



# Cross Laminated Timber (CLT)



CARPENTERS TRAINING COMMITTEE FOR NORTHERN CALIFORNIA

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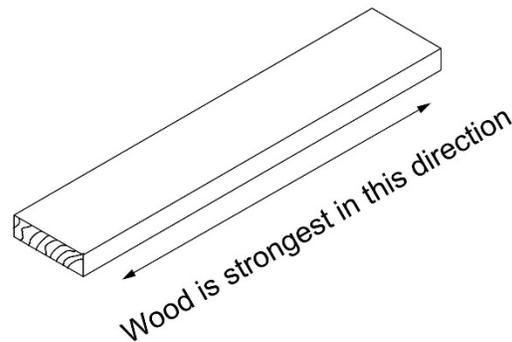


## Introduction to CLT Construction

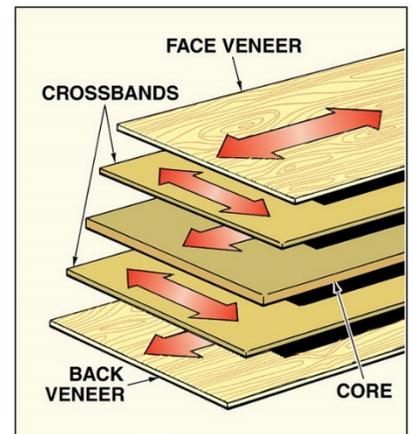
Cross-laminated timber (CLT) is a wood panel product that is made from layers of solid lumber that is joined together by gluing each layer at a 90° angle to each adjacent layer. CLTs are grouped with glu-lams and other large manufactured products under the heading of Mass Timber construction. When the superstructure is framed using these large wood products, it is considered to be Mass Timber construction. We will examine the nature, manufacturing and advantages of CLTs.

CLTs are a relatively new building material as it was first used in Germany and Austria in the early to mid-1990's and has since been used extensively in Europe. The use of CLTs has expanded in the U.S. and Canada as the product becomes more available and as building designers make use of some the advantages that CLT and Mass Timber Construction provides.

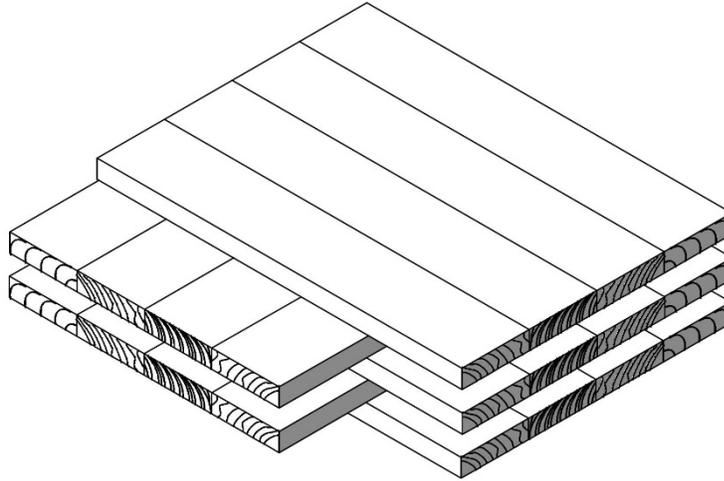
While the introduction of CLTs is recent, the idea behind the panels is found in another familiar and popular building product, plywood. Solid lumber is what is known as an anisotropic material, which means it is stronger in one direction (along the grain) than the other (across the grain).



The concept of plywood is that thin veneers of wood known as layers are glued together with each layer is placed with its grain running at 90° to the adjacent layers. This cross lamination provides greater strength and stiffness in both directions and minimizes shrinkage in each layer. The top and bottom veneers both face in the same direction, with the grain running the long way on the sheet. Plywood is usually made up with an odd number of layers, for example, 3 ply, 5 ply and 7 ply. Plywood is such a great building material because it is strong in all directions, so it gives lateral strength along the width and the length of an object, such as a subfloor, shear wall, or a roof.

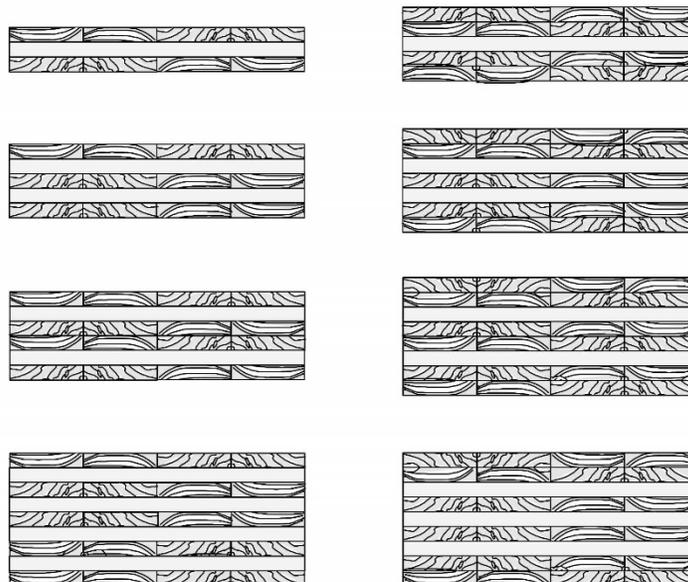


CLTs use the same principle as plywood, but the layers are made up of solid lumber. The APA-The Engineered Wood Associations, which sets standards for CLTs, states that the laminations are required to be at least 5/8" but not more than 2" and the width varies from 2.4" to 9.5".

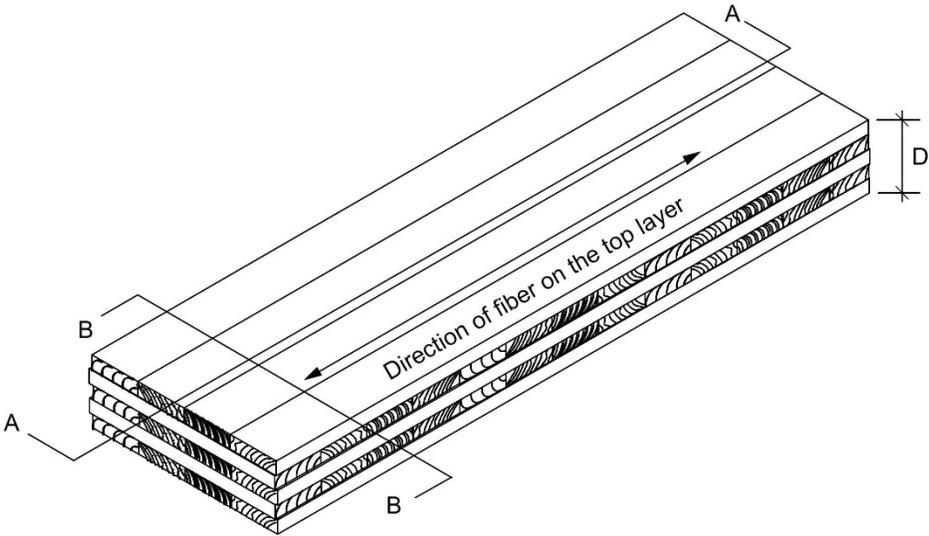


This is showing how the layers are placed at 90° to each other. The outer layers of the panels that are used as walls are normally running up and down to help maximize the vertical load capacity of the wall. When the panels are used for floor and roof systems, the outer layers run the same direction as the major span.

Just like plywood, most panels are made of an odd number of layers, however, some panels will have double layers of longitudinal planks. Show below are various examples of CLTs in cross-sections.



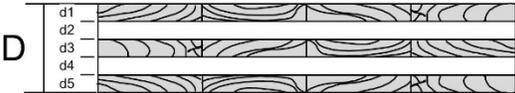
The next illustration shows a panel with a cross-section, A-A, along the length of the panel and another, B-B, across the width of the panel.



Section A-A



Section B-B



The APA states that any softwood species that is recognized by the American Lumber Standards Committee (ALSC) shall be permitted for use in CLT. The species can vary in the different layers of a panel, but a single layer should be made of same species.

The minimum grade of the lumber in the parallel layers is visual grade No. 2. The minimum grade of the lumber in the perpendicular layers is visual grade No. 3. The cross-laminated design has more to do with the strength of the panel than the strength of the individual layers.

For longer panels, the lumber for the laminations are finger-jointed together to make longer pieces.



Cross Laminated Timber

## Manufacturing CLTs

The typical manufacturing process for a CLT involves 9 basic steps, which we will cover here.

### 1. Primary lumber selection

The primary lumber selection consists of several different parts; Visual grading (shown below) moisture content, and, sometimes, structural testing (an E rating). The wood will be used to make a construction grade CLT or an appearance grade CLT.



The moisture content is important, it is recommended that the lumber in the CLT have a MC (moisture content) of  $12 \pm 3\%$  to ensure a proper bond quality of the product. It is recommended that the moisture content between adjacent pieces to be joined should not vary by more than 5%.

The panels need to be protected from moisture. They are wrapped in plastic and stored where they can maintain the required moisture content. If stored on the job site, they should be placed on a sufficient number of skids to keep the panels out of any standing water. In addition, a tarp may be placed over the load to ensure that the panels remain sealed.



### 2. Lumber grouping

The lumber will then be separated into the major and minor strength directions. Also the lumber will be grouped by appearance, with the outer surfaces needing to have a better visual appearance.

### 3. Lumber Planing

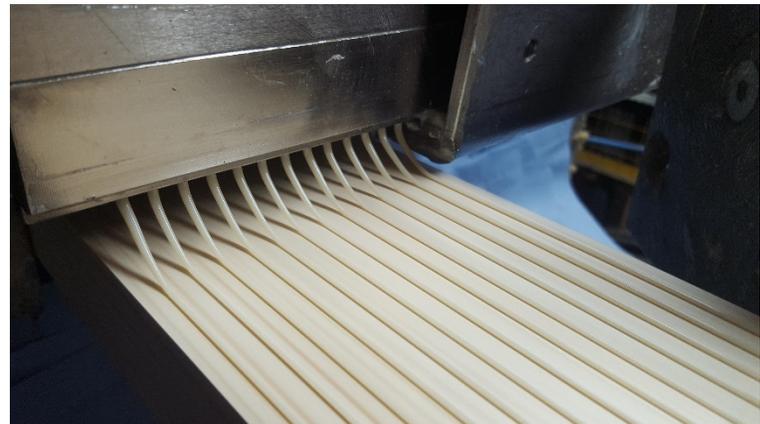
The planing or surfacing of the wood helps to prepare the surfaces for gluing. The lumber usually has been previously been surfaced on all four sides. This planing takes off a thin layer, approximately 3/32" off the thickness and 5/32" off the width, and creates a flat surface so that the adhesive forms a good bond.

### 4. Lumber Cutting

A cutting station cuts the lumber to the proper length of the panel. The length of a given panel varies, however, it cannot run longer than the transport vehicle, some of which run up to 60'. The APA allows tolerances for dimensional thickness of  $\pm 1/16"$ ,  $\pm 1/8"$  in the width and  $\pm 1/4"$  in length.

### 5. Adhesive Application

The glue applicator is a series of side-by-side nozzles on a beam that travels along the length of the panel. The typical speed is about 12 seconds for 50 feet of panel. The applicator needs to be airtight to avoid any holes or gaps, and the glue needs to be applied at a constant rate.



A minimum bonding area of 80% is specified by ANSI, so that is why the surface needs to be as flat as possible. Edge gluing is not generally done.

### 6. Panel Lay-up

This is similar to plywood, with adjacent layers placed perpendicular (90°) to each other. This cross laminating is what give the panels their strength. The layup can be done by machine or by hand. The assembly is done between the spreading of glue on the layers and the application of pressure to the assembly.



## 7. Assembly Pressing

The next step is the assembly pressing, which puts the laminations under pressure so that the components bond into the panel. There are two types of pressing methods; vacuum press and hydraulic press. Vacuum pressing is done by enclosing the work in a close vacuum bag and the air is pumped out. When air is removed from a closed vacuum bag containing a panel, the atmospheric pressure bears down on the work with a uniform pressure. As the air is drawn out of the wood cells, the glue is sucked into the cells. A vacuum press generates about 14.5 psi. This is sometimes not enough to flatten all of the warping, so some longitudinal members will have a saw kerf along the length to relieve the stress.

A hydraulic press can generate much higher vertical pressure and side clamping pressure than a vacuum press. Side clamping is used to eliminate gaps between the laminations. Hydraulic clamping pressure is in the 40 to 80 psi range. The pressing time varies from 10 minutes to several hours and can be speeded up using radio frequency (RF) technologies which heats the inside of the panel. In general, the pressing has to be twice the length of the gluing, for instance, if it takes 20 minutes for the glue to set up,, then the pressing should take 40 minutes. If panels are the same size and shape, some



plants can glue one panel, then cover it with a plastic barrier, and build another panel on top of the first one. The two panels are then pressed at the same time.

## 8. Quality Control, Machining and Cutting

Following the assembly pressing, the panel is sent to an industrial sanding machine to sand the panel to a thickness with a tolerance of 0.004 inch. After sanding, the panel is sent to a machining station where a CNC (computer numerical control) cuts, drills, and bores the panel. The CNC machine cuts out for doors, window and other penetrations such as electrical boxes. It also makes splices and notches out for some panel connections. The panel is cut to size, with controls to ensure maximum accuracy.

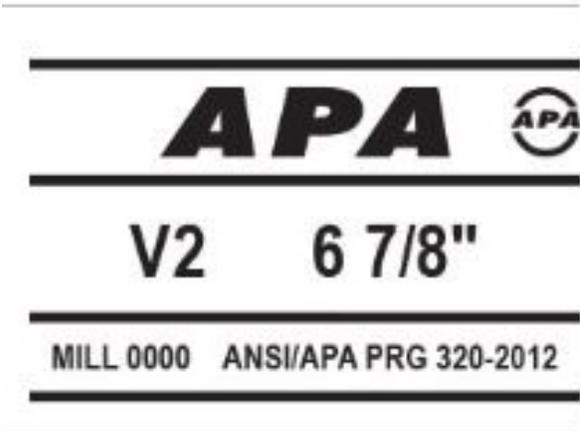
Projects with CLTs can be improved with the use of Building Information Modeling (BIM). The purpose of building modeling is to be able to identify when there will be conflicts among the different elements of the building and make adjustments before everything is built. BIM involves all of the subs submitting a digital model of their work and then combining those models into one integrated model. This is important with CLT because if the CLT will be

exposed, there may be penetrations that need to be drilled or routed out. These penetrations are best done by the CNC machine at the plant, but they must be accurate, because changes can be difficult to do, especially if it alters the appearance of the member. Cross-laminated timber jobs work best when the subs and the general all work together to assure the quality of the finished product. All subs should be familiar with their BIM model in relation to the location of their needed penetrations.



### 9. Marking, Packaging and Shipping the Product

The final step in the manufacturing process is the marking, packaging and shipping the product. Marking ensures that the correct product is specified, delivered and installed. The panels that are represented as conforming to ANSI/APA, PRG 320 standards are required to bear the stamp of the approved agency, or have a random test done to prove the standards are met.



This APA stamp is providing needed information including the grade (V2), and the panel thickness (6 7/8"). In addition, the word "Top" shall be stamped on CLT panels used for floor and roofs if manufactured with an unbalanced lay-up. Sometimes the main direction of the loading of the panels in the structure will be marked.

As stated before, since CLT panels are to be used under dry conditions, panels should be protected from the weather during transportation and storage.

The fact that CLT panels are used as structural elements such as roofs and floors means that every step needs to be done correctly to ensure the integrity of the panels.

### Advantages of CLTs

CLT construction has advantages over other types of construction and these advantages are the basis for the current interest in CLT construction.

- ❖ CLT construction is best suited to mid-rise (4-12 stories) and multifamily buildings where it is competitive with concrete or steel framed buildings.
- ❖ CLT construction is more lightweight than concrete, thus, that allows for a smaller foundation. Concrete weighs 150 lbs. per cubic foot, while the panels weigh between 25 to 37 lbs. per cubic foot, depending on which species of wood is used in the panel. The lighter weight means that a smaller crane may be used to lift the panel.
- ❖ There is flexibility in the design of CLT—it can be used as walls, floors and roofs.
- ❖ Prefabrication leads to better quality and a high degree of accuracy.
- ❖ Can be combined with many other building materials such as steel and concrete
- ❖ CLT is a sustainable product, the wood is from sustainably managed forests. The manufacturing of the panels produces less CO<sub>2</sub> emissions than steel or concrete.
- ❖ The system of CLT construction allows for a faster on-site construction. There is no wait time between stories as there is in concrete construction when waiting for the concrete to attain enough strength to remove and raise the forms to the next level.
- ❖ Work by the finish trades can begin almost as soon as the panels are set.
- ❖ Simple construction—most of the connections are made with screws, no special tools are needed.
- ❖ CLT panels are aesthetically pleasing and so they are often exposed in the interior of the building. They can add much to the interior finish.
- ❖ If panels are exposed, this enhances the working environment. There are studies that measured the health of two groups; one that worked in a wood environment and the other that worked in a non-wooden environment. The conclusions were that less tension and fatigue were generated in the wooden rooms than in the non-wooden rooms when the participants did their work. In addition, the study also found that the wooden environments benefit the autonomic nervous system, respiratory system, and visual system.
- ❖ Another advantage of working on the CLT panels is that, since it is made of wood, it is easier to attach things to, or make any modifications than would be possible with a concrete slab. An example of that is drilling for a penetration, it is

far less difficult to use a drill motor with a wood bit than to core drill a section of the slab.

- ❖ Compared to a pan deck, the top of the panels are flat and this makes walking and working on the deck safer and easier.
- ❖ Needs less truck traffic.

### Disadvantages of CLTs

While CLT offers advantages over other building materials, there are also disadvantages that include:

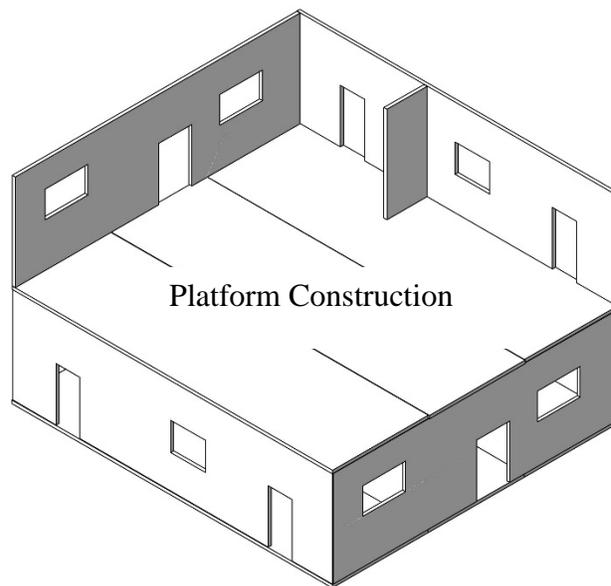
- ❖ CLTs do not perform well in acoustically sensitive environments, like back to back rooms. In some cases, to achieve the IBC code minimum for sound transmission, two CLT panels with mineral wool between them may need to be used.
- ❖ External walls need to be protected and must be clad.
- ❖ CLTs cannot be used below ground
- ❖ Small track record—since CLTs are relatively new, it may be hard to know how the CLTs will react over time.
- ❖ CLTs require more input in the earlier stages of planning.
- ❖ There are not many manufacturing facilities—long waiting periods to get product.



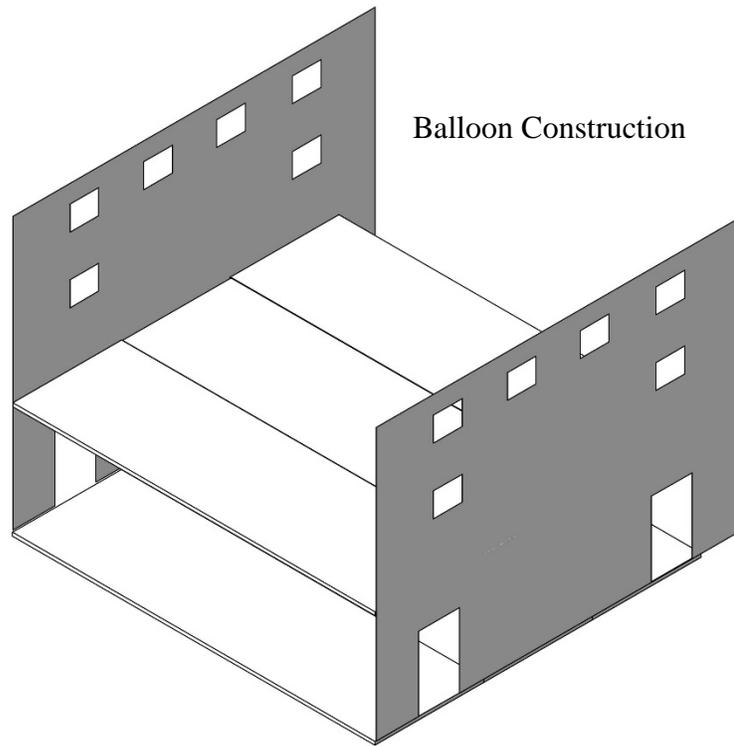
## CLT Connections

The main application of CLTs in our area is using the panels for a floor or a roof. A critical part of CLT construction are the connections that are used to ensure the panels are working together to make a safe building that resists the vertical and the lateral forces acting on the building. Connections are used to for a variety of jobs; walls to floors, floor to columns, walls to roof and panel to panel. The structural integrity of the system depends on the fasteners and connectors performing as designed. For example, if a floor system being used as a diaphragm, which pulls together the walls to resist lateral loads, a faulty connection could result in a serious failure. Common connections include self-tapping screws (often quite long), metal brackets and plates. Given that CLT construction is relatively new, it is likely that new ways and types of connections will be developed as CLT construction becomes more widely used. This chapter will cover many of the connections that are currently being used with CLT construction.

CLTs are used in several types of construction, including platform construction and balloon construction. Platform framing means that each floor rests on top of the wall panels below, and in turn, the new floor becomes the platform for the next story of walls. This method is often used in Europe for mid-rise construction of 5-10 stories.



The other form of construction is balloon construction which means that the walls are several stories tall and the floor is attached to the walls. This type of construction is used in low-rise commercial or industrial buildings. Balloon framing is less common than platform framing on jobs where walls are present.



Balloon Construction

### Types of Connectors

One of the most common fasteners is wood and self-tapping screws. Screws are easy to install and they can resist lateral and other loads. Self-tapping screws come in a large variety of lengths from 5/8" to 59" with many measuring 39.4" (100 mm). As seen here, the screws come in many different shapes and types of heads, including hex and washer heads.



When installing the screws, do not stop during the installation, the screws are designed to be driven in one run without stopping. When installing the screws into a steel to wood connection, use a drill that has a torque clutch. With most screws, predrilling is not necessary.

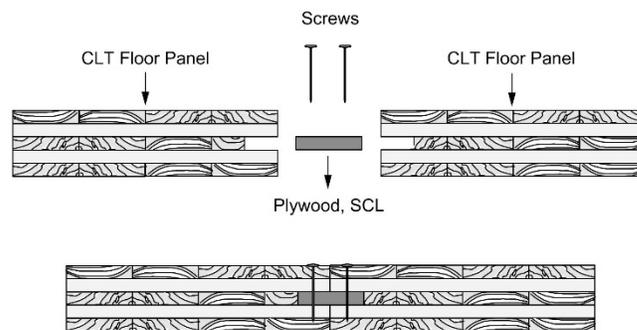
Other fasteners used with CLTs are nails, bolts and dowels. Nails are not very commonly used and when they are it is usually to attach metal plates and brackets. Bolts and dowels have long been used heavy timber construction such as glu-lams, and they are also used with CLTs.

## Panel to Panel Connections

The primary form of connections join together panels for walls and floors. Wall panels can be joined together to make long sections of walls and floor panels can be joined together to form a floor. While the size of panels is limited by the ability to transport the floor sections, the panels can be joined along the long edge to make larger sections of floor.

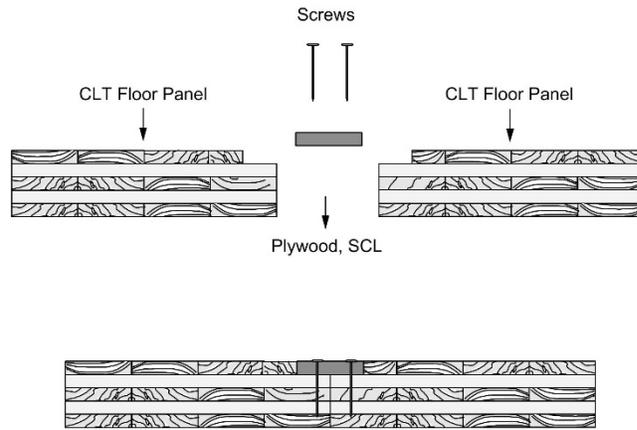
Oftentimes splines are used to join the panels. A spline is a strip of laminated lumber, plywood, or other material inserted into matching grooves, along the edges of two boards. The purpose is to reinforce and align the edges. A spline can be used as a substitute for the tongue and groove. The recess along the edge of the panel must be done at the plant before being delivered.

The illustration below shows a single internal spline.

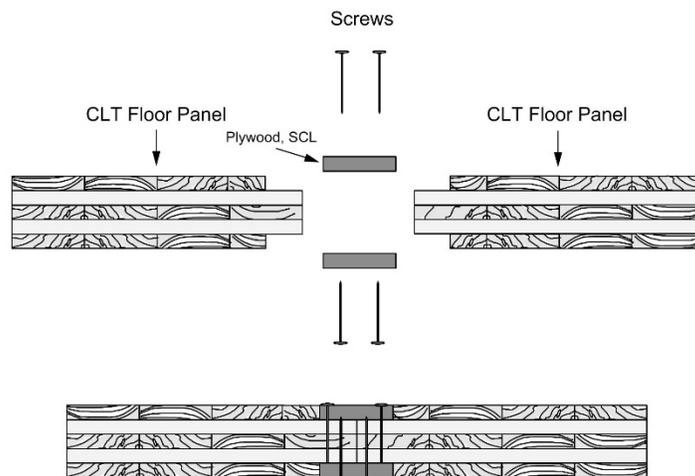


This is a strong connection, however, it needs to be accurately routed at the plant and it can be difficult to install in the field.

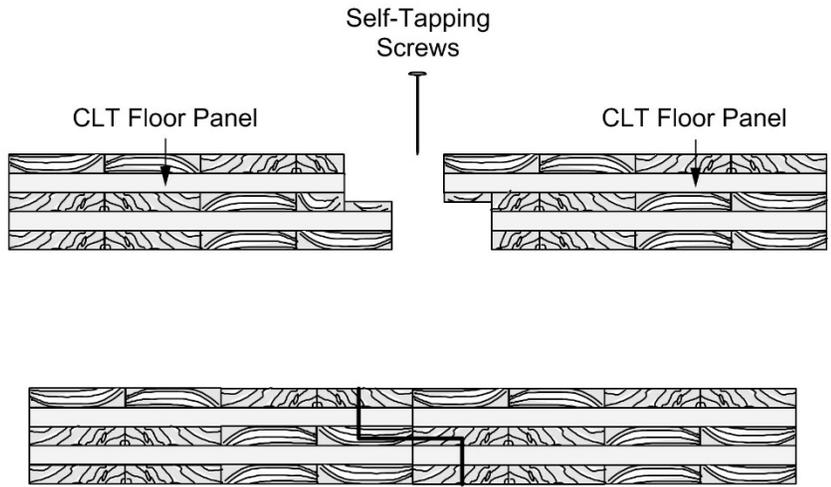
Another type of spline goes on the surface of the panels, which can be easily applied on site. These can be attached with nails, wood screws or self-tapping screws. Additionally, structural adhesive is sometimes used. Shown here is single surface spline.



Here is another type of surface spline, with splines on both the top and the bottom of the panel. This makes for a stronger connection, however, it requires more profiling at the plant. It is more difficult to erect because the two splines need to be screwed, and the bottom spline may be difficult to reach.

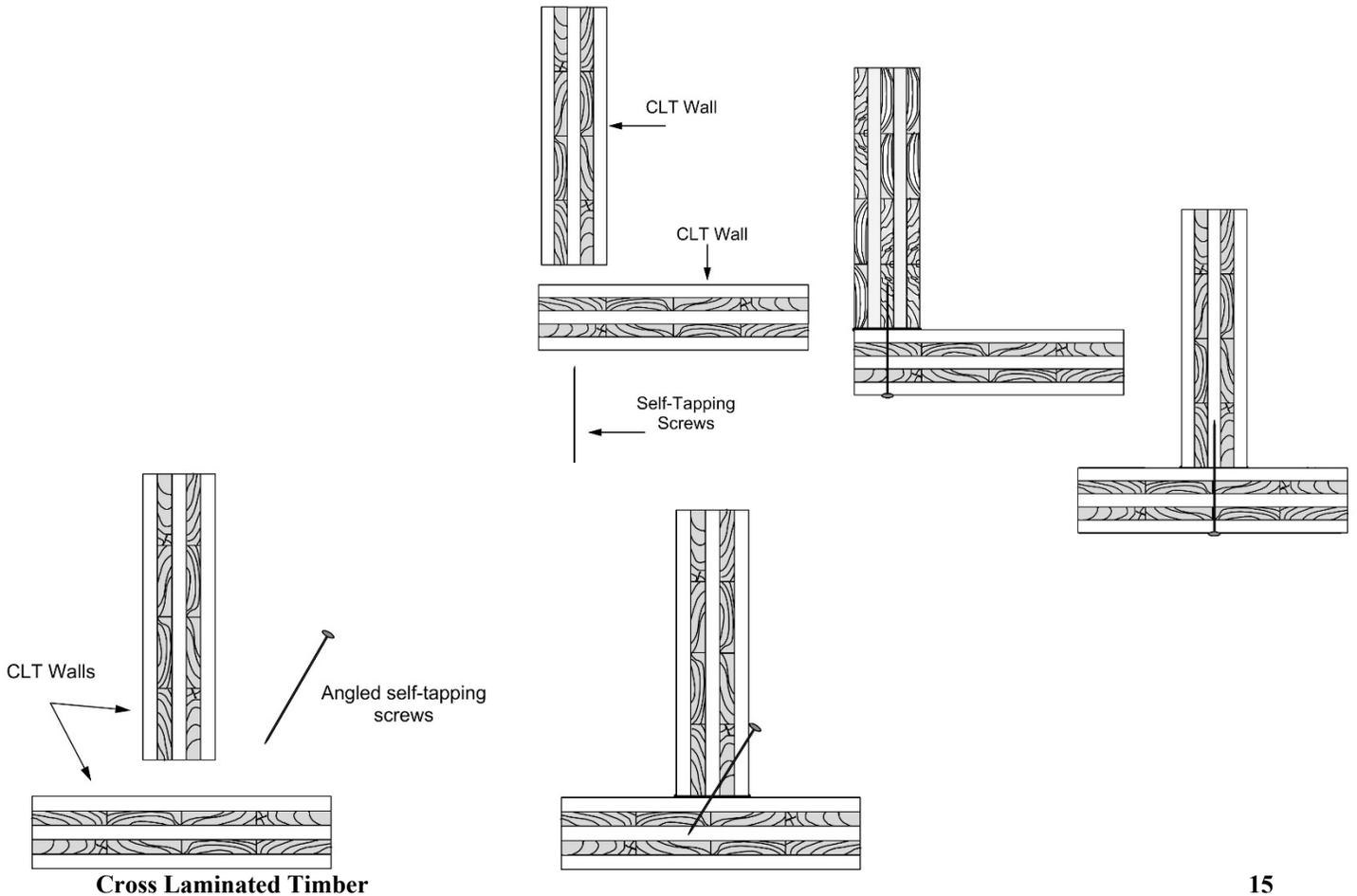


The half-lapped connection that is used in wall and floor assemblies is an age old joint that allows for fast installation. There are some potential problems that this kind of connection proposes, and thus it is not considered to be moment resisting. The panel edges are generally connected with long self-tapping screws.

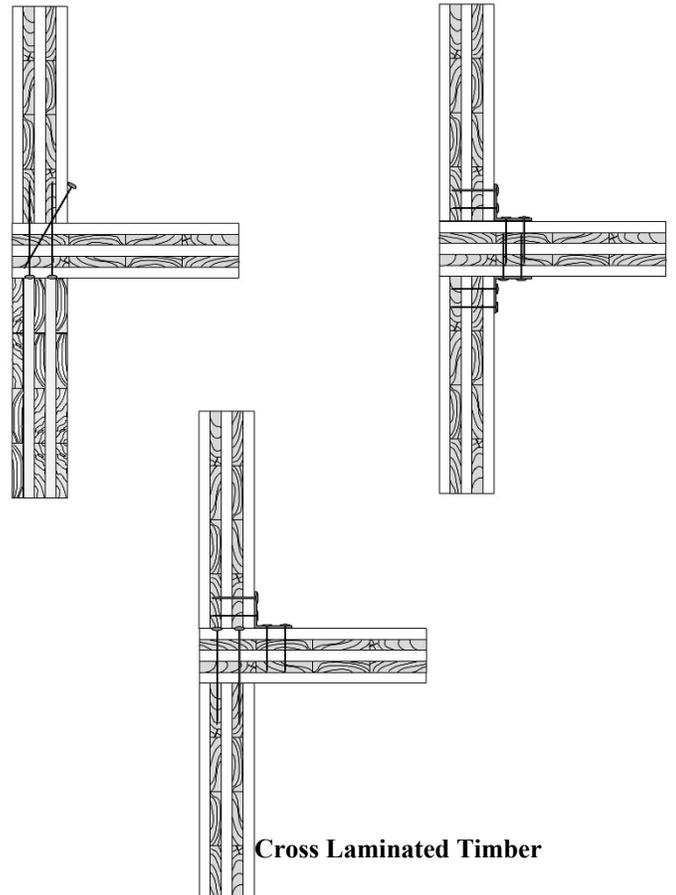
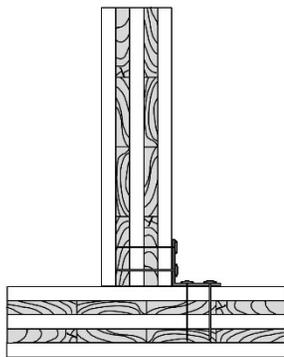
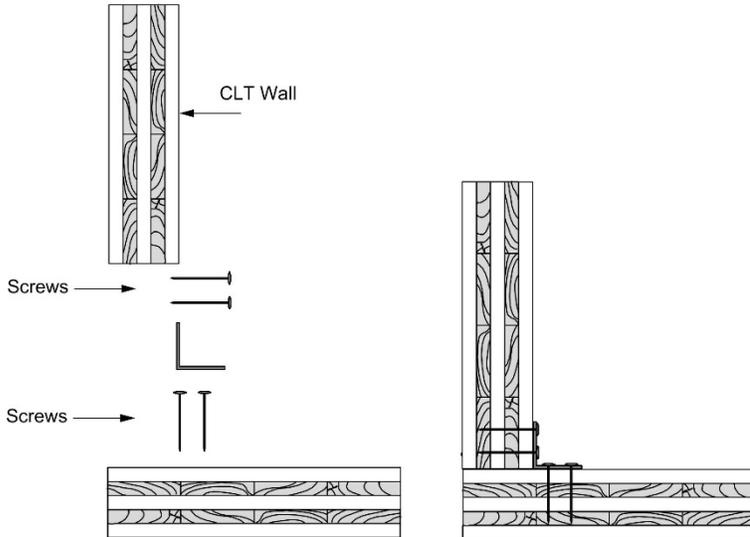


### Wall to Wall Connections

The connection between walls can be screws or metal brackets. Screws are the simplest method for connecting the walls, however, this raises some problems when screwing into the end grain. Below are some examples of screwing panels together directly.



A common type of connection that the carpenter will be familiar with, is the use of metal brackets. These metal brackets are either screwed on or nailed on, much like putting in hold-downs and other seismic hardware.

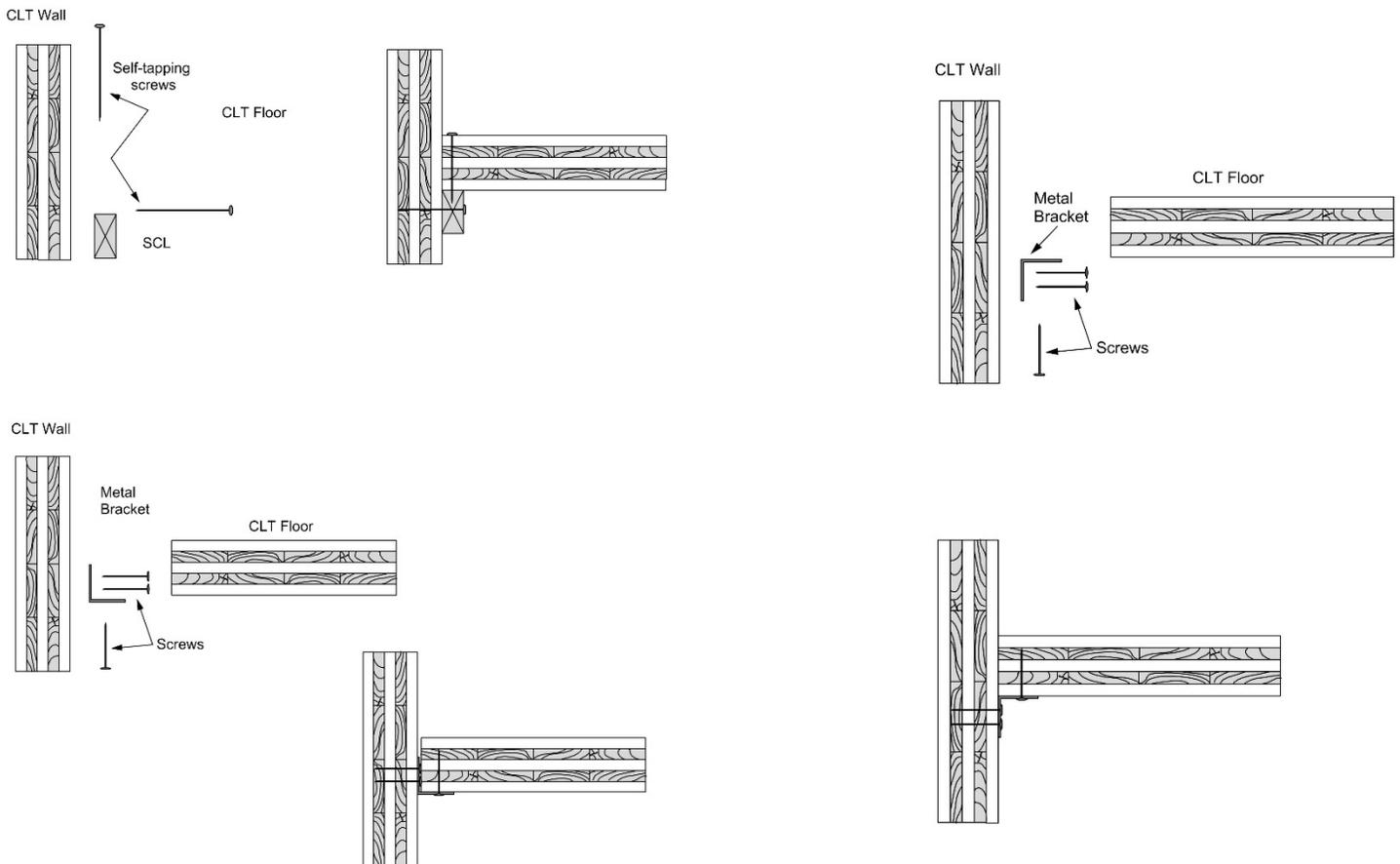


### Wall to Floor Connections

When it comes to connecting walls to floors, it is different for platform construction and balloon construction. Platform construction allows for the panels to be screwed together or they can be joined with metal brackets



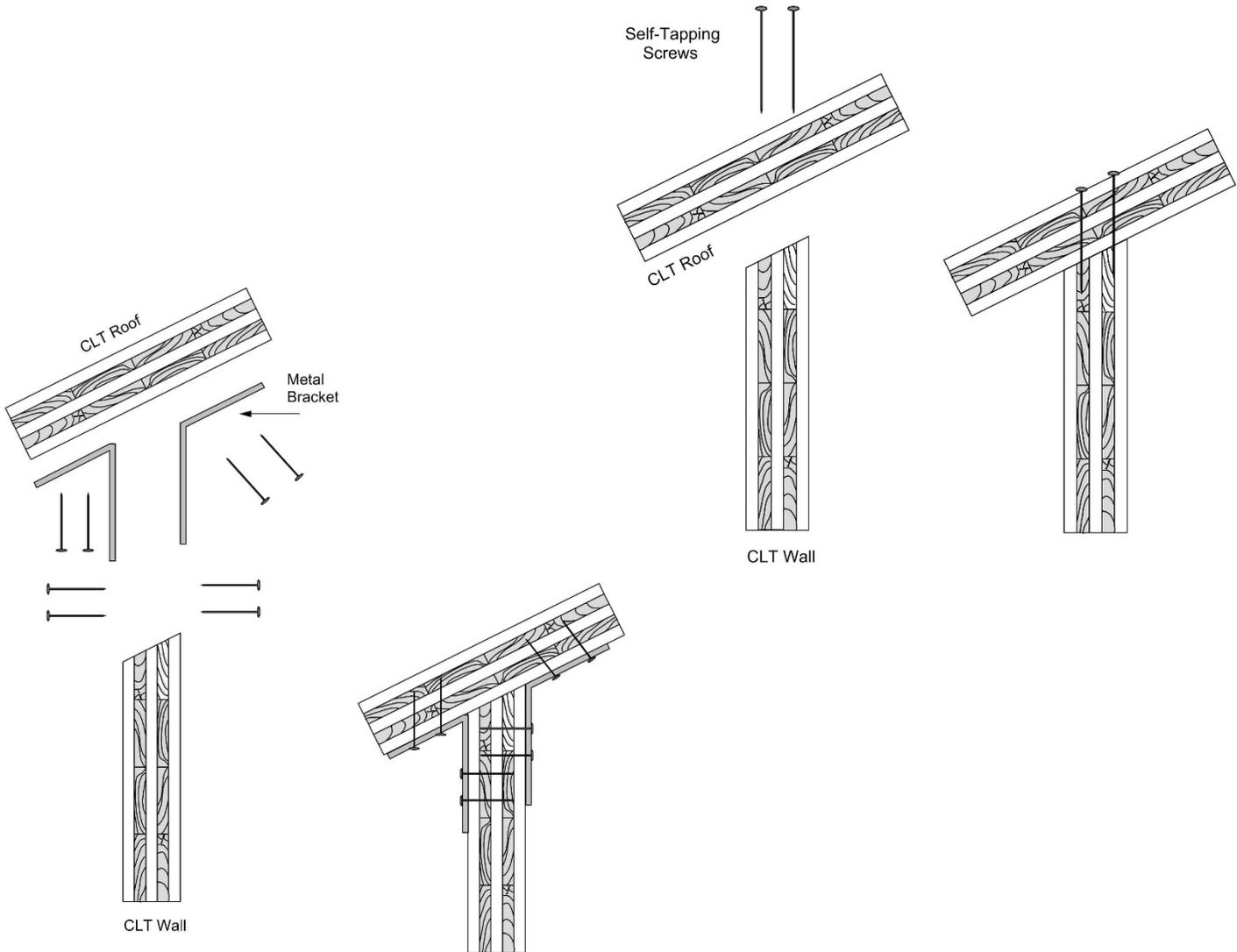
Walls and floors in balloon construction cannot just be screwed together, so a ledger or metal brackets must be used.



There are other connections used on the job that might be custom made for that application, rather than a standard bracket.

## Roof to Wall Connections

A roof panel may be flat or sloped. The connection can be done with screws but metal brackets are more commonly used. The slope of the roof will be done in production rather than on the job site.



There should be a tight fit between the panels and between the walls and the floors. There are several reasons for this:

- Structural integrity-to make sure the panels are sharing the load
- Improved fire resistance
- Sound insulation
- Air tightness

To improve fire resistance, fire resistant materials are used to seal joints and openings. In addition, the tighter the fit, the less passage of flames. To improve sound insulation, acoustic membranes may be put between walls and floors and under metal connectors. Air tightness helps energy loss and can be helped by putting tape over the gaps between components.

To bring the panels tight together, there are many tools that can help cinch up the joints. One is a come-along and another is a beam grip with a ratchet and hooks. Panels should be cinched up and then connected. As seen here, the hooks are driven into the panels, so if this is an exposed floor, the location of the beam grip should be where the holes won't be visible.



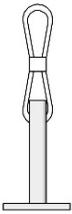
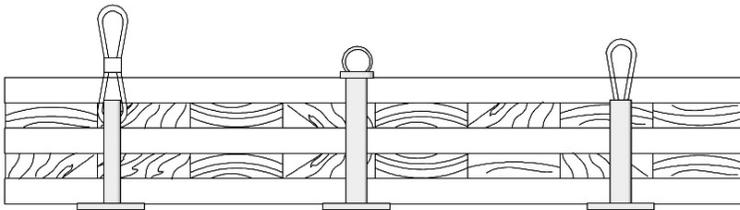
Connections are a vital component of CLT construction and the panels and the connectors need to work together to form a complete assembly.



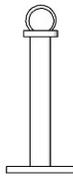
## Rigging and Installing CLTs

The nature of Cross-Laminated Timber construction means that the panels are heavy, and that they need to be erected with a crane. There are many similarities between lifting and setting precast concrete panels and lifting and setting CLT panels. This means that even though CLT construction is new, the erecting and setting the panels should be familiar to a company that has set precast members. The panels need to be rigged correctly so that there is no damage to the product and no danger to the workers.

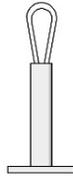
When choosing how to lift the panels and what lifting system to use, you must first know the weight of what you are lifting. Concrete is generally figured to weigh about 150 lbs. per cubic foot, whereas a CLT panel is calculated to weigh between 25 to 37 lbs. per cubic foot. This is an advantage of CLTs, they weigh less than a concrete panel. However, even though CLTs panels do not weigh as much as concrete, they are still quite heavy. For example, a 10' x 40' x 1' thick CLT slab will weigh over 12,000 pounds. Once the weight of the panels is known, a lifting system can be decided upon. There are many types of lifting pick points (attachment points for the rigging), including lifting loops, threaded eyelet bolts, screwed-on anchors, screwed-on plate and lifting rings and double-threaded sockets.



Articulated  
Lifting  
Loop



Threaded  
Eyelet  
Bolt



Single  
Lifting  
Loop



Many of these, like those on the left above, require holes to be drilled through the panel to allow threaded sleeves or dowels to be inserted. The holes are usually drilled at the plant and then after the lift, the holes are sealed to limit noise, smoke and fire. On the above right is a screwed on anchor system where a self-tapping screw makes the connection between the panel and the lifting ring. The screw is usually installed at the plant and it usually is located in a recess. The last of the above connections is a ring that is screwed to the panel.

As stated above, the process of rigging and lifting the panels into place is not very different from standing tilt-up panels or other precast products. The crane should be positioned in a place that will be able to reach all of the panel locations. If possible, the crane, or lifting device, should not be moved. The crane must be stable at all times, so the ground should be checked to ensure that the soil will not degrade when under a load. In addition, the range of the crane should be checked to make sure that it will not come in contact with any obstacles.

The rigging is usually done with slings which connect the pick point to the crane. Slings can be made of wire rope, chain or synthetic nylon, each of which is shown here.



Before each use, the slings should be thoroughly examined to see if there are any defects.

Wire rope slings are the most common slings and they should be inspected before each use for external wear, heat damage, kinking or excessive bending and, in particular, any broken wires in the wire rope. Industry standards require a wire rope to be removed from service if 10 broken wires are located in any one lay length or if there five broken wires in one strand of one lay length.



**Cross Laminated Timber**

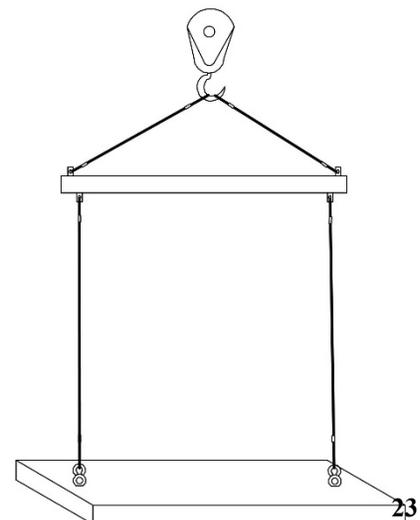
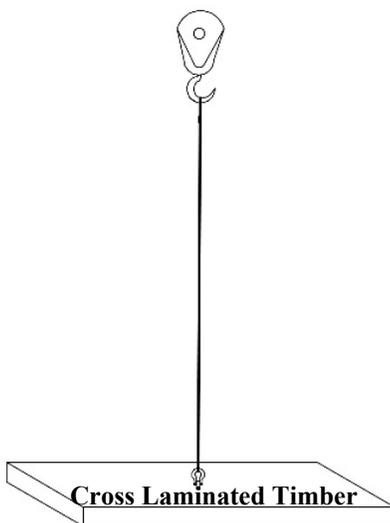
Chain slings should also be inspected before each use. With chains, you are looking to see how much wear there is on the inside of the links, or checking that the links have not been bent, twisted or stretched. In addition, you should check for cuts, nicks or gouges and you should also look for signs of heat damage.

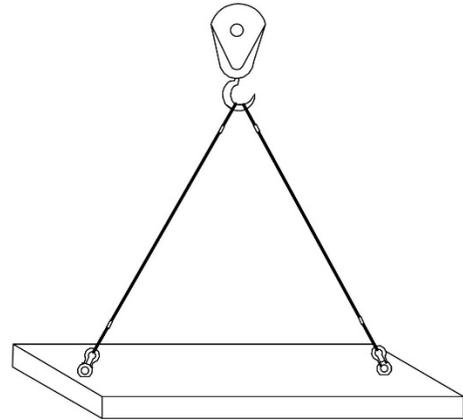
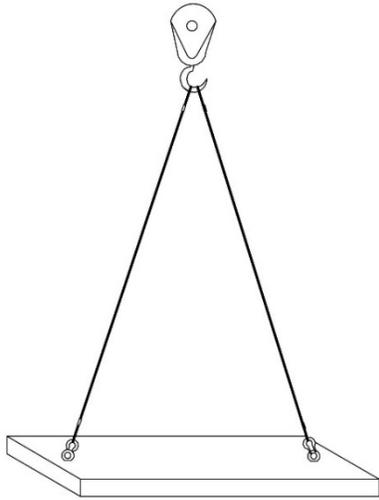
Inspection of the synthetic web slings include checking for worn or broken stitching, knots in any part of the sling, melting or charring or any part of the sling, and any cuts tears or snags in the sling.

While the decisions of how the panel will be rigged and what kind of lifting hardware is used are made long before the panel is to be lifted, the carpenter should understand some of the basics of rigging in order to work safely and efficiently.



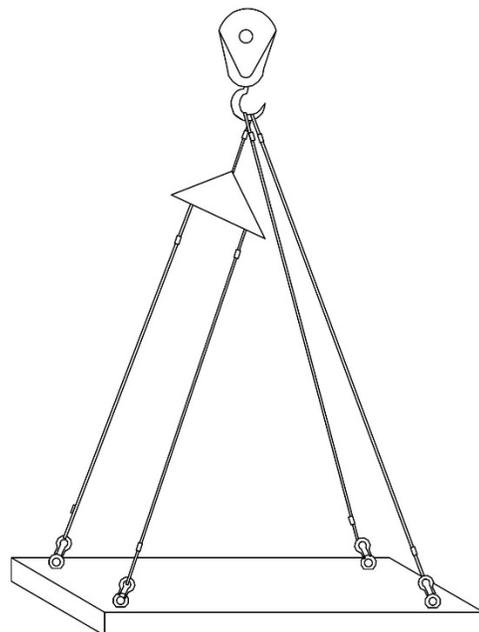
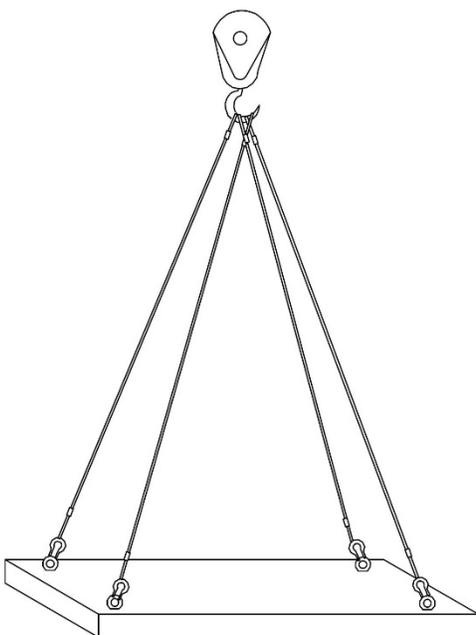
The number and location of the pick points are determined by an engineer who has calculated the load and where the center of gravity of the panel is located. In addition, there are other considerations that need to be considered. When a panel is lifted by a single point, the stress on the sling is simply the weight of the panel itself. For example, in the figure below, if the panel weighs 1,200 lbs., the stress on the wire rope is 1,200 lbs.. In the second drawing, a spreader beam is used to keep the wire ropes straight up and down. Each of these slings is supporting half of the 1,200 lbs., or 600 pounds of stress.





When the sling is attached to the panel and the hook at an angle, the amount of stress on the sling increases. In the example on the left, if the sling is 12' long and the panel is 9' below the hook, each leg will have 800 lbs. of stress. As the angle of the sling increases, so does the amount of stress on the legs. If the panel on the right was 6' below the hook (rather than 9'), the stress on each leg will increase to 1200 lbs.. When rigging a load, use the longest slings as is practical, this will help to lessen the stress on each leg.

Another common rigging configuration is a four-leg bridle hitch. When using a four-leg, the load may not be evenly distributed to all of the four legs. Because of this, the stresses on the legs are calculated as though there is three legs rather than four. To help ensure that the weight is evenly distributed, a triangular spreader is sometimes added and two lines are connected to it.



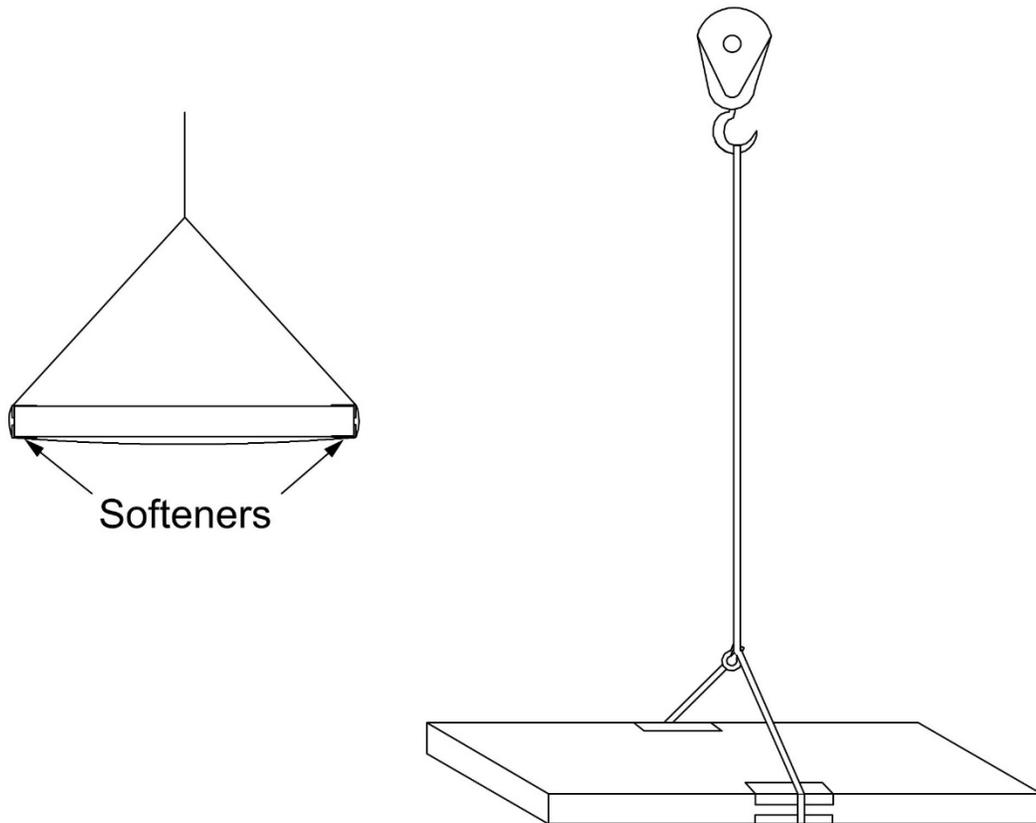
When walls are lifted, the rigging is usually attached to the top of the wall as shown here.



In this picture we see that L-shaped brackets have been attached to the floor along layout lines positioned and then secured once the panel is in place. Walls often will need to be braced until all of the components are put together. The bracing is usually done with metal braces that can be adjusted. The panels should be plumbed before moving on, especially if other components, like a floor slab, is going to be placed on top of the walls.



Much like glu-lam beams, care needs to be taken to avoid crushing or marring the face of the panel, and particularly the edges. If you are using a nylon sling and wrapping it around the panel, you will probably use softeners between the panel edge and the sling. Softeners can be thick pieces of cardboard or even blocks of wood that are placed over the edges to protect the edges and panel from damage due to the sling contacting the panel directly.



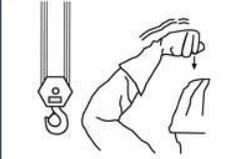
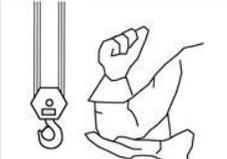
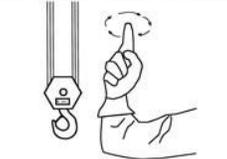
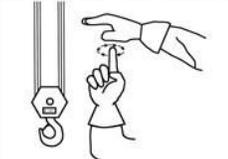
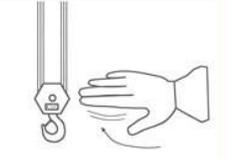
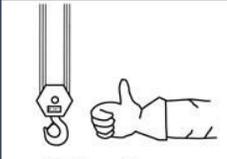
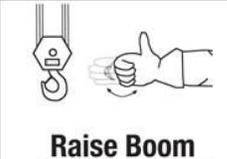
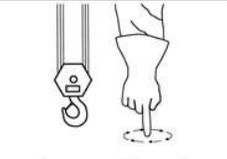
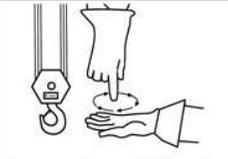
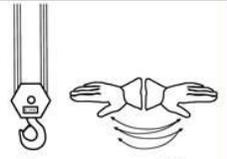
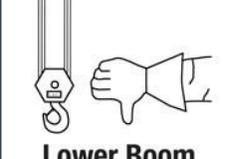
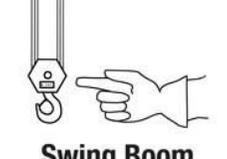
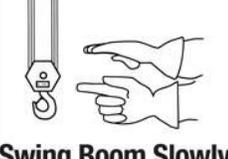
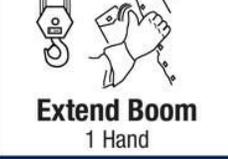
The configuration shown here is web sling that is choked. Choked means that the sling is wrapped around the load or object, and then back through itself. While this is a simple way to lift an object, it can put a lot of stress on the sling, particularly when the choke is driven down as close to the object as possible. As mentioned above, the lower the angle of the sling, the more pressure on the leg.

Since CLT panels are trucked to the job, the panels are oftentimes rigged and lifted into place directly from the truck. This helps to minimize the chance of the panels being damaged while having to be stored on the jobsite. This is where preplanning is necessary, if the truck is loaded with the panels in the order that the panels will be erected, the operation will go much smoother and efficiently.

If a job consists of many panels, it may not be feasible to have each trailer unloaded as it arrives on the jobsite. If there is not a sufficient amount of room to store the panels, sometimes a

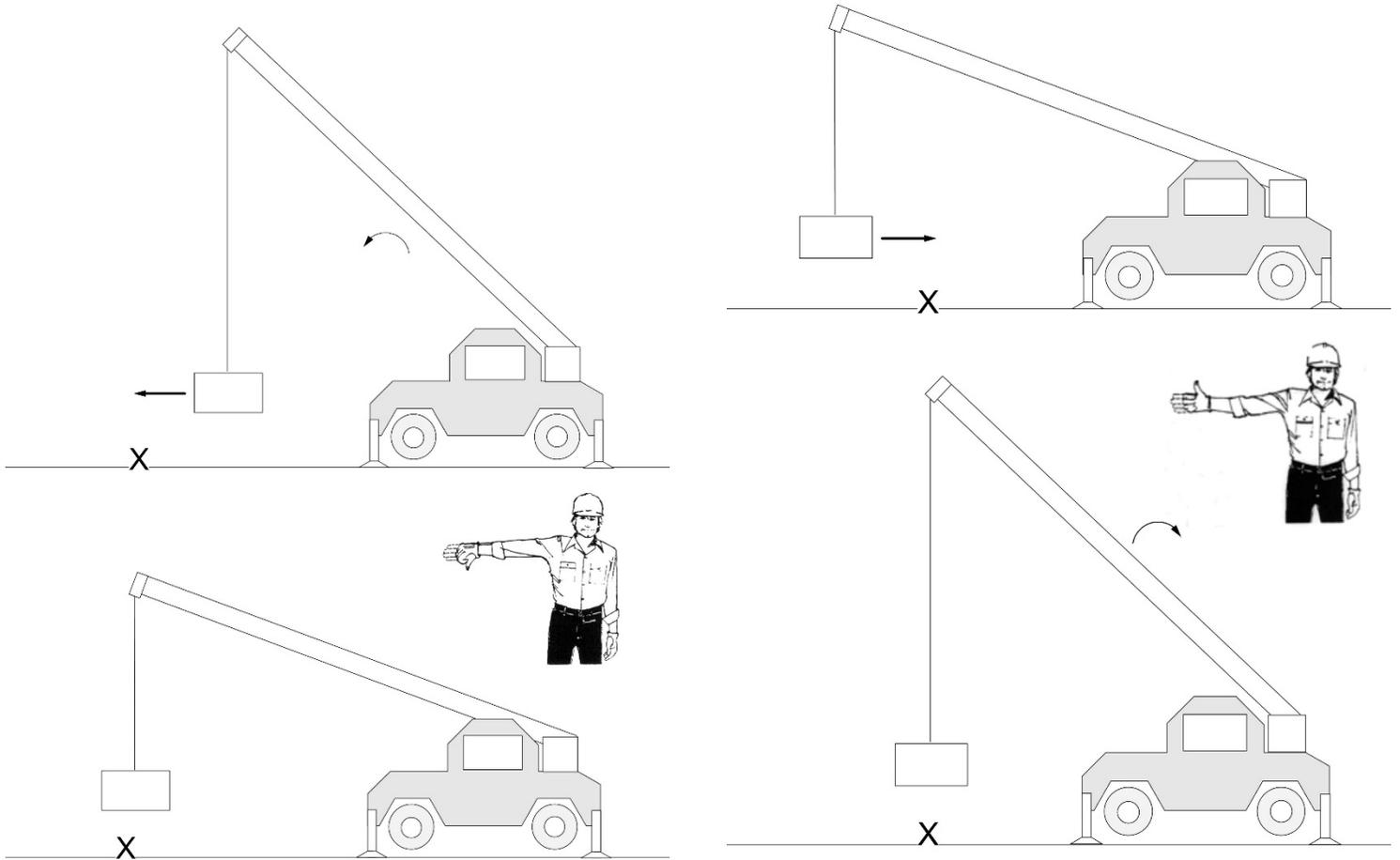
warehouse may be needed to store the panels out of the elements until time for erection. It may not be practical to put all of the panels on the truck in their exact order of installation if, for instance, a long panel, may need to be loaded on first to stabilize the load, even if it is out of order

One of the most important aspects of rigging is the communication between the crane operator and the signal person. The signaler and the crane operator must be in agreement with what each signal means. To eliminate confusion about signals, there are international hand crane signals that can be used to communicate what the signalers wants. Here are the international crane signals

<b>Mobile Crane Hand Signals</b>				
 <b>Main Hoist</b>	 <b>Auxiliary Hoist</b>	 <b>Hoist Load</b>	 <b>Hoist Load Slowly</b>	 <b>Stop</b>
 <b>Raise Boom</b>	 <b>Raise Boom &amp; Lower Load</b>	 <b>Lower Load</b>	 <b>Lower Load Slowly</b>	 <b>Emergency Stop</b>
 <b>Lower Boom</b>	 <b>Lower Boom &amp; Raise Load</b>	 <b>Swing Boom</b>	 <b>Swing Boom Slowly</b>	 <b>Travel</b> (mobile equipment)
 <b>Retract Boom</b> 2 Hands	 <b>Retract Boom</b> 1 Hand	 <b>Extend Boom</b> 2 Hands	 <b>Extend Boom</b> 1 Hand	 <b>Dog Everything</b>

The finger controls the line, that is, by extending the finger up or down and rotating it, you are signaling that you want the load to go up or down. The thumb controls the boom, by extending the thumb up or down, you are saying that you want the boom to go up or down. When the thumb is raised and the fingers are pumped in and out, this means that in addition to raising the boom, the load will be lowered at the same time, thus keeping the load at the same height. An important thing to remember is that when the boom is raised, the load moves towards the crane, and conversely, when the boom is lowered, it moves away from the crane. In addition, when the boom is raised, it also raises the load, and when the boom is lowered, it also lowers the load .

Even though the boom can be extended or retracted, this puts stress and wear on the boom arm and should be avoided. Instead of extending or retracting the boom, use the illustrations below to move a load nearer or farther from the crane.



If you are not comfortable with having two things happening at one time, you can simply signal to raise or lower the boom and then, separately raise or lower the load.

In addition to hand signals, which are used when the operator has a clear view of the rigger, the signaler can use voice signals. When the operator's view of the rigger is blocked, the rigger must use voice signals. This is accomplished with radios, telephones or other equipment. The signaler should speak clearly and state:

1. The function--such as "swing the boom".
2. The direction—"left "
3. Distance and speed—"30 feet slowly"

When stopping, the signaler should state the function and then the stop command.

Some other considerations include:

- Who can be a signaler? A person qualified to give crane signals to the operator.
- There should be only one designated signaler at a time.
- If signalers are changing between each other, the one in charge should wear a clearly visible badge of authority.
- A crane operator should move loads only on signals from one signaler.
- **A crane operator must obey STOP signals no matter who gives it.** This is because another worker may see a dangerous situation that the signaler cannot see.

The signaler must:

- Be in clear view of the crane operator.
- Have a clear view of the load and the equipment.
- Keep persons outside the crane's operating area.
- Never direct a load over a person.

## Installing the Panels

The crew must act as a team to ensure that the process goes smoothly. For example, while one crew is landing the panels, another crew should be prepping the next panel. The crew doing the prep should unwrap the panel and verify that the panel is correct and that it contains the proper penetrations and pre-drillings that are specified. The first thing that the installing team should do once the panel is resting securely on its support, is unhook the rigging, thereby freeing up the rigging to be connected to the following panel. However, the rigging should remain in place, until it is established that the load is stable and secure in its place, for example, making sure a wall panel is braced before the slings are unhooked. The crew on the panel can then adjust the panel to the layout lines and cinch the panels together using a beam grip or other device. The first panel in a given area must be installed accurately to a precise layout, since subsequent panels will be connected together. If the first panel is off layout, those that follow will also be off. In addition, they will line up the tops of the panels to make them flush. The long edges of the panel may chamfered, which disguises any unevenness with the adjacent panels. The installing team can then secure the panels with screws or lag bolts or whatever system is engineered. By this time, hopefully the next panel is arriving and the process continues. In this manner, the structure can go up quite quickly.

It should be remembered that landing the panels is usually what is considered to be "leading edge" work. The leading edge is the end or the outer limit of an elevated surface where a person could fall to a lower level. The leading edge changes locations as floors or additional constructions are added. The worker should tie off as soon as possible. Because the panel is made of wood, it is possible to attach an anchor point to the panel while it is on the ground and then the installation crew can tie off as soon as they step onto the panel. Another method for tying off would be to use the pick points for your anchor, provided they are rated for 5,000 lbs.

Safety is important to the success of any rigging operation. Everyone involved in the operation is responsible for their own safety and the safety of the other workers around them.

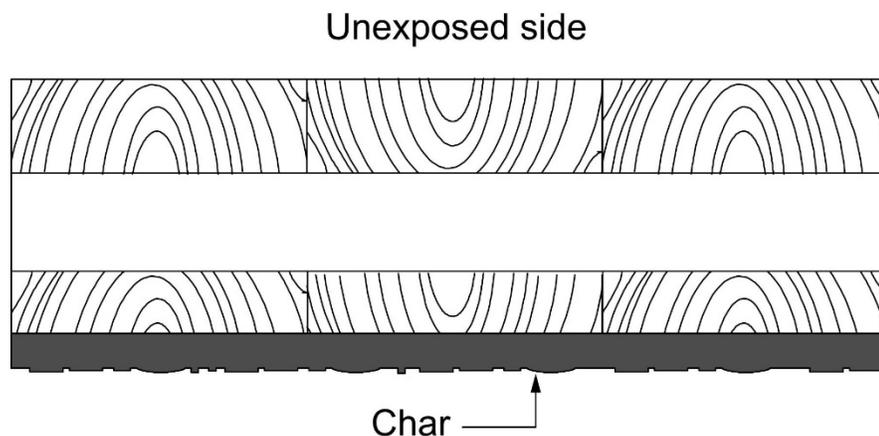


# CLT and Fire Performance

One of the key elements of any building that is constructed is the safety of the people that are working or living in the building. The health and safety of the public is the reason that we have building codes and fire safety is an essential part of the code. An example of building according to fire codes would be: setting doors to open out of a room into a protected corridor and installing a door closer on the door. The International Building Code (which recognized mass timber construction in 2015) establishes minimum requirements for public safety through structural strength, means of egress, life safety, and property protection as well as providing safety for firefighters and other first responders. The objective is to ensure the building will stay structurally sound in a fire and limit the spread of a fire once it has begun. Not all buildings are the same, so the code classifies buildings according to the type of materials used, the height of the building, and the number of occupants, among other things. The IBC classifies buildings as types I, II, III, IV and V. There are fire safety requirements in each of these types. Mass Timber construction generally falls in type IV. In this chapter, we will discuss the fire performance characteristics of Cross-Laminated Timber panels.

## The Pros of CLT in a Fire

CLT panels provide excellent fire resistance. This is due to the outer layer charring which creates a protective shell for the rest of the beams or panels. Charring is a result of wood timbers being subjected to fire; the surface of the wood burns and becomes blackened.



If the panel or column is thick enough, the exposed wood will char until the charred portion is enough to prevent additional charring, possibly self-extinguishing the fire. The charred layer provides protection to the remaining portion of the structural member allowing it to continue to carry the load it was designed to carry. The char rate of timbers is known so that engineers can calculate the rate the panel will deteriorate. This allows engineers to predict how the CLT will perform in a fire. The engineer can then design a building to meet or exceed the building codes for the type of construction the CLT will be used in.

When CLT is used for floors and load-bearing walls, it creates an environment much like when concrete is used for the same purpose. If a fire starts within a room surrounded by CLT, the fire has the potential to remain compartmentalized (the fire is contained to the room of origin) and slow the spread of the flame.

### **The Cons of CLT in a Fire**

The main concern of fire with CLT is the fact that it is made out of wood. Being a combustible material, CLT may contribute to the spread of a compartment fire. Some studies show that the charred layer may delaminate and fall off, exposing a fresh layer of wood to ignite. Because of this, some non-combustible materials may need to be added to protect the panels.

For instance, for exterior walls, the code requires all surfaces to be covered with a fire-retardant treated wood (FRTW) sheathing, gypsum board, or some other noncombustible material on the exterior side of the exterior wall.

To increase the fire resistance of loadbearing interior walls, they could be covered by drywall. To increase the fire resistance of the ceiling, a layer of mineral wool insulation and drywall can be added. This, however, conflicts with one of the basic attributes of CLT, namely, the pleasing aesthetic appearance of the exposed wood.

### **Building Code Changes**

Some code changes have been proposed that are intended to assure the public and the fire officials that tall wood buildings can be code compliant by giving the occupants a safe and strong structure with the implementation of rigorous and redundant fire protection systems.

One proposal creates new types of construction within type IV, namely, IV-A, IV-B, and Type C depending on the type of mass timber construction. Type IV-A would have the CLT completely covered. Type IV-B would allow some exposed surfaces of the ceiling, walls and beams. Type C would allow the mass timber to be fully exposed. This means the aesthetic of the CLT will be fully displayed.

Changes to the code is not a matter that is taken lightly. Many tests are completed to verify the safety of the proposed changes. In 2017, five tests were performed on mass timber buildings at a federal lab. Tests showed, some exposed walls and ceilings were able to self-extinguish after 4-hours. However, a fully-exposed mass timber structure must have a sprinkler system to contain the fire.

### **Fire-Resistance Rating**

The tests that are performed result in a fire-resistant rating being given to the building. A fire-resistant rating is defined as the period of time building components can continue to perform the functions they were designed for. A standard resistance test includes three items. These items are: (1) Structural Resistance: the assembly must support the applied load for the duration of the test. (2) Integrity: the assembly must prevent the passage of flame or gasses hot enough to ignite a cotton pad. This tests the CLT's ability to contain the fire and resulting smoke into the room where the fire started. (3) Insulation: the assembly must prevent the temperature rise on the

unexposed surface from being greater than 325° at any location or an average of 250°F at several locations.

At the point the assembly can no longer satisfy any one of the three criteria mentioned above, that becomes the assembly's fire resistance. Fire-resistance ratings are usually assigned a number of hours or parts of an hour. For example, a wall may have a 2-hour rating or a 30-minute rating.

To maintain the assembly's rating in areas where there are through penetrations, fire stop systems must be applied. Fire stop materials are used to fill gaps at abutting panels or around pipe penetrations.

Due to the newness of CLT construction, there is not a large amount of data published about the reaction of CLT in fire situations. While CLT meets most fire requirements, changes are currently being considered to allow for more exposure of the CLT panels while maintaining proper fire resistance.



## Other Considerations

While we have covered a variety of topics about CLT's, here are some other considerations related to CLT's and their use.

### Moisture Control

CLT panels are vulnerable to damage from excessive wetting due to the nature of the laminated construction and because they may absorb large quantities of water through the faces, exposed end grain, and gaps between the panel laminations. It should be noted that water absorption is more rapid at end grain surfaces. The mass and thickness of CLT means that these panels will likely take longer to dry out if allowed to become wet. In addition, cycles of wetting and drying can cause the wood to expand and contract, which may damage the laminations and distort the panels. This means it is imperative that the CLT panels be kept dry throughout construction. This can be achieved by covering the panels with plastic while being stored awaiting installation. Additionally, by paying attention to the weather and construction schedules, delivering the product just on time and minimizing construction time can all help in keeping the panels dry.

Exterior walls should be protected as soon as possible with a water resistive barrier (WRB). A vapor permeable WRB is desirable to allow the wood to dry while preventing further water absorption. Applying an impermeable membrane over CLT panels that are already wet is problematic for two reasons. First, drying of the CLT will be impeded. Second, the membrane may not adhere well to wet wood. If roof panels are wetted before the protective membrane is applied, it may be necessary to provide temporary shelter above the roof and to dry the panels.

When it comes to the interior of the building, ensure panel is below 20% moisture content before enclosing it behind drywall and other materials.

One of the properties of wood is that it can check. Checking is when the wood dries unevenly and causes cracks. It can be reduced or avoided with moisture content control. Panel moisture content should be around 12%-15%. Once a building is enclosed it must be heated up slowly and conditionally so that the wood material has a chance to adjust to its new environment. Avoid directing hot, dry, flowing air across wood material surface during construction. This is sure to cause unwanted checking and is especially important to consider during the drywalling stage of construction.

### Energy Efficiency

CLT panels provide some degree of thermal insulation. The thicker the panel, the higher the R-value which means less insulation is required. The R-value is the resistance to heat loss or gain. Softwood in general has about one-third the thermal insulating ability of a comparable thickness of fiberglass batt insulation, but about ten times that of concrete and masonry, and 400 times that of solid steel.

CLT provides a number of environmental benefits along with energy efficiency. The lumber used in the panels is from sustainable forests and it has a lighter carbon footprint because wood products continue to store carbon absorbed by the trees while growing, and wood manufacturing requires less energy and results in less green house gas emissions. With CLT the stored carbon mass is significant. In one project, the potential carbon benefit of the wood used was enough to keep 132 cars off the road for a year or provide enough energy to operate a house for 59 years.

## **Green Building**

In addition to CLT's being energy efficient, there are other ways in which CLT can add to the building's green objectives. As mentioned before, one way is that occupants exposed to wood have shown benefits in their well-being. In addition, CLT do not adversely affect indoor air quality.

Due to its size and thickness CLT has some thermal mass. Thermal mass is a contributor to savings in the building's heating and cooling loads.

Another green aspect of using CLT, is that it uses resources efficiently. Because it is a prefabricated product, there is little waste on the construction site. Waste in the production of the panels is minimal because the CNC machine is programed to make the most efficient use of the product.

All of these green attributes of Mass Timber mean that CLTs are a good way to build when environmental factors are considered.

## **Finished Product**

When unloading, placing and handling the CLT panels, it should be remembered that it is a finished product. Hands must be kept clean or gloves should be worn as the panels are typically unsealed wood which can easily stain. Floor panels may be covered with a layer of concrete. If this is the case, gaps and voids between the panels or around penetrations must be sealed to prevent leakage of concrete onto panels below.

It cannot be stressed enough that if the CLT is exposed, it needs to be protected, from the factory until the building is fully enclosed. Leakage from water, or especially from concrete, can spoil the appearance of the wood and it is difficult to repair or conceal the stained wood. This means that any penetrations need to be filled, like around an electrical box or a sprinkler head. The joints between the panels can be covered with a highly adhesive tape that seals the seam. This taping also makes the panels more air tight and can help keep a fire contained.

Care should be taken when lifting and placing the panels to avoid striking other objects which could mar the edges.



## **Field Preparation**

During the manufacturing process the Computer Numerical Control (CNC) machine can locate and drill or cut the panels for any penetrations or mechanical chases needed. However, there are some situations when the penetration locations are determined after the panels are installed. This requires the UBC member to have precision layout skills. Some projects allow for the use of robotic total stations to layout the penetrations. This reduces the chance of wrong layout locations. It should be noted, care must be taken when field drilling penetrations as the laminations on the opposite side could blow-out. To avoid this blow-out, if possible, the panel can be drilled from both sides toward the center. However, if this is impractical, a wood block can be held under the panel and secured with a shore to act as backing for the drilling. Modifications to the panels may be required if the structure is not built square or plumb. This means that the carpenter needs to have good layout and tool skills as the modifications need to look like they were done in the factory if they will be visible. Even sanding an area of the panels may blemish the panel. Routers, chisels, beam saws and even chainsaws may be used to modify the affected panels. Sometimes holes up to 8" in diameter need to be drilled in the panel. All of these tools can be dangerous and must be handled safely and with the proper precautions.

## **Mechanical, Plumbing and Electrical**

When CLTs are exposed on the interior of the building, there is a question as to where the mechanical, plumbing and electrical runs will be placed. Some options are:

- ❖ Furr out a wainscoting on the lower half of the wall for electrical outlets and plumbing pipe.
- ❖ Run the chases, conduit and pipes on the face of the CLTs for an exposed architectural look.
- ❖ Build a drop ceiling to cover the MEP (mechanical, electrical and plumbing).
- ❖ Create a built-up floor on top of the deck to house the MEP.

When CLTs are covered you can:

- ❖ Rout and bore the panels to house the electrical conduit, plumbing pipes and mechanical chases. This could be done on site with common carpentry tools or in the factory. However, being done in the factory would take more coordination and could be more costly.
- ❖ Fur the wall out to accommodate the MEP. This may be the more common approach because this extra wall would help to meet the sound insulation requirements.

### **CLT Construction and Mall Code**

Some buildings may qualify to build under Chapter 4, Section 402 of the IBC code, which covers malls. This type of building classification will allow for much of the CLT to be exposed, thereby enhancing the beauty of the building. The code has its own requirements, such as this type of construction shall not be over 3 floors above ground. Buildings under this code also must have automatic sprinkler systems.

### **Mass Timber Shoring**

When a Mass Timber floor or roof is going to be topped with concrete, just as with a concrete deck, it may be necessary to place shoring under the deck to carry the weight until the concrete has cured. The shoring could be Ellis shoring or a scaffold frame shoring, however, where the shores contact the floor or roof panels, care must be taken to ensure that there is no marring or discoloration of the wood. Again, the appearance of the exposed CLT is of the utmost importance.



