Abstract—Cross-laminated timber (CLT), which is an engineered wood product introduced in Germany and Austria in the 1990s, is an excellent example of the ramifications the importance of sustainability in the construction industry. This paper defines sustainability in the context of the construction industry as concerning pollution, including greenhouse gases, renewability of the factors of production, and the energy and resources used during the lifetime of the structure or installation. The production of CLT has risen dramatically in recent years, as it is a sustainable material with favorable attributes. The material properties of CLT, which include strength, fire resistance, and seismic safety capabilities, have been shown experimentally to be suitable for low-rise and mid-rise construction applications. CLT is best suited to residential construction, as the typical span of a panel is about twenty-five feet. If used properly, this material can be used in primary load bearing applications, such as walls, columns, and beams. Another important aspect of CLT innovation is the manufacturing process for the material, which heavily utilizes computerized machinery, including automated presses for adhering the planks and Computer Numerically Controlled routing. Following utilization of these techniques, the panels are commonly prefabricated and delivered to the construction site for assembly. The prefabrication of the components ultimately saves time, money, and reduces carbon emissions on the jobsite. Because of the reduced carbon footprint in comparison to other materials, along with the fact that timber is a renewable, well-managed resource in North America, prefabricated CLT is a very sustainable material.

Key Words—Automated Manufacturing, Construction, Cross-Laminated Timber, Infrastructure, Sustainability

POTENTIAL OF PREFABRICATED CROSS-LAMINATED TIMBER

CLT, a sustainable and cost-effective contemporary construction material, is in heavy use both in research and in the infrastructure industry in recent years. In 2010, 300,000 cubic meters of the material were produced, and in 2015 1,000,000 cubic meters were produced, a more than threefold increase in half a decade [1]. Due to the large amounts of production forest in the United States and Canada, the raw timber materials for CLT are widely available, which allows for savings in production cost for CLT manufacturers. In addition, prefabricated CLT offers savings to builders because of its speedy and simple construction scheme. Prefabricated CLT arrives on the jobsite ready to assemble, in a way like flat-pack furniture. Far fewer workers are needed, along with less heavy equipment, which saves on overhead costs. In addition, the construction is quite fast; CLT buildings such as the Bridport House apartment building in London and many others have been built comparatively quickly. Along with these economic advantages, CLT is an attractive material to builders and building owners due to its sustainable aspects. CLT is sustainable in a large part because its primary material, timber, is intrinsically a renewable resource, provided that it is sourced from well-managed forests, of which there are a plethora in the United States and Canada. Another aspect of the material that contributes to sustainable construction is its high thermal insulation properties, which reduce the climate control costs of a timber building over time. Life-cycle analyses of several CLT structures provide quantitative evidence for the economic benefits of the thermal properties of CLT. One of the most attractive aspects about CLT structures is their ability to serve as carbon dioxide storage, otherwise known as a carbon sink. During growth, trees lock away carbon dioxide from the atmosphere into their cellular structure, and it is stored there while the CLT building is in use. Carbon dioxide storage capabilities are an important consideration for climate change mitigation and for reducing the net output of carbon dioxide emissions generated by the construction of the building. Prefabricated cross-laminated timber is a structural component that can help save time and money for construction companies while also producing positive results in sustainability.

CROSS-LAMINATED TIMBER PROPERTIES

Strength of The Material
In general, the capabilities of any given construction material are determined by several essential properties of the basic manufacturing unit of the construction material. The base material of CLT is timber, which has unique physical properties, described below, that stem from its botanical origin. One property that affects the strength of a timber member are the moduli, such as shear modulus or bulk modulus, of the various stresses that a material can undergo. These stresses include compression or pushing force, tension or pulling force, and torsion or twisting force. A modulus is simply a ratio, determined experimentally, that describes the resistance of the material to bending, compression, buckling, and other corresponding stresses to the material. In physics, it is not uncommon for the moduli of a material to be the same in all directions, but this is not the case with timber. Based on its internal structure, wood has a grain, which is easy to see in a piece of firewood or furniture. The effect of this attribute is that the moduli, and therefore strength, rigidity, and ability to flex, of wood are significantly higher in the axis following the grain of the wood than the axis orthogonal to the grain. An example of this property is given by the shear modulus, which describes the stiffness of a material. This modulus is important in determining the properties of a material in still, linear, and rotational conditions, of which the latter includes rolling-shear. A study by the International Journal of Solids and Structures details this intrinsic property of wood as such: “...the shear stiffness between radial and tangential directions in timber, called also rolling-shear, is two hundred times lower than the stiffness in fibers’ direction” [2]. This property limits the use of single element timber members to low-stress applications, such as smaller buildings, as the strength of these members is limited. In the 1990s, engineers developed cross-laminated timber, named as such because it is comprised of multiple members of timber, laminated, or pressed together with an adhesive, in such a way that the alternating layers of panels are oriented orthogonally [3]. This innovation creates a panel or beam of significant thickness, commonly 10 to 30 centimeters, with the thickness spread among the layers of alternating components. In addition, the material has significantly more strength in the transverse direction, due to layers of timber with grain in this direction, which augment the shear modulus [2]. The properties of the panel as a whole allow engineers and architects to design a variety of structures to suit more of society’s infrastructure needs.

In addition to providing innovative manufacturing methods, computerization is providing means for intense development into materials research, including digitized experimentation in the properties of cross-laminated timber. Among several new techniques, this new body of research includes computational analysis of stress testing with a new theory behind the strain undergone up until failure by a timber component, published in The International Journal of Solids and Structures. Based on the more classical physics of materials, CLT panels behave like a homogenous material because they have strength in all directions. The research published by the journal goes beyond one and two-dimensional mechanics of classical physics, and uses digital computational power to calculate the strain of a geometric region in three dimensions instead of a plane in two dimensions [4]. This technique became what is known as the bending-gradient theory in the article, or simply explained as relying on the computational aspects to create a much more accurate scientific description of the strength properties of CLT. Increased accuracy. The premise of the bending-gradient theory is that each infinitesimal part of timber provides a tiny amount of resistance to bending that follows a smooth increase and decrease, which is the reason for the name “gradient”. This is comparable to the concentration in salinity of an estuary, with a smooth increase in salinity from zero at the source of freshwater to a maximum where the estuary meets the ocean. When trying to determine the ability of a CLT panel to resist bending, an engineer will sum the contributions of each infinitesimal piece of timber to conclude the overall resistance across the gradient of bending. This technique allows for increased accuracy in determining the strength of the panel. Because engineers can predict where the most stress will be in a building, taking into account the changing conditions such as temperature and wind speed, they can use the bending-gradient theory to design buildings to meet more stringent standards, which allows for increasingly diverse utilization of CLT.

Researchers at NC State University conducted a study that showed that orienting the layers of panels at 45 degrees instead of the conventional orthogonal arrangement increases the shear and bending strength of the CLT members [5]. The mathematics behind the innovation involves an optimization of the capabilities of wood to resist breaking in its grain direction. This innovative arrangement is shown in the following diagram, from the technical article that tests different arrangements of CLT [5]. Due to its inherent strength, CLT also offers resistance to natural wear and tear and severe conditions, such as fire and earthquakes.

FIGURE 1 [5]
A diagram of 45 degree oriented CLT panels, showing a cutaway view

Resistance to delamination

In order to demonstrate safety, CLT panels need to be able to show significant resistance to delamination. Because CLT is a multi-unit construction component, and each unit of timber is glued to its neighbors, in the large majority of designs, it is crucial to scrutinize the bond strength of CLT. This bond depends primarily on the adhesive used, along with the defects and irregularities present in the timber. Because of
the large surface areas covered by the adhesive, most CLT members are assembled using common wooden structural adhesives. This is the most economically sustainable option, but safety must also be considered. For instance, a study from the Queen’s University in Belfast compared Polyurethane (PUR) and Phenol-Resorcinol-Formaldehyde (PRF), and found that PRF is more effective than PUR in bond strength [6]. This is not the ideal solution, however, as PRF contains toxic formaldehyde. Without treatment, the use of this adhesive is hazardous. Further experimentation will lead to a safer material with the bond strength necessary for delamination resistance. In addition to the type of adhesive used, CLT resistance to delamination depends on the geometric qualities of the individual timber pieces. It is important that the components line up snugly and evenly across the structure, in order to provide maximum bonding strength. According to the study, “...factors such as distortion and wane have a negative influence on bonding strength due to their effect on the bond line geometry” [6]. Distorted timber can be avoided by careful machining and drying processes. The study also describes the standards that components need to meet to provide sufficient resistance to delamination. “Therefore...an ‘effective bonding area’, defined as the proportion of the lamination wide face averaged over its width that is able to form a close bond upon application of pressure, of 80% is required” [6]. This level of resistance to delamination allows for CLT construction to function under stresses associated with infrastructure that could result in delamination.

Fire Resistance

Along with its resistance to delamination, CLT has been shown in studies to possess fire resistance worthy of use in larger structures. Although flammable, large timber construction members such as CLT are very fire resistant, burning at a slow and predictable rate. Following a study published by the Fire Safety Journal, the “...charring rate, which is applicable for structural fire design of CLT planar elements subjected to an ISO 834 standard fire...is 0.65 mm/min” [7]. Basically, the experimentation team determined the rate at which a CLT component will char when exposed to a typical or model fire event; the use of a standard fire is important to the experimental design. The reason for their experiment is the application in which CLT elements need to be designed to meet fire safety standards. The study then goes on to explain why the charring rate is slow and predictable. As the wood burns, a layer of charred material forms on the surface of the member, which “...is of low effective thermal conductivity and acts as natural insulation for the underlying timber, reducing the rate of charring and insulating the core of the timber element; it insulates the interior from fire damage very effectively” [7]. For a large panel, the surface area to volume ratio decreases rapidly as the thickness of the panel increases, which in effect creates a large interior volume of protected wood. In addition, the interior at a certain depth, in this case 3.84 centimeters, from the surface of the charred wood retains structural integrity. The following chart shows the dramatic difference in strength at the transition point between the char layer and the intact wood layer. Although the char layer offers protection to the interior timber, it also yields minimal strength, as evidenced by the following chart.

![A graph illustrating the boundary of strength of charred CLT](image)

**Figure 2 [7]**

This set of properties for CLT allow it to have suitable fire ratings for various types of construction. The following table, from the National Research Council Canada’s full-scale fire resistance study on CLT construction members, illustrates a variety of strategies and results for attaining longer fire ratings [8]. For instance, thicker members, with more plies of wood, are able to burn longer before failure, as one would expect. Also, the addition of gypsum board for fire protection significantly increases the fire rating of the applicable members of CLT. Gypsum is a mineral that is fire resistant and much safer than asbestos, and is commonly used in construction of all types for fire protection [9]. Because of this the Canadian team tested CLT members with gypsum attached, as that approach gives the most realistic and useful fire resistance data for practical applications.

Seismic Capabilities

A final important aspect of any construction material is its usability in zones where earthquakes are frequent, such as the Pacific rim. Engineers have utilized ingenious methods for increasing seismic safety, including tuned mass dampers and base isolation through hybrid-material bearings, such as those mentioned in an article from the journal Shock and Vibration [10]. A new addition to the strategic toolbelt is CLT, as it has been shown in studies to be capable of resilience in earthquakes. A joint study between scientists from Italy and Japan, published by Earthquake Engineering Structural Dynamics academic journal, involving the world’s largest
earthquake simulation shake table, investigated the effects of seismic oscillation on a full-scale seven-story CLT structure. Along with testing the CLT material strength, the project also investigated the strength of the connections between panels in seismic conditions. The CLT structure was subjected to 7.2 magnitude earthquakes, taking a total of 14 consecutive seismic tests before being minimally damaged [11]. Data taken showed the building having a 1.5” linear-story drift and a max of 11.3” lateral deformation during the manufactured earthquakes, even though it survived without residual deformation [11]. This research is very important for CLT development in earthquake prone zones, such as the west coast of the United States.

The properties of CLT, including strength, delamination resistance, fire resistance, and seismic safety, are attributed to the material properties of raw timber, the quality of adhesive and pre-assembly geometries, and the innovative orientation of the timber elements used to construct the panel. These properties allow for CLT use in many applications, which is a factor in the recent increase in use of the material. Another important reason that CLT has increased in popularity is the economic benefits associated with computerized manufacturing of CLT.

**FABRICATION UTILIZING DIGITAL MANUFACTURING SYSTEMS**

The impact of CLT on the building industry stems in part from its flexibility in manufacturing options. In particular, the automated manufacturing processes developed in the last century have been applied successfully to CLT production, as it is an ideal material for prefabrication. CLT is commonly produced with the computer-numeric-control system (CNC). A CNC machine system uses a computer with custom programming to read a drawing and send the information to a tool to cut away material from the item that is in working progress [12]. The drawings are two-dimensional or three dimensional and are created using CAD, computer assisted drawing, which is a very common method of drafting in the digital age. CNC systems include a variety of tool options, with the most common being lathes, drills, and especially milling, which removes metal in multiple axes. The CNC system is commonly used for machining of precision components in metals such as steel and aluminum, but the technology can be applied to many materials, including CLT [12]. The machining of CLT components is a prime example of the possibilities of automated manufacturing, because it represents a complete switch in the manufacturing focus away from the economy of scale model towards a model of maximum customization and flexibility.

**Computational Manufacturing in Comparison to Traditional Mechanization**

For traditional factory settings, the main factor of efficiency is the economy of scale, which is the concept that larger volumes of production lead to less cost per unit. This is because the cost of more efficient machines, which are usually bigger and more resource- and labor-intense, is spread amongst many units, making an overall more cost-efficient process. The pros of this system also include more time efficiency, as well as a large centralized factory that makes logistics management simpler. The cons of the system include high initial costs, such as machinery and warehouse costs, and the need to process high volumes of products to maintain economic efficiency. For example, the cost of a mid-sized CNC machine is roughly $20,000, as shown by the article written by Ginger Gardner [13]. Also, it is very time-consuming to change the tool heads and other machinery items in the factory, so all of the items must be identical to be efficient, which sacrifices the ability for customization.

In comparison, CNC manufacturing and other types of computational manufacturing generally work on one product unit at a time, which is similar to a skilled artisan building a product from the beginning to end. Some of these digitally controlled machines are capable of precision to the level of 0.002 inches [13]. As in the case of the artisan, a high level of manufacturing precision can be achieved with the digital methods, but much more rapidly. In addition, the CNC milling process is reset for each product item, allowing for a very high level of customization.

**Customization**

The quick turnaround from concept to finished component afforded by CNC milling is particularly suited to the building industry. Innovative building designs include many different components with a wide array of shapes, sized, and uses. This is particularly common in curved structures, multi-use buildings, and structures on hilly terrain. For example, the tallest buildings today include huge mass dampers, as mentioned before, that serve to stabilize the building. Most mass dampers are hidden, but in the Taipei 101 tower on the island of Taiwan, the mass damper is exposed to the public as an art installation, and appears as a huge golden ball, with graceful curves [14]. This custom component adds even more spectacle to the innovative building. The ability to customize components like the mass damper allows for its innovative design. Therefore, it is of importance for the manufacturing process for the customized components to be efficient. CNC milling is a very useful manufacturing process to meet this demand. The applications include CLT structures, with which innovative designs can be achieved through automated manufacturing. Since each CLT panel or beam is created from many smaller pieces of dimensional lumber, one of the early stages of the fabrication of these components is the assembly, adhesive, and pressing process. In the precision and customization focus of digital manufacturing, assembly and cutting of the components can be defined and executed for each individual product, which saves on material waste...
and therefore creates an economic benefit. Because the adhesive is one of the most crucial aspects of CLT to create reliable strength and longevity, it is immensely important to provide the required adhesive layers in precisely the right locations and amounts, which is a task that is ideal for a computer-controlled system to execute [15]. One of the final steps in the pre-cutting stage of CLT component fabrication is the pressing, in which the members are joined precisely under pressure from a large apparatus. Since the panels are various shapes, including curved panels, it is important that the machines for press the panels can adjust to any shape, as it would be uneconomical to build a new expensive machine for each shape. An example of a curved CLT structure is Kjellster Bridge in Norway, at 158 m it is a very impressive structure [15]. This bridge connects two military training areas and as such receives heavy traffic. It is currently the world’s strongest vehicular timber bridge [15]. Personnel have demonstrated its sturdiness by firing cannons from atop the bridge.

In addition, engineers are taking advantage of the relative ease of working and tooling timber to create unique solutions for CLT structures. A paper published in Bioresources, published by NC state University, claims it is very efficient to machine openings in the CLT panels for doors and windows, as well as ductwork for HVAC, electricity, and water routes [16]. In comparison, such apertures would have to be built on site for traditional construction materials (such as concrete and steel), which requires more components, and therefore more time to construct, which translates to a more expensive construction process. According to a Canadian study, a building constructed with CLT in this manner saves costs in a range of 10 to 50 percent. The following image, taken from an Australian website focusing on CLT construction, shows an example of a such-machined panel [17].

The construction process for prefabricated CLT is unique and efficient. Compared with other types of construction, it offers savings in construction time and number of necessary workers which ultimately stem from the manufacturing of the CLT components themselves. Because CLT is prefabricated in large sections, it is quicker to erect the components, provided that the contractor is equipped with heavy lifting machinery. This is in comparison to brick or concrete block, in which time must be used both to place and to set the components with adhesive; in CLT, the adhesive has already been applied. The evidence of efficient construction can be seen in previously completed buildings. In the London Borough of Hackney, the Bridport House was constructed in 2010 as an eight-story, 41-unit residential housing complex made out of about 30-40 m3 of timber per unit [18]. The construction process begun October of 2010 with 30 deliveries of 1,100 CLT boards and fully finished 12 weeks later [18]. The construction time is unprecedented for a building of this magnitude and performance, being that this is a reduction in 6 weeks of construction time compared to traditional construction techniques [19]. Because the CLT panels were prefabricated, there was no time lost on the job site to prepare materials. Once on the site, the panel had to just be lifted by crane, placed into position, and then fixed into its permanent position. Being that only a crane operator and some handymen are needed to place the CLT, there is a decrease in labor.
When compared to the popular building material concrete, CLT comes out on top, economically. Schmidt and C.T. Griffin, architecture professors from Portland State University, proves this in their 2013 article, Barriers to the design and use of cross-laminated timber structures in high-rise multi-family housing in the United States. For the construction of a building using CLT, only a crane operator and carpenters are required, compared to a normal project where more skilled laborers may be required. Because CLT panels are premanufactured and digitally-made specific to a project, it seems as they are as simple to put together as a child’s puzzle. The fact of the matter is that CLT panels are easily placed and then fixed into position. However, post-tensioned concrete requires “pump men, workers to set up the formwork, lay rebar and tensioning cables, and to pour concrete… (and) most trades on hand to set in the rough spots for the various services needed within the building” [20]. This will lead to a much longer and more expensive construction process rather than that of utilizing CLT. By decreasing time on site and the number of paid laborers, a project’s overall cost may be decreased while also using sustainable materials.

Materials

In addition to efficiency in construction, CLT can also reduce costs associated with heating, ventilation, and air conditioning (HVAC). Wood itself is a natural thermal insulator due to its cellular structure, and compared to concrete and steel, timber has significantly greater insulating properties. The Canadian Wood Council released a publication in 2013 that highlighted the thermal performance of light-frame wood assemblies in comparison other popular construction materials. They pointed out that the average building, in temperate climates, used about 20% of overall building energy for heating and cooling, and by choosing the right materials, the building’s owner can save more money in the long-run in terms of energy costs [21]. When looking at the thermal insulating properties of steel, concrete, and timber, sheet steel has no significant resistance, whereas concrete has a resistance of 0.001 RSI/mm and then timber with 0.009 RSI/mm, where RSI/mm refers to thermal resistance value with units of m²°C/W) [21]. Overall, timber is 10 times more capable of insulating versus concrete, and 400 times that of solid steel. By putting these numbers into perspective, the Canadian Wood Council thermally tested the difference between steel and wood-framed walls. They concluded that steel-framing had significantly worse thermal properties, compared to wood-framed walls, and required extra exterior insulation to produce thermal performance similar to wood. For an example, 50 mm of foam sheathing is required on a steel-frame wall to have performance similar to a 38 x 140 mm wood-frame wall [21]. CLT structures will thereby require less insulation material for their sustainable operation. As sustainability becomes prioritized in the infrastructure industry, the savings in energy use associated with the thermal properties of CLT make it a very attractive material for designers and engineers.

SUSTAINABILITY

Harvesting

CLT has been shown in studies to possess the material properties and flexible use of a sustainable and capable material, but there are concerns as to its sustainability. One such concern is that large-scale timber harvest for the construction industry could adversely affect ecological health. However, sustainable production of CLT, which we will define as utilizing a renewable, well-managed resource, is possible in North America. In a report produced by the United States Department of Agriculture in 2014, “the volume of annual net growth of what is currently 2 times higher than the volume of annual removals” of standing timber resources, at about 2.7% growth in 2011 [22]. This also considers the timber industry, with about 26,413 million cubic feet grown and only 12,854 million cubic feet of timber removal [22]. The statistics for America’s forest growth show strong similarities in forests of Canada. In the annual Canadian forest report in 2012, given by the Canadian Forest Service, “less than 0.2% of all forest and other wooded land in Canada is harvested each year… well below the level needed to maintain sustainable stands” which shows the propensity to sustainably harvest timber in Canada [23]. By these numbers, the production of CLT, using American and Canadian forests as resources, will not have a negative impact on the environment in terms of forest volume and greenhouse gas production. However, there is still concern that increased demand for CLT will overcome the current sustainable harvest levels and create an unsustainable product. This concern is best addressed with the professional analysis given by the US CLT Handbook. Currently, with the laws and codes pertaining to the forest industry, “stringent sustainable forest management practices in the U.S. and Canada restrict harvesting levels, while maintaining other forest values such as biodiversity and wildlife habitat” [24]. With these laws and
standards in place, it would be impossible for harvest level to exceed regrowth level in the future. Given that American and Canadian harvesting of timber is environmentally safe and reliable, CLT has potential in North America to make a positive impact on the timber industry and nearby regions.

Ecological Externalities

Timber is a promising resource for construction applications, with many positive ecological externalities. The production of CLT is a solar-based process. From the carbon cycle, carbon dioxide is taken from the atmosphere and used in a biological process to create cellulose in trees. This cycle continues if the trees were to be burned or eaten where carbon would be released back into the environment. CLT is a sustainable building material. By taking the timber and using it in its natural form, it will retain the carbon that may have been released. CLT is also significantly more environmentally safe compared to the most popular options for construction, steel and concrete. A life cycle study of CLT was presented for The American Institute of Architects Continuing Education System by WoodWorks, a Wood Products Council, in 2012 that demonstrates the environmental aspects of CLT. In a life cycle comparison of wood, steel, and concrete in the construction of a large office building such as the Athena Sustainable Materials Institute in Ottawa, Canada, wood ranked the highest in terms lowest embodied energy and carbon dioxide emissions [25]. Steel has a total energy use of 7350 gigajoules (GJ), then concrete with 5500 GJ, and finally wood with 3800 GJ [25]. For carbon dioxide emissions, in terms of 1000 kg units, concrete ranks worst with 132, then steel with 105, and then wood with 73 [25]. Concrete suffers greatly with its carbon dioxide emissions due to its production via the decomposition of calcium carbonate into calcium oxide and carbon dioxide. From that data, it can be concluded that carbon emissions of a wood structure is only 60% of concrete and 70% of steel structures. Summarized, wood has the lowest energy usage and carbon dioxide emissions which makes it the most environmentally safe compared to concrete and steel.

Woodworks Study: Library Square

WoodWorks then proved their point with actual data from a CLT-based building, Library Square, in Kamloops, BC. This five-story building, with 140 condo units, 14,000 ft2 of commercial space, a 20,000 ft2 library, and underground parking, was constructed out of 2,927 m3 of wood [25]. This building, calculated by WoodWorks, stores 2,124 metric tons of carbon dioxide, avoiding 4,520 metric tons of carbon dioxide greenhouse gases, with a total carbon benefit of 6,645 metric tons of carbon dioxide [25]. To put that into perspective, the carbon dioxide stored and avoided release of is equal to about 1,269 public cars or enough energy to power a home for 565 years [25]. By using CLT, there was a significant amount of carbon dioxide saved from possibly being released into the atmosphere and adding to global warming greenhouse gases.

FIGURE 6 [26]
A view of Library Square in Kamloops, BC

A MULTIDISCIPLINARY SOLUTION

Modern-day engineers of various occupations are faced with a variety of challenges, including increasing greenhouse gases and environmental protection regulations. In addition, they face more constraints as certain resources become more scarce. However, rapidly developing technology has allowed for innovative interdisciplinary solutions to such complex problems. One of these solutions, the prefabrication of CLT, depends upon the advancing bodies of knowledge of mechanical engineering, industrial engineering, and materials science. These science and engineering fields together are able to respectively design machinery, manage systems, and create adhesives that allow CLT to be further improved. Civil engineers play a large role in the development of prefabricated CLT, as the professionals responsible for the design, testing, construction, and maintenance of CLT buildings and systems. Many experts in the infrastructure field recommend increased construction with CLT, being that the material is durable, flexible, and sustainable. Cross-laminated timber has been a proven technology for decades, but the recent rapid growth in its use is due to sustainability benefits and advanced manufacturing techniques.

SOURCES

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