The Disruptive Application of Cross-Laminated Timber as Load Bearing Structure:
The Stadthaus at Murray Grove. Jack Northrup
Cross-laminated timber is the next step in the evolution of engineered wood buildings systems and has the potential to become a versatile and environmentally responsible building material for future development. The Stadthaus (German for “town house”) is a residential apartment building in the Murray Grove neighborhood of London, England. It was designed by Waugh Thistleton Architects, structurally engineered by Techniker Ltd., and built using cross-laminated timber panels produced by the Austrian company KLH. At nine-stories tall, the Stadthaus is the tallest modern wooden structured load-bearing building in the world; it is a great example of a building designed to capitalize on the advantages of an emerging material.

A Brief History of Engineered Wood
The core principle of engineered wood construction, the lamination of small pieces of wood to create a product that is more than the sum of its parts, is not a new idea. German and English architects and engineers made significant advances in laminated wood processes during the 18th and 19th centuries but the capability to produce these new materials wasn’t streamlined enough for widespread use until the early 20th century (Muller, 2000). It was the industrialization of material production in the first half of the 20th century that really brought engineered wood into the future. The innovations of this era are responsible for the production processes used to make contemporary glue-laminated beams and the development of other engineered wood materials like plywood (Muller, 2000).

Plywood came of age in the United States in the 1940s due to technological advances and required production volumes brought
on by WWII. It was declared an essential war material and the U.S. Government took control of production facilities, increasing their output volumes and efficiency of production to meet wartime needs. At this time there were about 30 war-time plywood production mills that were producing 1.2 and 1.8 billion square feet annually. Plywood was a vital part of the war effort in nearly every division of the military. The Army built plywood barracks to house infantrymen because the material was so fast and easy to work with. The Navy built PT patrol boats out of the material (PT is rumored to stand for Plywood Torpedo) that were notoriously light, fast, and easy to repair. The U.S. Air Force not only built plywood gliders that were used for reconnaissance missions, but the British Royal Air Force even built light bombers and spy planes like the Mosquito out of plywood because of blockades restricting imports of other materials (APA Wood, 2010). Also notable are the experiments in bent wood processes done by Charles and Ray Eames for the U.S. military in the late 1930’s and early 1940s. The Eames’ were hired by the military to investigate plywood forming for the construction of leg splints to be used by sailors, and in aircraft seats to be used in fighter planes, where light weight and long-term comfort are key issues (Kirkham, 1995).

Cross-Laminated Timber Panels
Cross-laminated timber panels are the direct successor to modern plywood and glue laminated beams but they can be realized on a gigantic scale. Cross-laminated timber panels are formed using planed boards 1” thick x 5”-7” wide and are laid-up and glued using formaldehyde-free adhesive in a vacuum press. The press alternates layers, each new layer at 90 degrees to the last, creating panels that are from 3 to 11 layers thick (Open Energy, 2010). The panels are used as large wall, floor, and roof elements, and are pre-manufactured with openings for doors, windows, and building services. KLH manufactures three grades: “non-visual quality, industrial visual quality and domestic quality for living spaces” (KLH, 2010). In the UK, KLH offers panels up to 14m long and 2.95m wide, with size only
really limited by the ability to transport the panel after fabrication (Trada, 2010). There is significant interest in bringing this technology to North America, a production facility is planned in Whitefish, MT, but there are not currently any examples of cross-laminated timber panel construction in the United States as building codes strictly regulate wooden construction (Wood Awards, 2010).

Fire protection is a serious issue in any building but is an especially important concern when considering a nine-story residential building made of wood. Many people fear the idea of living in a tower that is structurally supported by a combustible material, something that can actually become the fuel for a fire. Wood is obviously a combustible material, as opposed to concrete or steel which are not directly combustible, but without realizing how susceptible these non-combustible materials are to the heat that is created by a burning building full of other types of fuel, it is hard to fully understand the implications of fire performance of any material. When actual testing was done on the cross-laminated timber panels (or CLT panels) used in the Stadthaus project, “the CLT structure comfortably achieved the required fire resistance” (Trada, 2010). “The structural engineer allowed for charring to achieve 60-minutes fire resistance and achieved 90-minutes fire resistance by adding plasterboard” (Trada 2010).

One of the main benefits of the CLT system is the speed of the building assembly process. The Stadthaus structure was assembled in just 9 weeks with only 5 people on site, each working only 3 days per week. The panels were craned into place and were able to be mostly assembled with cordless drills and corner brackets since all of the openings had been pre-cut. In practice, the construction process with CLT panels is much like building with pre-cast concrete; in Australia they are even referred to as “tilt up timber” or “pre-cast timber” panels. One architect visiting the site during construction is said to have described the timber panels as “like concrete but better” (NZ Wood, 2010). The total cost per square foot is even about the same between CLT panels and concrete construction; the main difference is in the distribution of the costs
throughout the project, because of all the planning required, CLT is more front-loaded with expenses in design and production (NZ Wood, 2010). Sub-contractors, like plumbers and electricians who were working in the building after the structure was complete, were also able to work more quickly and efficiently than in traditional construction. Many of the passageways and mechanical chases being designed into the panel was helpful, as well as the relatively forgiving nature of wood compared to steel or concrete (NZWood, 2010).

**Sustainability Considerations**

As mentioned in the previous section, CLT panel construction operates very similarly to pre-cast concrete construction, but without the concrete, and without all of the environmental concerns that come along with concrete. This fact has the potential to redefine the way that buildings use energy and the way that materials for construction are acquired and processed. As buildings are becoming more disposable, a renewable resource like timber that can be farmed and controlled is far more desirable than finite mineral resources like concrete that must be mined and heavily processed. Also unlike concrete, CLT panels can be disassembled and recycled at the end of their service life. Once a CLT building can no longer perform its intended function, the modular nature of a panelized system allows for repairs or modifications to be made relatively easily. The separation of mechanical, electrical, and plumbing systems from the wall system allows remodels and repurposing to be done with relative ease and provides for future flexibility in layout and function (Open Energy, 2010).

Wood, if grown sustainably and engineered using non-toxic glues, is a completely renewable resource. Timber absorbs carbon from the atmosphere throughout its growing life and sequesters that carbon until it decays. The wooden fabric of the Stadthaus tower stores over 188 tons of carbon. Additionally, by not using a reinforced concrete frame, another 124 tons of carbon were never produced and therefore never enter the atmosphere. This is equivalent to 21 years of carbon emissions from a building of this
size, or 210 years at the current requirement of “10% renewable” for new buildings in the city of London (Wood Awards, 2010). Cross-laminated timber panels have a relatively low carbon footprint and are considered to be a rather “green” building material. This is figured by comparing the system to similarly performing structural systems and taking into consideration the embodied energy of all the components of the systems (Open Energy, 2010).

The cross-laminated timber panel as a thermal envelope, being a solid but air-filled surface, when combined with rigid insulation, wood cladding, and taped plasterboard, is actually rather effective as an insulator and mitigator of drafts. That said, CLT wall systems are breathable and resistant to mold growth and when paired with high functioning mechanical and air management systems, and produce an indoor environment that encourages occupant health.
Additionally, the CLT panel system is a simple composite that is only comprised of two materials, wood and non-toxic/non-off-gassing glue; unlike some foams and other panelized systems, they do not introduce any additional toxins into the air (Open Energy, 2010).

The sheer volume of renewable materials used in this project, combined with the fact that the building is better insulated and more airtight than the London building codes require, moved the local building department to allow a variance from the ‘Merton’ rule which normally requires at least 10% of the volume of energy consumed by a building to be generated onsite. Because of this allowance, the building was able to avoid hosting an in-house power plant in its basement and was able to use most of its roof space as an outdoor space for residents. The building does however have a modest photovoltaic array on the roof that powers lights in common areas and other operational requirements (Trada, 2010).

**Application of CLT in the Stadthaus Project**

Designed by Waugh Thistleton Architects, the Stadthaus building was constructed in Hackeney, a historic borough of London England, in early 2009. It is a nine-story, 29 unit, high-rise residential building built of cross-laminated timber panels and set on a one-story concrete foundation. The apartments are laid-out in a “honeycomb” pattern and arranged around centralized wooden elevator and stair cores. The arrangement of the cores, as well as the locations of solid interior load-bearing walls, help the building to be resistant to progressive collapse. This arrangement also increases the building’s acoustic performance by isolating sound in the same way that a traditional load-bearing building would (Trada, 2010).

While it would have been possible to use CLT panels in the construction of the walls for the ground floor, the decision was made to use reinforced concrete instead. The designers and engineers realized that one of the main weaknesses of wood is its susceptibility to moisture and it would be wise to keep the timber as far from the ground as possible. Not only would a concrete first floor help with damp proofing the timber components, but it would provide an
obvious separation between the program of the first level and the separate program of the eight upper levels (Trada, 2010).

The panels were fabricated in the order they would be used, delivered to the site, and craned into position immediately so as to avoid storing them and risking damage. This construction method proved to be so efficient that the structural system was fully assembled in only 9 weeks. Scaffolding was not required since the building was built up one floor at a time using a “platform” construction method where each story is built upon the preceding story. The panels were secured with special angled plates and screws making assembly a relatively low-tech process that does not require a large amount of skilled labor. The building was designed with stresses on the material in mind and has a certain level of redundancy built in to its support system. Even so, some areas were outfitted with additional fasteners to help distribute the stresses more evenly and prevent the possibility of progressive collapse (Trada, 2010).

Since the main program of the Stadthaus is residential, acoustic isolation was an important factor in designing the building. Sound transfers through surfaces much in the same way that heat does, so most steps taken to acoustically insulate a building will also serve to thermally insulate it. The hollow wall cavities in most traditional wood framed buildings do little to stop sound infiltration and can make living in a high-density environment extremely frustrating. The use of CLT wall panels as load-bearing demising walls between the units takes advantage of the fact that they are constructed of solid timber and serves to raise the acoustic and thermal performance characteristics of the building to levels above those required by codes (Trada, 2010).

The increased cost in materials that came with the design, planning, and orchestration necessary to build a project like this out of CLT as opposed to concrete was justified by the drastic decrease in on site construction time, a total of only 49 weeks for CLT compared to 72 weeks for concrete. The CLT construction tolerances achieved were half the 10 mm expected with concrete which not only added to airtightness of the envelope but also helped with interior build out...
and exterior cladding application (Trada, 2010).

The installation of mechanical and other building systems was relatively straightforward with most cables and pipes able to be fixed directly to the timber panels and covered with plasterboard that was elevated to clear the conduit by steel hat-channel. Some conduit was able to be recessed into the panels due to KLH’s employment of a CNC router that could cut out the chases. With more experience and better planning in the future, the installation of building systems could become even more integrated into the design process and speed the installation further (Trada, 2010).

The fact that the building is located in a well-populated historic neighborhood makes CLT construction a great choice because of its short construction time and relatively low impact on surrounding buildings (Trada, 2010). One challenge that could arise in a densely populated neighborhood would be navigating the delivery truck and crane around existing buildings. Still, the reduced project time and lack of need for on site storage are potentially enough to outweigh these difficulties.

**Future Trajectories**

Building regulations in Europe, Japan and the United States prohibiting large-scale wood construction have meant there are not many precedents for this type of structural scheme. Finland only allows no more than three stories in timber buildings; Austria, the home country of CLT technology, even prohibits timber housing above five floors. Thankfully, with the success of the Stadthaus, the engineering methods pioneered by Waugh Thistleton and Techniker Ltd. are now being added to UK building codes. For the moment, the UK remains home to the tallest cross-laminated timber panel high-rise in the world, (Wood Awards, 2010). Hopefully, that will soon change.

The continued development of environmentally responsible wood-based building systems, like cross-laminated timber panels, is vital if humanity is going to continue building and expanding our cities. Systems like CLT, constructed using renewable timber
resources that are grown in a sustainable way and designed with efficiency in mind, are perhaps a way to begin to mitigate some of the destructive effects that common building practices and popular materials are having on our environment. One of the major hurdles to popularizing new building systems is the inflexibility of building codes in most developed countries. The UK is showing some progress in this area with the approval of the Stadthaus building but projects of this kind are still rare in most places. If new systems are supported by the building codes of more countries in Europe, Japan, and the United States, more architects will be trained to design with them and will specify them on more projects. If building with renewable materials was as easy and cost-effective as building with traditional materials, and potentially much less time consuming, their use could become a very positive trend.

References


