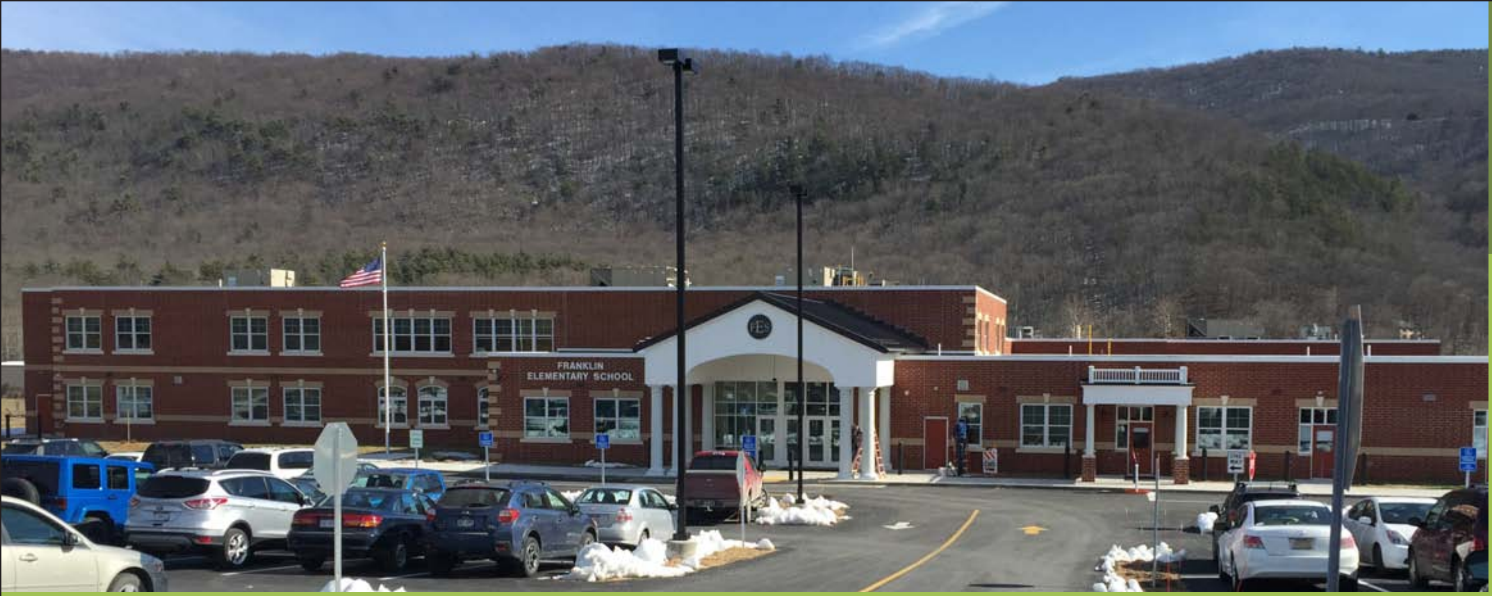
Human Response to Wood

The term biophilia describes the instinctive connection and attraction people have to natural materials, and many building designers cite the warm and natural attributes of wood as a reason for its use. Evidence also suggests that the use of natural materials can contribute to an individual's sense of well-being, productivity and even health.

An Austrian study, for example, found that interior wood use in classrooms reduced pupils' stress levels, as indicated by criteria that included heart rate and perceived stress from interaction with teachers.[1]

Another study, this one at the University of British Columbia and FPInnovations, demonstrated that the presence of visual wood surfaces in an office environment lowered sympathetic nervous system (SNS) activation. The SNS is responsible for physiological stress responses in humans.

According to study author David Fell, these stress-reducing effects are in theory transferable to any building type as they are innate reactions to natural materials. By extension, the application of wood in schools can be expected to contribute to lower stress activation in students and teachers.[2]



Carbon Benefits

Wood lowers a building's carbon footprint in two ways. It continues to store carbon absorbed by the tree while growing, keeping it out of the atmosphere for the lifetime of the building—longer if the wood is reclaimed and reused or manufactured into other products. When used in place of fossil fuel-intensive materials such as steel and concrete, it also results in 'avoided' greenhouse gas emissions.

Volume of wood products used:
818,736 board feet (equivalent)

U.S. and Canadian forests grow this much wood in:
4 minutes

Carbon stored in the wood:
1,014 metric tons of CO_2

Avoided greenhouse gas emissions:
2,155 metric tons of CO_2

TOTAL POTENTIAL CARBON BENEFIT:
3,169 metric tons of CO_2

EQUIVALENT TO:

605 cars off the road for a year

Energy to operate a home for 269 years

Source: US EPA

Estimated by the Wood Carbon Calculator for Buildings, based on research by Sarthre, R. and J. O'Connor, 2010, A Synthesis of Research on Wood Products and Greenhouse Gas Impacts, FPInnovations. Note: CO_2 on this chart refers to CO_2 equivalent.

Use the carbon calculator to estimate the carbon benefits of wood buildings. Visit **woodworks.org**.

WoodWorks is an approved AIA provider.

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1. C. Kelz[a,b], Grote V.[a,b], Moser M.[a,b], *Interior wood use in classrooms reduces pupils' stress levels,* [a]Institute of Physiology, Medical University of Graz, Austria; [b]HUMAN RESEARCH, Institute for Health, Technology and Prevention Research, Weiz, Austria
2. *Wood and Human Health,* Issue 1, FPInnovations

Image credits: (rendering) MSES Architects; (photos) MSES Architects, City Construction Company