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Mass Timber Modular Construction: Developments in Oregon

Judith Sheine[1], Mark Donofrio[2], and Mikhail Gershfeld[3]

[1] *Professor, Department of Architecture, University of Oregon*
[2] *Associate Professor, Department of Architecture, University of Oregon*
[3] *Practice Professor, Department of Civil Engineering, California State Polytechnic University, Pomona*
[*]*Corresponding author's e-mail: jesheine@uoregon.edu*

ABSTRACT
With the mass timber industry taking off in 2015 in Oregon, when DR Johnson Lumber in Riddle, OR started producing CLT panels, government officials were eager to support it for its promise of economic development in rural communities and also had hopes of addressing the state's affordable housing crisis using mass timber modular construction. While mass timber modular housing has had some success in Europe, the different construction standards and building culture in the United States make it more challenging. With few areas in Oregon in which housing is likely to be built over six stories tall or in large-scale developments, it did not seem possible that mass timber could solve the affordable housing crisis where it cannot compete in cost with standard light wood-frame construction. However, it did seem feasible that mass timber panels, which are so well-suited to customizable pre-fabrication through digital manufacturing, might be successful in an alternative building type for modular construction: classrooms. In successful models of mass timber modular classrooms in Austria and Germany, schools were built in much shorter timeframes and for 25% less cost than steel or concrete construction. The authors are now working with a modular building manufacturer in Oregon, Modern Building Systems (MBS), that produces custom-designed modular light wood-frame classrooms. While mass timber classrooms cannot compete in price with light wood-frame, particularly in single-story applications, they could be competitive for two story (or taller) schools, which are usually built using steel braced-frame and concrete block. Because MBS is 18 miles west of Freres Lumber, which is newly producing Mass Plywood Panels (MPP), and the MBS facility needs no modifications to use MPP instead of wood-frame, the authors are working with them to design an economically competitive mass timber module, with several potential clients interested in testing a prototype in 2019.

KEYWORDS
Modular construction; Offsite construction; Mass timber; Oregon; School construction

INTRODUCTION
In 2015 two notable events in Oregon signalled the acceleration of mass timber development in the United States: DR Johnson in Riddle, Oregon became the first U.S. producer of structurally certified cross-laminated timber (CLT) and the Oregon State Legislature funded the TallWood Design Institute (TDI), a collaborative research center of the University of Oregon (UO)'s College of Design and Oregon State University (OSU)'s Colleges of Forestry and Engineering with a

mission to advance the manufacture and application of wood products in Oregon through research, testing, outreach and education. By combining faculty expertise in the three colleges in sustainable design, wood science, and engineering, the legislature believed that TDI could promote economic development, particularly in rural areas of the state, through the development and application of sustainable wood products in building design. Like many states in the U.S., Oregon suffers from a critical lack of affordable housing and legislators throughout the state, from County Commissioners to the Governor, initially had high hopes that mass timber modular construction could produce sustainable, affordable housing. While we explored this possibility, we also looked at other avenues that might make modular mass timber construction successful in Oregon: school design.

METHODS

Students in UO's Department of Architecture explored the design of mid-rise CLT housing in their First Prize-winning entry in the Association of Collegiate Schools of Architecture "Timber in the City" Competition developed in a design studio in spring 2013 (Figure 1). The studio was taught by Professor Judith Sheine in collaboration with California State Polytechnic University, Pomona Practice Professor of Civil Engineering Mikhail Gershfeld and his senior project students who were designing a mid-rise CLT building in Los Angeles. The interdisciplinary studio focus was critical to the success of the project, promoting a realistic and creative approach to the design problem (Sheine et. al., 2014).

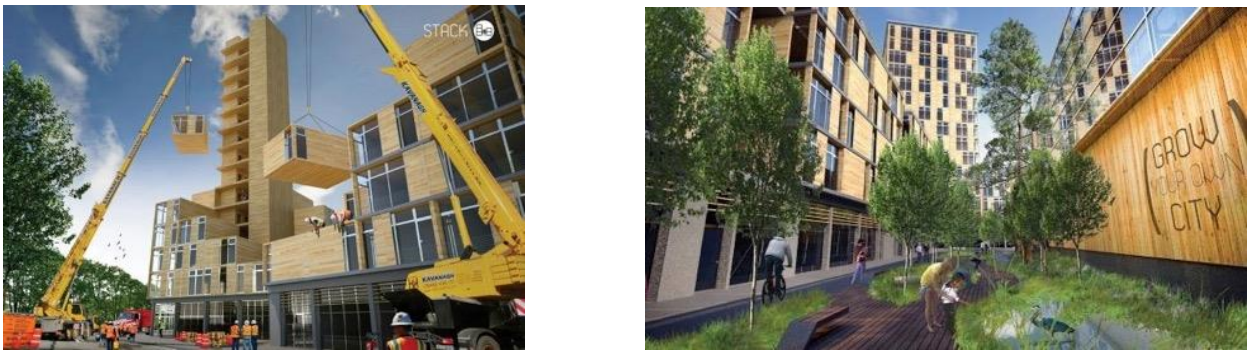

Figure 1: "Grow Your Own City," First Prize-winning entry in the 2012-13 Association of Collegiate Schools of Architecture "Timber in the City" student competition, by UO Department of Architecture students Benjamin Bye, Alex Kenton, and Jason Rood.

In the studio and in subsequent ones focused on mass timber students researched case studies of mid-rise housing using some form of pre-fabricated CLT construction, all in Europe, primarily in Scandinavia, but it wasn't clear that these systems could compete economically in the U.S. where light wood-frame construction is the norm for residential buildings under five or six stories. In Europe, there are generally higher building standards and a greater emphasis on pre-fabrication in timber housing. For example, in Germany, while only 20% of the single-family housing is timber frame, 80% of that is pre-fabricated. to very high standards to compete with masonry and to meet the tough building energy codes. However, these houses start at $230/sq. foot (without kitchens) making it possible to have solid mass timber walls with similar costs (Sheine 2018). Here in the

US., light wood-frame manufactured houses average around $50/sq. ft. (with kitchens), making CLT modular housing unlikely to be able to compete on costs (U.S. Census, 2018).
TDI organized a symposium in March 2017 with housing experts to examine this issue, including representatives from the team designing and developing the Framework building, the 12-story CLT building planned for Portland, Oregon, that was one of the two winners of the USDA Tall Wood Building Competition in 2015, a mixed-use project that included workforce housing. Oregon government officials were invited to the symposium and a white paper summarizing the discussions was posted on the TDI website (Sheine, 2017). The paper concluded that while there were promising developments in residential high-rise construction with CLT in North America, notably Brock Commons, the 18-story student residence at the University of British Columbia, then currently in construction, that below five or six stories it would be difficult to compete with light wood-frame construction, largely because CLT, as a solid wood product, uses more wood than frame. However, at the larger scale, six stories and above, it seemed that it could be economically feasible for residential projects to use CLT for floor and roof decking; Brock Commons, which used CLT decking in combination with glulam columns and a concrete core, was cost competitive with concrete construction of a similar building type (Haden, 2017). Modular CLT residential construction, in which the entire structure would be CLT, seemed less likely to work economically, and with a hold put on the Framework building in July 2018 due to costs, it increasingly appeared that CLT residential construction was not a path for affordable housing in Oregon, at least in the near term.

In the meantime, we had been exploring the potential for CLT modules in another building type in which light wood-frame prefabrication was fairly common: classrooms. In Fall 2014, we worked with Modern Building Systems (MBS), a manufacturer of stick-frame modular buildings (75% classrooms) in Aumsville, Oregon, to develop a modular CLT classroom, based on their standard designs and on the CLT panels that DR Johnson was planning to produce in 2015. Working with a student team and consulting from Gershfeld, Sheine developed a conceptual design for a CLT modular classroom maximizing the use of the CLT panels and designed to be shipped by truck in two pieces, as is the standard for modular classrooms on the west coast of the U.S. While MBS was interested in developing the design into a prototype, there were not yet prospective clients ready to take this on (Figure 2).

Figure 2. CLT modular classroom developed with Modern Building Systems by UO Professor Judith Sheine with UO architecture students Cameron Huber and Kelsey McLaughlin.

Figure 3. CLT classrooms developed in Washington State program, 2017. Left: Adams Elementary School, Wapato, WA; Atelier Jones. Photo: Atelier Jones). Right: Greywolf Elementary School, Sequim, WA; Mahlum Architects (Photo: Michael Dashiell, Sequim Gazette).

In fact, in 2017 when the Washington State legislature appropriated $5.5 million for five additions of four CLT classrooms each to promote the use of mass timber in the state, they explicitly stated that they did not want modular classrooms, which they thought signified low quality as compared to site-built ones (Figure 3). However, it seemed feasible for mass timber modular classrooms to achieve at least as a high a quality as site-built ones and that there could be a market for them.

Along with the argument that mass timber can promote economic development through sustainable design, there have been studies in the U.S. Canada, Europe and Australia attesting to the healthful properties of wood environments. These have been cited in publications from wood manufacturers (Binderholz 2019, Pollmeier 2019, Katerra 2018) and wood products industry groups (Fell, WoodWorks 2014, Think Wood 2019, Make It Wood 2017), who, while not disinterested parties, cite academic studies. In the UK there have been numerous schools built with CLT (Waugh Thistleton Architects, 2018) and there are many examples of mass timber schools across Europe. In particular, Austrian manufacturer Kaufmann Bausysteme has produced CLT modules that have been used in hotels but also in schools, including two in Frankfurt, both designed by NKBAK Architects. The modules were initially selected for a temporary building in 2015 due to their short construction time, but the architectural design was so successful, and the 25% saved in construction costs so significant, that the school became permanent and a second one was commissioned in 2017 (Figure 4). Other examples include the CLT manufacturer Stora Enso's collaboration in 2014 with Mobile Raumsysteme GmbH to build CLT modules for a series of school additions in Vienna.

Figure 4. Left and Center: European School, Frankfurt, Germany; NKBAK, 2015. Right: Integrated Comprehensive School, Frankfurt-Riedberg, Germany - NKBAK, 2017. Photos after completion: Thomas Mayer; Photos during construction: Norman Radon.

These schools make the case for mass timber modules as a substitute for steel braced frame, masonry or concrete construction in two and three story schools that can achieve savings in construction time and costs and without loss of architectural or aesthetic qualities. To illustrate this potential, Sheine taught a UO architecture studio in Spring 2018 focused on the design of two elementary schools using modules of CLT and MPP. Instead of designing new schools with these modules, two newly built elementary schools in Eugene, Oregon, designed by Pivot Architecture with DOWA-IBI Group (2017) were selected as the "sites" and the students were asked to design mass timber modules and substitute them for the classrooms in the existing school designs, along with timber construction for the larger spaces. Seven teams of two students each produced a variety of designs, again with consulting by Gershfeld. At the same time as the studio, TDI teamed with UO's Institute for Policy Research and Engagement (IPRE) to commission the Oregon Consulting Group (OCG), which engages teams of students in the UO Lundquist College of Business to work on client-driven projects, to survey Oregon school districts to determine interest and potential market demand for mass timber schools in the state.

RESULTS

In the design of the modules the students were asked to follow the standards for shipping sizes used by MBS and to design two modules, one using CLT with DR Johnson's panel dimensions and one using MPP with Freres Lumber panel sizes. What we had quickly realized in the 2014 design was that to minimize waste and routing time, it was best to use as much of the panels as possible and to avoid waste and routing by making vertical cuts in the panels instead of cutting out holes for windows and doors, and the student designs followed these principles. Along with the modules, the students were asked to lay out the panels with the cuts they needed for their classrooms to demonstrate their panel usage. They were then asked to select one module type, either the CLT or MPP one they had designed, and apply it to their chosen school. Of the seven teams of two students each, five teams chose MPP and two chose CLT. The MPP had what could be viewed as an advantage with a wider panel width (11'10" MPP vs. 10'0" CLT) and allowed thinner panels to be used for walls (3" MPP vs. 4 1/8" CLT).

The studio had the generous support of Scott Clarke and Karen Williams of Pivot Architecture, who discussed the two recently built schools in Eugene, their design process, current thinking about school design and programming, took us on a tour of the two schools and came to reviews of the student work. In addition to engineering consulting from Gershfeld, we also had input from architect Wendy Rogers, CEO of LPA Inc., a firm with a large portfolio of school designs. With the assistance of faculty members Kevin Van Den Wymelenberg, Jeffrey Kline and Alen Mahic from UO's Department of Architecture Energy Studies in Building Laboratory, the students used the lab's Artificial Sky to analyse daylight penetration in the classrooms and adjusted the designs to minimize glare and ensure reasonable daylight levels. This had some challenges as the modules had to have enough solid walls to make them into an essentially solid box to withstand seismic forces, which ruled out horizontal bands of clearstory windows.

The student teams developed a variety of designs, with some classrooms designed in two modules and some in three modules, and with two- and three-story schemes. Several teams also explored

modules with sloping roofs for the upper story (Figures 5 & 6). The projects were reviewed at the end of the term by architects, mass timber manufacturers and representatives from Modern Building Systems.

Figure 5. Design for elementary school using MPP classroom modules by UO architecture students Payton Narancic and Simone O'Halloran.

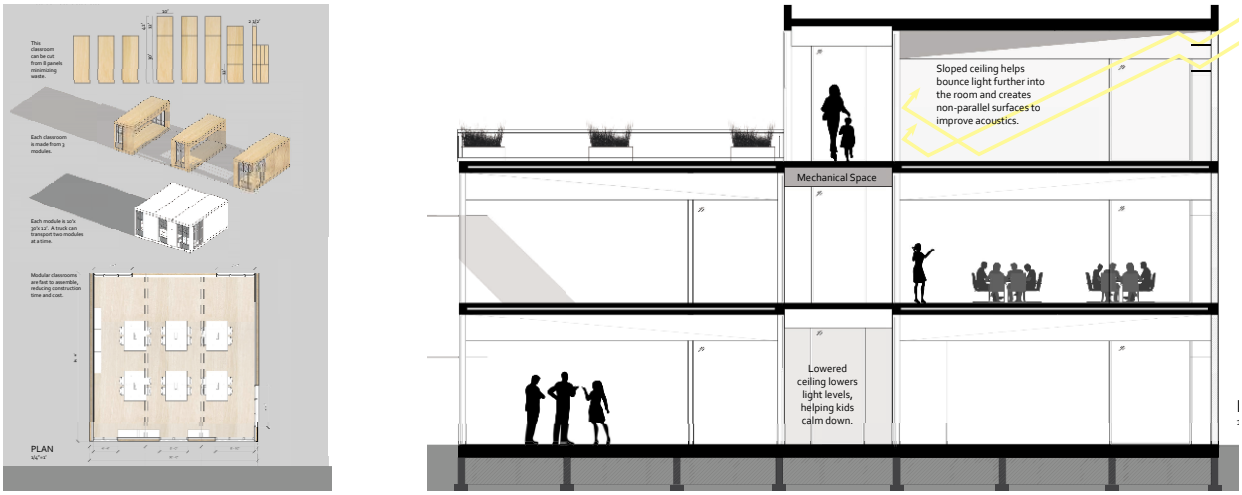

Figure 6. Design for elementary school using MPP classroom modules by UO architecture students Nick McGuire and Molly Winter.

While the studio was running, Sheine and IPRE faculty member Josh Bruce worked with the OCG group on background research and developing the survey, designed to assess market potential for mass timber in Oregon school construction. The OCG team surveyed all 198 school districts in Oregon, which vary widely in size from small rural communities to large urban centers. They had responses from 23 districts, from across the state. They survey asked about districts' plans for new construction, additions and seismic retrofits, about their familiarity with mass timber as a material, and to rank their criteria for consideration in capital projects. Not surprisingly, Construction Cost came out as the leader, but with Structural Safety/Resilience and Long-Term Durability only very slightly behind. Next, grouped close together, were Public Opinion, Environmental Sustainability

and Project Duration. The team delved further into the responses, including narrative ones, to determine which school districts would be the best candidates for mass timber schools. Along with identifying the most high-growth districts and ones that have acquired or would soon acquire bonds, the team recommended focusing on school districts whose values would most closely align with the development of the mass timber industry in the state, which would include those close to timber manufacturing facilities. They also found that architects and construction managers were more critical than school superintendents in making decisions on material selection and therefore were more critical to educate about the benefits of mass timber. The OCG team assessed the potential market for mass timber in school construction by looking at total capital expenditures for school construction in Oregon, estimating that about 20% of the cost was in structural systems and then estimating that if 25% of upcoming school projects could utilize mass timber the market would be about $20 million/year.

CONCLUSION

With ever increasing interest in mass timber in Oregon, it does seem possible that the time is right for mass timber modular school construction to gain a foothold without additional large capital investment. Freres Lumber is producing MPP 18 miles down the road from MBS and the firm principals know each other and are interested in collaborating. MBS could produce the modular classrooms in their current facility without alteration; they would start their construction process halfway through the current plant, bypassing the framing operations. However, there are still challenges to overcome. For example, addressing mechanical, electrical, plumbing and insulation issues takes more planning than in light wood-frame, where changes can easily be made during construction, and MBS will have to become comfortable with that process. But there is a potential client for a prototype; a local county has funding for a new public restroom that they have previously built of pre-cast concrete modules and are eager to have this project be a demonstration mass timber prototype for MBS. And the local school district is building a new high school and has expressed interest in using MPP. Currently, school construction in Oregon is running about $255-$320/sq. ft. If MBS can make MPP modular classrooms to fit into that budget or reduce it, mass timber modular classrooms may become a new Oregon product (Figure 7).

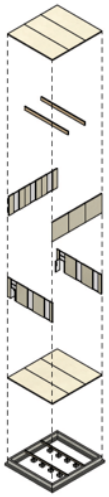

Figure 7. Modular Mass Plywood Panel classroom, designed by Judith Sheine and Mark Donofrio with UO architecture student David Moreno.

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