The Expanding Use of Wood in School Construction

By Roxane Ward

Last November, the South Carolina Public School Facilities Committee overturned a long-standing policy when it voted to allow the use of wood in school construction. The year before, the state of Arkansas did the same, going so far as to change legislation that for many years had prohibited wood schools. These changes were logically based on the prevalence of wood-frame schools elsewhere in the country, as well as benefits such as cost, speed of construction, and sustainability. But what do design professionals have to say and what are the unique elements that need to be considered?

Wood Schools 101

With certain caveats, the *International Building Code* (IBC) allows the use of wood in building Types I through V. Types I and II, for example, are permitted to include heavy timber in their roof construction and for secondary members – and wood is often used in these buildings to add aesthetic appeal in libraries, gyms, and other common spaces. In Type III construction, wood is allowed in roof and floor systems, and to frame interior walls. Type IV buildings are permitted to include solid or laminated wood members, such as glued laminated timber (glulam), wood decking and structural sheathing where there are no concealed spaces. Fire-retardant-treated (FRT) wood may be used in Types I through IV in certain applications. And wood is permitted anywhere in a Type V building, the most common type of wood construction.

According to School Planning and Management's *School Construction Report*, the average size of a new school in 2009 ranged from 80,500 square feet for an elementary school to 225,000 square feet for a high school. However, there is also a clear push toward smaller schools, which are widely believed to be better for learning. Type V construction is an especially cost-effective option for one-story structures less than 87,875 square feet (which is the limit for a single story).

In California, about 60 percent of all schools are wood construction. "In this market, schools tend to be on the smaller scale," says Ken O'Dell, S.E., a partner at MHP Structural Engineers, who has worked on more than 10 wood schools in the last five years, mostly in and around Los Angeles. "They're often relatively simple structurally, one or two stories with square footage up to about 25,000 square feet for classroom buildings, which makes wood an obvious choice both architecturally and economically."

Michelle Kam-Biron, S.E., is a technical director with the WoodWorks initiative, which provides free support to architects and engineers who design wood schools and other non-residential wood buildings. "In addition to solid sawn lumber, I-joists, wood structural panels, and other products typically associated with a wood building, exposed glulam beams are a popular choice for schools that want to bring the warmth of wood into the interior. Wood also offers an effective engineering solution for large rooms with tall walls and long clear-spanning roofs, such as gyms and cafeterias." To meet the requirements for longer spans and increased loads, designers use wood framing members such as glulam or structural composite lumber studs, to frame the walls and deep-depth joists and heavy timber trusses to frame the roofs.

As an example, Kam-Biron points to the Cayucos Elementary School in Cayucos, California. The structure is almost entirely framed in wood, including the gym, cafeteria, auditorium, and multi-purpose room – each of which have walls between 20 and 30 feet high. "The roof has custom glulam trusses that span 66 feet and I-joists that make up the intermediate framing, and the walls are made of 1¾-inch x 10-inch glulam studs at 16 inches o.c. and 24 inches o.c."

Likewise, the 59,700-square-foot Gunter Primary School in Gunter, Texas is framed in wood, but also features glulam beams both for visual appeal and structural support (including one that spans 82 feet), laminated wood decking for support over the gym and cafeteria, and sheathing over the decking for added shear resistance.

Why Wood?

It's common for designers to have the challenge of creating an enriching environment with limited budgets. However, given that most educators agree that a school's design affects how well students learn – coupled with the strict budget constraints faced by many school boards – the duelling objectives of form and function vs. cost are especially pronounced for schools.

In Japan, a three-year study of 700 schools examined the impact of building materials on the educational environment. While those surveyed generally expressed positive impressions of wood schools over other materials, results also indicated that teachers and students in wood buildings felt less fatigue, and that students perceived schools with wood interiors to be brighter than other structures.

In terms of cost, a 2005 study comparing wood-frame and steel-frame designs for a one-story, 73,557-square-foot elementary school concluded that construction costs could be reduced by nearly $450,000 with the wood design (which, based on the Consumer Materials Price Index, would have translated into $1.5 million in 2008). Operational savings resulting from the roof system's additional thermal resistance were projected at $15,000 a year.

In Arkansas, where several wood schools have been constructed since the change in legislation, the savings go beyond theoretical. Bruce Westerman, an engineer with Mid-South Engineering Company who sits on the board of the Fountain Lake School District, was involved in a project to build a new middle school and renovate an existing high school, which had a combined total of 63,362 square feet. "We considered masonry and steel first, only turning to wood when the initial estimate came in well over budget at $150 a square foot. The wood-frame option came in at $107 a square foot, saving the district $2.7 million."

Safety First – Lateral Loads and Fire

Dwindling budgets or not, schools are required to meet a higher level of safety performance than other building types – both in the IBC and more stringent *California Building Code* (CBC) – for the protection of students and teachers, and because they're often used as shelters during times of crisis.

"The ability of wood buildings to perform well in seismic events is one of the reasons wood is used for so many California schools," says Kam-Biron. "Forces in an earthquake are proportional to the structure's weight, and wood is substantially lighter than other materials. Some engineers think they need masonry or concrete for the tall walls, but this actually adds a lot of load to the structural system from a gravity and seismic standpoint. The fact that wood buildings tend to have a lot of redundancy built into their framing systems and numerous nail connections means they have more load paths, resulting in less chance that the structure will collapse should some connections fail. This is also why wood buildings have inherent ductility, which allows them to dissipate energy when subjected to the sudden loads of an earthquake."

An assessment of damage to schools caused by the 1994 Northridge earthquake in southern California concluded that school structures performed well on the whole, adding that "This type of good performance is generally expected because much of the school construction is low-rise, wood-frame design, which is very resistant to damage regardless of the date of construction."

At Cayucos Elementary School, the roof is made from custom glulam trusses. Courtesy of RRM Design Group, Taylor & Syfan Consulting Engineers.

When properly attached to wood framing, diaphragms and shear walls made from wood structural panels, structural fiberboard, and board sheathing form stable roof, floor, and wall systems that enable the building to effectively resist lateral loads caused by earthquakes and high winds. However, the effectiveness of the system is only as good as the number and quality of connections, says Kam-Biron, who stresses the importance of proper specifying of fasteners and detailing. Criteria for designing and detailing of wood structural systems, members and connections in lateral force resisting systems is covered in the American Wood Council (AWC) publication, *ANSI/AF&PA Special Design Provisions for Wind and Seismic Standard with Commentary (Wind and Seismic)*.

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Fountain Lake Middle School was the first wood-frame school constructed in Arkansas following the legislative change that allowed more wood in school construction. Courtesy of Bruce Westerman.

"At MHP, we work with the architect to strategically take advantage of the walls available, and provide an engineering solution that allows the best distribution of loads throughout the building," says O'Dell. "If we make the decision to use a masonry shear wall or a steel brace frame, we tend to design it to take a major portion of the load to make up for the extra cost and time involved, which often results in building out some of the redundancy. With wood, my diaphragms are going to be divided much more evenly by the demising walls between classrooms. In my mind, it gives you a system that's better distributed."

In terms of fire protection, "heavy timbers perform particularly well because they char on the outside while retaining strength, slowing combustion and allowing time to evacuate the building," says Scott Lockyear, P.E., a technical director with WoodWorks in Georgia and a specialist in fire issues. "In a controlled fire test sponsored by the National Forest Products Association (now AWC), researchers exposed comparable steel and glulam beams to the same fire conditions for the same length of time. After 30 minutes, the steel beam lost 90 percent of its strength and collapsed while the glulam beam remained straight and true, having lost just 25 percent."

For Occupancy Group E buildings, which include most schools, IBC 903.2.2 stipulates that sprinklers are required in areas larger than 20,000 square feet. However, the CBC and other local codes go further, often requiring sprinkler systems and other fire protection measures in new schools of any size. Round-the-clock fire protection is especially important, given that 32 percent of school fires start under suspicious circumstances and most occur in July when school is out of session.

"Protected construction improves overall life safety, but it can also be utilized to increase allowable areas," says Lockyear. Under the IBC, the addition of sprinklers gives the designer an additional 200-300 percent in allowable area (though, under the CBC, increased area cannot be combined with increased height or number of stories). Wood framing also utilizes assemblies with rated gypsum wall board, which improve the safety of the building by protecting structural elements. The AWC publication, *Design for Code Acceptance 3 – Fire-Rated Wood-Frame Wall and Floor/Ceiling Assemblies*, includes a list of examples. Fire-rated details are also incorporated in the AutoCad/Revit library available on the WoodWorks website (**www.woodworks.org**).

Speed, Flexibility and Adaptability

Although many buildings have tight construction schedules, completion deadlines are especially important for school boards that need everything in place when students show up on the first day of classes.

"School construction schedules tend to be fast track," said Lockyear. "With wood, the timeline for delivery is short and assembly is fast. Even though many schools use wood products that you aren't going to buy at the local lumber yard, they still take considerably less time to manufacture according to spec and deliver than steel. Most communities also have a large and readily available labor pool that's familiar with wood-frame construction."

With the exception of major members that are made to spec off-site, wood can be easily adapted in the field, providing a quick work around if mistakes are made or drawings are revised. That same adaptability can also save schools money in the long run. A survey of buildings demolished between 2000 and 2003 in Minneapolis/St. Paul found that North American buildings often have a service life of 50 years or less, regardless of material, not because they've fallen into disrepair, but for reasons such as changing needs and land values. Wood's workability and light weight make it well suited to additions and retrofits if schools need to expand; however, wood systems are also dismantled with relative ease and the materials used elsewhere.

Regarding durability, which is a priority for schools, Westerman said the only hurdle his team ran into when reviewing the design for Fountain Lake Middle School was what material to use for the interior corridors. "We were concerned that students might knock holes in the gypsum wallboard," he said, "so we installed OSB (oriented strand board) over the wood studs and covered it with impact-resistant gypsum."

"Wood also offers good sound absorption, which is important in schools," says Lockyear. "Because wood has more sound damping capacity than other materials, it's relatively easy to achieve the required noise control – especially where wood framing is surfaced with wood structural panels."

The Greening of America's Schools

With an increase in government policies that require public buildings to meet environment-related criteria, it isn't surprising that the education sector is one of the fastest growing markets for green building – or that wood is playing an increasing role in school construction.

Wood is the only major building material that's renewable and sustainable, and the only one with third-party certification programs to verify that products being sold originated from a sustainably managed resource. Wood buildings are energy efficient, and life cycle assessment (LCA) studies have consistently shown that wood performs better than other materials in terms of embodied energy, air and water pollution, and global warming potential. Between the greenhouse gas emissions avoided by not using steel or concrete and the fact that wood buildings continue to store the carbon absorbed by trees during their growing cycle (wood is 50 percent carbon by mass), using wood helps to significantly reduce atmospheric levels of carbon dioxide (CO_2).

According to Gilbert Baez of HMC Architects, the design team chose to frame Harada Elementary School in wood because of its low cost compared to masonry and steel. However, it also had environmental benefits. At 69,853 square feet, the school stores approximately 490 metric tons of carbon in its wood-frame construction and is estimated to have saved twice that amount in avoided greenhouse gas emissions.

A+ for Wood Schools

With the benefits of wood becoming more widely recognized, an increasing number of designers are exploring its use as a structural and finish material in school construction. Engineers who have questions, or would like assistance solving a technical issue, are invited to visit **www.woodworks.org** and contact a technical director in their region.▪

Roxane Ward is a Vancouver, Canada-based writer who has written extensively on sustainability, forest and wood-related issues for more than 15 years.

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