CLT Handbook

CROSS-LAMINATED TIMBER

U.S. EDITION

The U.S. Edition of the CLT Handbook: cross-laminated timber can be electronically downloaded without charge from the website www.masstimber.com. Additional information can be obtained by visiting the websites of FPInnovations, USFPL, American Wood Council (AWC), APA and U.S. WoodWorks. Hard copies can be obtained through AWC (www.awc.org).

CLT Handbook

CROSS-LAMINATED TIMBER

Edited by
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Brad Douglas, P.E., AWC

FPInnovations
Pointe-Claire, QC
Special Publication SP-529E

2013

U.S. EDITION

Forest Products Laboratory

Funding for this publication was provided by

Publication

FPInnovations
570 boul. St. Jean
Pointe-Claire (QC)
H9R 3J9
www.fpinnovations.ca

Distribution of hard copies

AWC
222 Catoctin Circle SE
Suite 201
Leesburg, VA 20175
www.awc.org

Library and Archives Canada Cataloguing in Publication

CLT handbook : cross-laminated timber / edited by Erol Karacabeyli, Brad Douglas. -- U.S. ed.

(Special publication, ISSN 1925-0495 ; SP-529E)
Co-published by U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Binational Softwood Lumber Council (BSLC).
Includes bibliographical references.
Issued also in electronic format.
ISBN 978-0-86488-553-1

1. Laminated wood. 2. Laminated wood construction. 3. Engineered wood construction. 4. Laminated wood--Standards. 5. Laminated wood--Handbooks, manuals, etc. I. Karacabeyli, Erol, 1954- II. Douglas, Brad, 1960- III. Forest Products Laboratory (U.S.) IV. FPInnovations (Institute) V. Binational Softwood Lumber Council VI. Title: Cross-laminated timber. VII. Series: Special publication (FPInnovations (Institute)) ; SP-529E

TA666.C57 2013 624.1'84 C2012-908154-X

Library and Archives Canada Cataloguing in Publication

CLT handbook [electronic resource] : cross-laminated timber / edited by Erol Karacabeyli, Brad Douglas. -- U.S. ed.

(Special publication, ISSN 1925-0509 ; SP-529E)
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TA666.C57 2013 624.1'84 C2012-908155-8

PREFACE

Expansion into mid-rise, high-rise and non-residential applications presents one of the most promising avenues for the North American wood industry to diversify its end use markets. This may be achieved by:

- Designing to new building heights with **Light Frame Wood Construction**
- Revival of **Heavy Timber Frame Construction**
- Adoption of **Cross-laminated Timber** (CLT)
- Facilitating **Hybrid Construction**

There are concerted efforts both in Canada and in the United States towards realizing that goal. In fact, the Canadian provinces of British Columbia and Quebec went even further and created specific initiatives to support the use of wood in those applications.

This Handbook is focused on one of these options – adoption of cross-laminated timber (CLT). CLT is an innovative wood product that was introduced in the early 1990s in Austria and Germany and has been gaining popularity in residential and non-residential applications in Europe. The Research and Standards Subcommittee of the industry's CLT Steering Committee identified CLT as a great addition to the "**wood product toolbox**" and expects CLT to enhance the re-introduction of wood-based systems in applications such as 5- to 10-story buildings where heavy timber systems were used a century ago. Several manufacturers have started to produce CLT in North America, and their products have already been used in the construction of a number of buildings.

CLT, like other structural wood-based products, lends itself well to prefabrication, resulting in very rapid construction, and dismantling at the end of its service life. The added benefit of being made from a renewable resource makes all wood-based systems desirable from a sustainability point of view.

In Canada, in order to facilitate the adoption of CLT, FPInnovations published the Canadian edition of the CLT Handbook in 2011 under the Transformative Technologies Program of Natural Resources Canada. The broad acceptance of the Canadian CLT Handbook in Canada encouraged this project, to develop a U.S. Edition of the CLT Handbook. Funding for this project was received from the Binational Softwood Lumber Council, Forestry Innovation Investment in British Columbia, and three CLT manufacturers, and was spearheaded by a Working Group from FPInnovations, the American Wood Council (AWC), the U.S. Forest Products Laboratory, APA-The Engineered Wood Association and U.S. WoodWorks. The U.S. CLT Handbook was developed by a team of over 40 experts from all over the world.

Both CLT handbooks serve two objectives:

- Provide immediate support for the design and construction of CLT systems under the alternative or innovative solutions path in design standards and building codes;
- Provide technical information that can be used for implementation of CLT systems as acceptable solutions in building codes and design standards to achieve broader acceptance.

The implementation of CLT in North America marks a new opportunity for cross-border cooperation, as five organizations worked together with the design and construction community, industry, universities, and regulatory officials in the development of this Handbook. This multi-disciplinary, peer-reviewed CLT Handbook is designed to facilitate the adoption of an innovative wood product to enhance the selection of wood-based solutions in non-residential and multi-storey construction.

Credible design teams in different parts of the world are advocating for larger and taller wood structures, as high as 30 stories. When asked, they identified the technical information compiled in this Handbook as what was needed for those applications.

A Renaissance in wood construction is underway; stay connected.

ACKNOWLEDGEMENTS

The great challenge with this U.S. Edition of the CLT Handbook was to gather experts from the United States, Canada and Europe to bring together their expertise and knowledge into a state-of-the-art reference document. The realization of this Handbook was made possible with the contribution of many people and numerous national and international organizations.

Such a piece of work would not be possible without the support from financing partners and, as such, we would like to express our special thanks to Binational Softwood Lumber Council, Forestry Innovation Investment (FII), Nordic Engineered Wood, Structurlam, and CLT Canada for their financial contribution to this project.

First and most of all, we would like to express our gratitude to AWC, APA, USFPL, FPInnovations, U.S. WoodWorks and their staff for providing the effort and expertise needed to prepare this work. We would also like to express our special thanks to all chapter authors, co-authors, and reviewers who shared their precious time and expertise in improving this manual.

Our very special thanks go to Loren Ross at AWC and Sylvain Gagnon at FPInnovations for their work as project leaders and for their special efforts in gathering the expertise of everyone into a unique document. Special thanks also go to the Working Group, Dr. Borjen Yeh from APA, Dave Kretschmann from the U.S. Forest Products Laboratory, and Lisa Podesto from U.S. WoodWorks. Thanks also to Madeline Leroux for her work on the drawings, Odile Fleury for her help with bibliographic references, and Marie-Claude Thibault for her support in editing and coordination work.

Erol Karacabeyli, P.Eng. and **Brad Douglas**, P.E.
Co-editors
CLT Handbook, U.S. Edition

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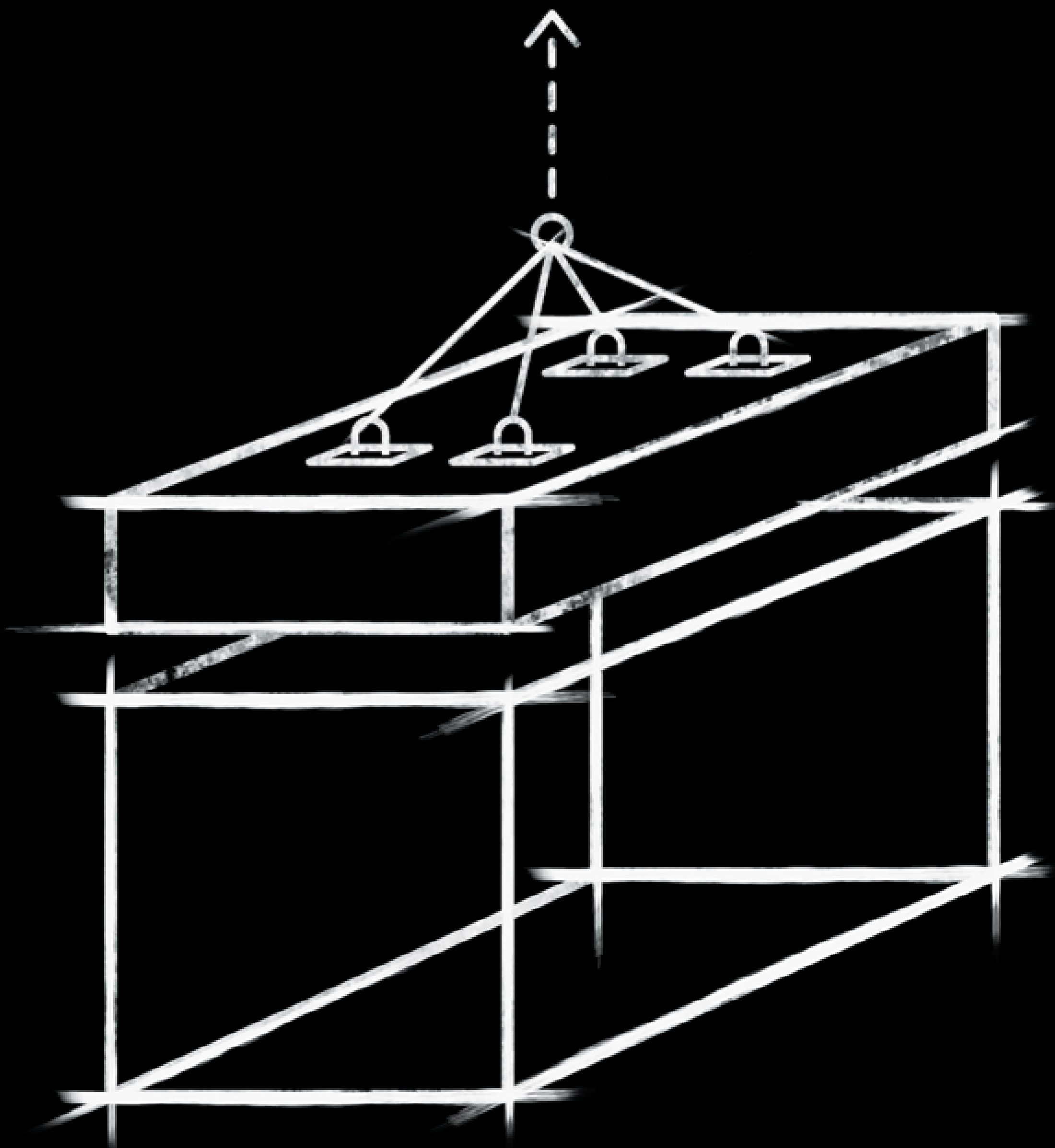

Lifting

Lifting and handling of cross-laminated timber elements

  

CHAPTER 12

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ACKNOWLEDGEMENTS

The U.S. Edition of the CLT Handbook: *cross-laminated timber* combines the work and knowledge of American, Canadian and European specialists. The handbook is based on the original Canadian Edition of the CLT Handbook: *cross-laminated timber*, that was developed using a series of reports initially prepared by FPInnovations and collaborators to support the introduction of CLT in the North American market. A multi-disciplinary team revised, updated and implemented their know-how and technologies to adapt this document to U.S. standards.

The publication of this handbook was made possible with the special collaboration of the following partners:

FPInnovations

Forest Products Laboratory

American Wood Council

APA

WoodWorks

The editing partners would also like to express their special thanks to Binational Softwood Lumber Council, Forestry Innovation Investment (FII), Nordic Engineered Wood, Structurlam, and CLT Canada for their financial contribution to studies in support of the introduction of cross-laminated timber products in the United States of America.

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ABSTRACT

Cross-laminated timber (CLT) construction is a relatively new process. There is therefore very little specific technical documentation for the erection of structures designed and built with CLT panels. Current CLT manufacturers provide recommendations on lifting systems for the installation of prefabricated wood assemblies. However, technical documents currently available mostly come from Europe or Canada and may appear incomplete to some design professionals and builders/contractors in the United States.

This Chapter presents a variety of lifting systems that can be used in the construction of structures using CLT panels. We discuss the basic theory required or suggested for proper lifting techniques. In addition, we introduce various tools and accessories that are frequently required for CLT construction, as well as good building practices to help contractors build safe and efficient CLT panel structures. Finally, we discuss issues related to the transportation of CLT assemblies from factory to building site. Regulatory aspects of transportation are also discussed.

It is important to note that the lifting, handling, and installation of CLT panels involve multiple interest groups including design professionals, contractors/erectors and CLT manufacturers, each with different areas of interest and expertise. Therefore, the information presented in this Chapter is broad in scope and may or may not be relevant to each interest group.

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1 INTRODUCTION

This Chapter presents a variety of lifting systems that can be used in the construction of structures made of cross-laminated timber (CLT) panels. We discuss the basic theory required for proper lifting techniques. In addition, we introduce various tools and accessories that are frequently required during CLT construction, as well as good building practices to help contractors build safe and efficient CLT panel structures. Finally, we discuss issues related to the transportation of CLT assemblies from factory to building site. Regulatory aspects of transportation are also discussed.

1.1 Parallel with Precast Concrete Industry

CLT construction is a relatively new process. There is therefore very little specific technical documentation for the erection of structures designed and built with CLT panels. Current CLT manufacturers provide recommendations on lifting systems for the installation of prefabricated wood assemblies. However, technical documents currently available mostly come from Europe or Canada and, to some design professionals and builders/contractors in the United States, these documents may seem incomplete or insufficiently adapted to the standard construction techniques that they use. This Chapter intends to correct that situation.

A close look at Figure 1 reveals that precast concrete construction using large concrete slabs is, in many ways, similar to the current techniques used in CLT construction. As the precast concrete construction industry is more developed and experienced, it is advantageous for CLT designers and contractors to obtain or use systems and lifting accessories adapted to this more mature industry and to build on their experience.

For example, certain systems discussed in this Chapter, which are sometimes used in CLT construction, are directly inspired by the systems used in precast concrete construction. In addition, a large amount of technical data contained in the following sections is taken from documentation developed and provided by major producers of precast concrete or by manufacturers of lifting devices specialized for use with precast concrete.

Figure 1
Lifting and handling of precast concrete elements

1.2 Lifting and Handling of CLT Elements

The emerging CLT construction industry offers various techniques for lifting and handling CLT panels so that they can be used in the erection of buildings and other structures. The complexity of the building or its location often dictates the techniques and systems to be used. Of course, erecting a 5-story building in a downtown area typically requires more preparation and precaution than a single-family residence built in the suburbs or surrounding rural country. But if that country house is to be perched high in the mountains, the techniques used may often be surprising (Figures 2 and 3).

Figure 2
Lifting and handling of CLT elements by cableway (courtesy of KLH)

Figure 3
Lifting and handling of CLT elements by helicopter (courtesy of KLH)

Figures 4 to 10 show examples of CLT panels during the lifting and handling process on construction sites. The techniques and lifting systems used are discussed in detail further in this Chapter.

Figure 4
Lifting and handling of relatively light CLT elements, in Norway (courtesy of Brendeland and Kristoffersen, Architects)

Figure 5
Lifting and handling of CLT wall elements, in Belgium (courtesy of HMS)

Figure 6
Lifting and handling of CLT elements, in Canada (courtesy of KLH ELEMENT, photo: © Marc Cramer)

Figure 7
Lifting and handling of CLT elements in an hybrid structure, in the United States (courtesy of Binderholz)

Figure 8
Lifting and handling of CLT elements, in Canada (courtesy of Nordic Engineered Wood)

Figure 9
Lifting and handling of CLT elements, in Sweden

Figure 10
Lifting and handling of CLT elements, in Norway
(courtesy of Brendeland and Kristoffersen Architects)

2 SLINGING AND FASTENING SYSTEMS FOR THE LIFTING AND HANDLING OF CLT PANELS

A variety of systems available for lifting and handling CLT panels are presented in this section. Some systems are commonly used in CLT construction. Others are for illustrative purposes, some of which are inspired by systems used in the precast concrete industry.

Many of the systems proposed use slings. A sling is a cable that connects the fastening system to the lifting device. It usually consists of textile rope, synthetic fiber woven strips, steel cables, or chains. Slings must always be calibrated (working load permitted) and validated (wear and tear) before use. Also, the inspection of all lifting devices is the responsibility of the user and must be done by qualified people.

Please refer to the applicable U.S. Department of Labor, Occupational Safety and Health Administration regulations (OSHA) for more information.

2.1 Contact Lifting Systems

Lifting systems using steel plates that provide compressive resistance on the lower face of the panels during lifting are popularly considered the safest CLT panel handling methods. However, to avoid accidents on the lower levels of the building once the panels are in place, great care must be taken when removing the system as the steel plates are usually not secured once the system is unbolted.

This lifting technique typically requires in-plant drilling to allow the insertion of dowels or threaded sleeves with nuts. This technique uses the wood's efficient strength in compression perpendicular to the grain. However, when CLT elements are intended to be visible inside the building, local repairs will be required using wooden dowels.

It is important to note that, in all cases outlined hereafter, the holes must be sealed to ensure proper air tightness and to limit the spread of sound, smoke, and fire.

The following examples describe some contact lifting systems; cutaway views are shown for simplicity and clarity.

2.1.1 Single Lifting Loop with Threaded Sleeve Used with Socket Steel Tube Welded onto Flat Steel Plate

The system, comprised of a single lifting loop with threaded sleeve, is widely used in the construction of precast concrete. The system shown in Figure 11 is a modification of the system commonly used to lift precast concrete. Instead of enclosing the welded plate socket in concrete at the plant, the socket is welded to a steel plate and inserted into a previously machined hole. The lifting loop is then screwed from above using the threaded sleeve. This system is considered simple, safe, economical, and quick to use on the construction site.

The single lifting loop used in the precast concrete industry can be reused but the contractor must verify its ongoing performance through rigorous design and a careful inspection and quality control system to ensure safety. When using this system, the recommended maximum angle (β) is 30° (see Figure 34). The use of a spreader beam can help reduce the lifting angle. It is also recommended that the radius of the hook be at least equal to the diameter of the lifting loop steel cable. When handling is completed, the two components must be removed carefully.

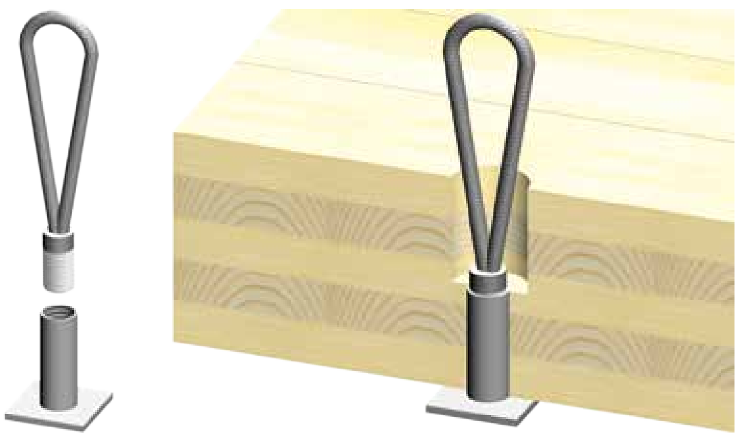


Figure 11
Single lifting loop with threaded sleeve used with socket steel tube welded onto flat steel plate

2.1.2 Articulated Lifting Loop with Threaded Sleeve Used with Socket Steel Tube Welded onto Flat Steel Plate

The system made of an articulated lifting loop with threaded sleeve also comes from the precast concrete industry and is installed in the same manner as the previous system. One advantage of this system is the ability of the steel cable to rotate in all directions around the threaded sleeve. However, the lifting angle should still be limited to 30°. When handling is completed, the two components must be removed carefully.

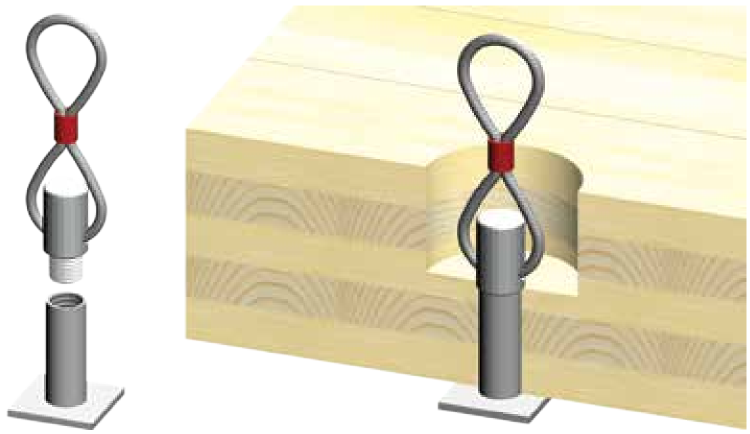


Figure 12
Articulated lifting loop with threaded sleeve used with socket steel tube welded onto flat steel plate

2.1.3 Articulated Lifting Hook with Threaded Sleeve Used With Socket Steel Tube Welded onto Flat Steel Plate

The system with articulated lifting hook and threaded sleeve used with a socket steel tube welded onto a flat steel plate also comes from the precast concrete industry. The hook allows for quick installation on the lifting system and has the ability to rotate around the steel ring. The lifting angle should still be limited to 30°. When handling is completed, the two components must be removed carefully.

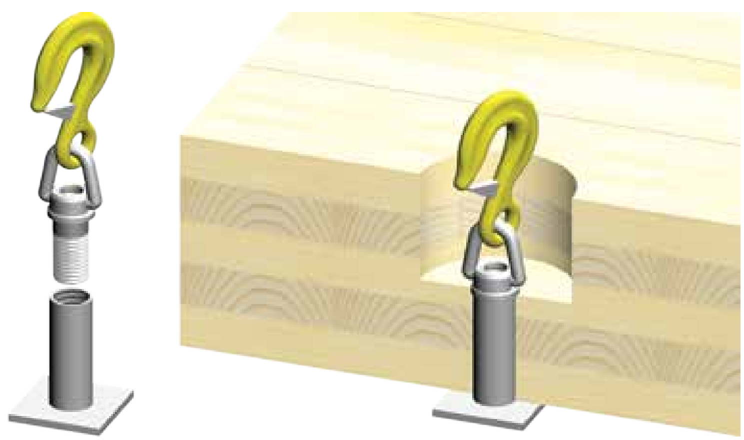


Figure 13
Articulated lifting hook with threaded sleeve used with socket steel tube welded onto flat steel plate

2.1.4 Threaded Eyelet Bolt Used with Socket Steel Tube Welded onto Flat Steel Plate

The threaded eyelet bolt used in conjunction with a socket steel tube welded onto a flat steel plate is also a good option for quick and safe lifting. However, it is important to choose the right eyelet bolt and to install it correctly (Figures 14 and 15). It is recommended to use an eyelet base bolt when lifting heavy loads at an angle. Ensure there is proper contact between the base and the wood panel. Ensure sufficient thread engagement between the eyelet and threaded sleeve. Plain or regular eyelet bolts (without base) are normally used in straight tension when lifting light loads; that is, when used with a spreader beam or with only one attachment point. Also, according to good practice, the eyelet bolts must be oriented in the same direction as the tensioned slings since the eyelet could bend under heavy oblique loads. When handling is completed, the two components must be removed carefully.

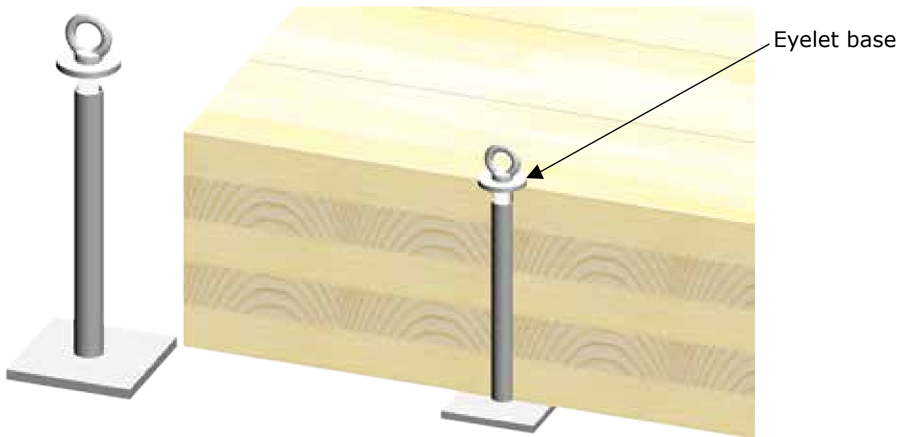


Figure 14
Threaded eyelet bolt (with base) used with socket steel tube welded onto flat steel plate

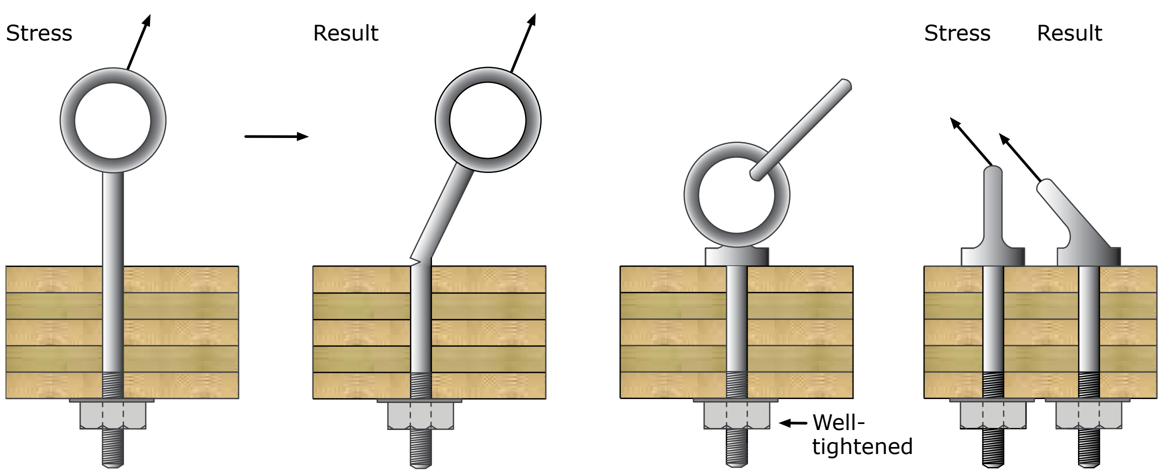


Figure 15
Correct use of threaded eyelet bolt (with and without eyelet base)

2.1.5 Threaded Eyelet Bolt Used with Steel Plate and Nut

The system using the threaded eyelet bolt in conjunction with a steel plate and nut is widely used in CLT construction. However, it is important to choose the proper eyelet bolt and to install it correctly. The use of an eyelet base bolt when lifting at an angle is also strongly recommended. Also, according to good practice, the eyelet bolts must be oriented in the same direction as the tensioned slings since the eyelet could bend under heavy oblique loads. When handling is completed, the system must be carefully removed.

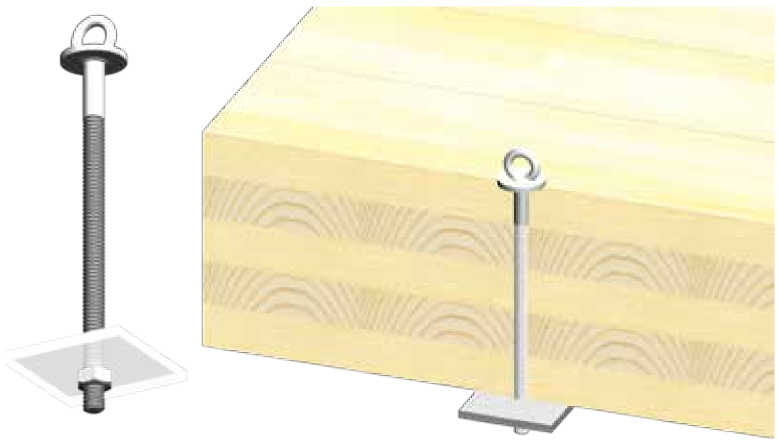


Figure 16
Threaded eyelet bolt used with steel plate and nut

2.1.6 Eyelet Used with Bolt or Threaded Sleeve and Steel Plate

The following system is similar to the system presented in 2.1.5, and the same recommendations apply. In this case, the eyelet is independent from the sleeve or bolt. It is important to use an eyelet with base when lifting at an angle. Baseless eyelets should only be used when lifting in straight tension. When handling is completed, the system must be completely and carefully removed.

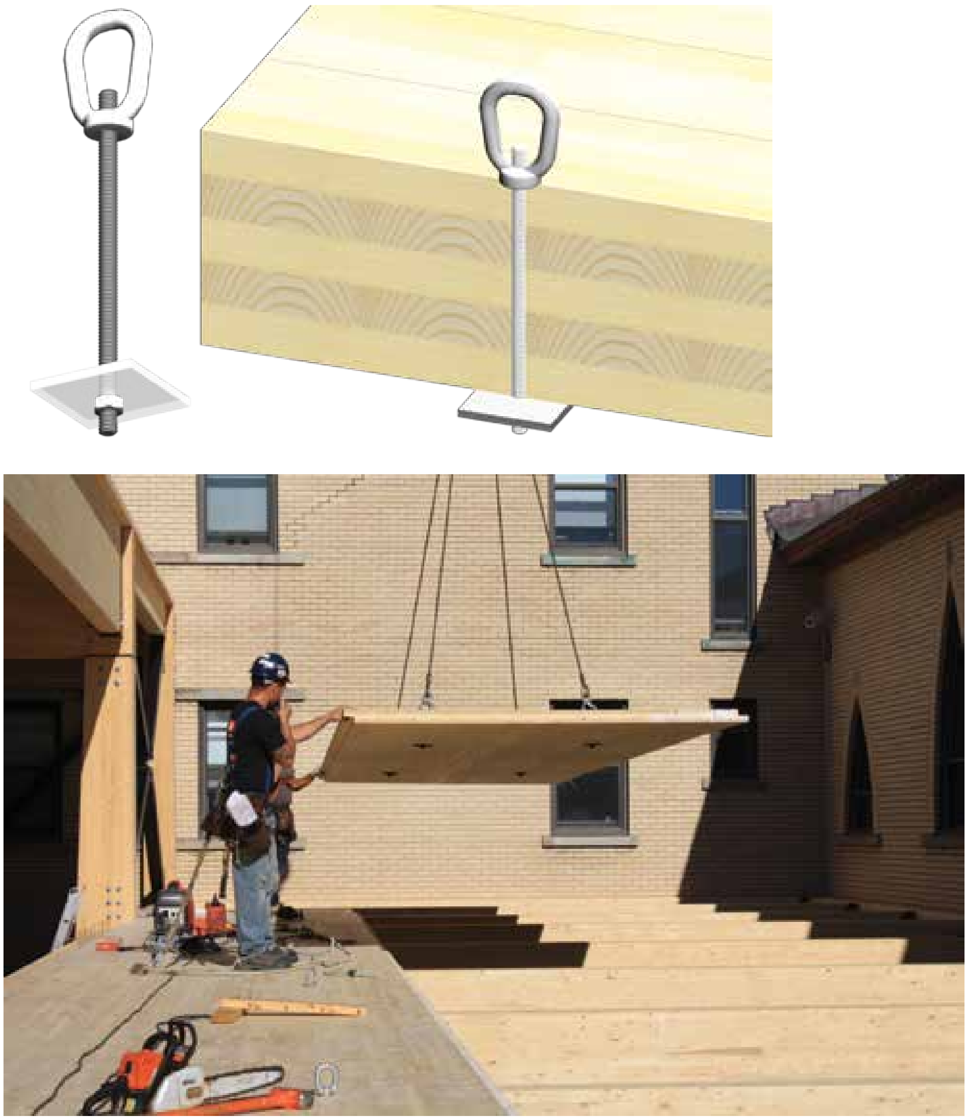


Figure 17
Eyelet used with threaded bolt or sleeve and steel plate (courtesy of Nordic Engineered Wood)

2.1.7 Threaded Eyelet Bolt, Threaded Socket, Threaded Bolt and Steel Plate

The threaded eyelet bolt can be used with a threaded socket, a bolt, or a threaded rod and steel plate. The threaded socket is normally pre-installed in the CLT plant for future use on site. On the construction site, the eyelet bolt and the single bolt or the threaded rod are easily screwed to the plate. Again, it is important to choose the right eyelet bolt and to install it correctly. When handling is completed, the two bolts and the steel plate are removed. The threaded socket remains in place for future use. For instance, adaptability and dismantling in a building, as well as repairing and upgrading operations, require the presence of elements or tools that facilitate the future handling process of building components.

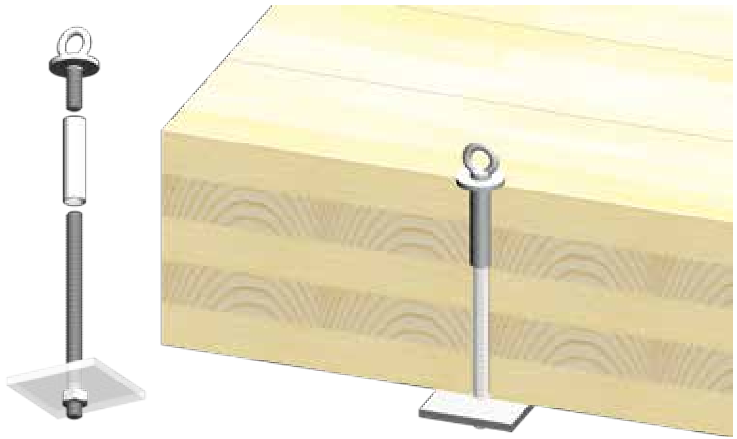


Figure 18
Threaded eyelet bolt, threaded socket, threaded bolt or sleeve and steel plate

2.1.8 Threaded Eyelet Bolt, Threaded Socket and Steel Round Rod

Another product that comes from the precast concrete construction industry can inspire a new system for lifting light CLT panels. A threaded socket with holes at the tip is inserted into the CLT slab. This socket is normally embedded in the concrete. An eyelet bolt is screwed into the socket. The lifting system is then locked with a steel round rod that is in contact with wood. When handling is completed, the three elements are removed. However, this system can leave marks on the timber and may not be suitable if the panel must remain visible on the underside. This proposed system is suitable for lightweight CLT panels only (e.g., less than ½ ton).

Figure 19
Threaded eyelet bolt, threaded socket and steel round rod

2.1.9 Soft Lifting Sling Used with Support

Another system widely used in CLT construction is shown in Figure 20. A hole is drilled into the panel usually at the plant (2~3 inches or 50~75 mm in diameter). On the construction site, a soft sling is inserted into the hole and a locking piece is used on the underside. The next figure shows a piece of dimensional lumber being used. However, it is important to ensure that the locking parts are properly fixed and will not slip during handling. This proposed system is suitable for small and lightweight CLT panels only (e.g., less than ½ ton).

Figure 20
Single lifting sling used with support

2.1.10 Soft Lifting Sling Without Support for Vertical Elements

The lifting systems presented in the previous examples are intended mainly for floor and roof slabs. For wall assemblies, a simple system requiring only one hole and a flexible sling is often used. The sling must be load rated for the panels being tilted and/or lifted. Since walls are often lighter than thick floor slabs, this system is often appropriate for tilting up, lifting, and placement of the panels. The holes must be plugged once handling is completed, especially those in the exterior walls.

Figure 21
Lifting sling without support (with hole)

2.1.11 Soft Lifting Sling Without Support for Horizontal Elements

This simple lifting system requires no holes to be drilled in the panels. However, this technique comes with a risk of instability due to the possibility of slings slipping during lifting. Also, in order to leave enough space to release the slings once the element is in place, the panels cannot be completely juxtaposed. Therefore, they must be drawn together with the appropriate tools (refer to Sections 4.3 to 4.5).

Figure 22
Lifting sling without support (without hole)

The next technique requires two holes drilled in the CLT plant for each anchor point. These holes have a diameter of approximately 2 inches (50 mm) and are relatively close together but not less than an amount equal to the thickness of the CLT panel. A soft sling is inserted as shown in Figure 23.

Figure 23
Lifting sling without support (with holes)

2.2 Screw Hoist Systems

There are several lifting techniques that rely only on the withdrawal resistance of fastenings. Although these techniques are simple and effective, they require a careful design analysis for the loads involved and strict control during installation and use. One advantage of this system is that it does not affect the wood appearance when sections must remain visible on one side. This section describes some examples.

2.2.1 Screwed Anchor

The most widely used screw hoist system in Europe is shown in Figure 24. This system is based on an anchor used in precast concrete construction. The original system uses an anchor embedded in the concrete with a protruding head to allow connection to a lifting ring.

Figure 24 shows the two components required for lifting. A self-tapping screw makes the connection between the CLT panel and the lifting ring. It is strongly recommended to use the self-tapping screw only once. The self-tapping screw is usually installed in plant by the CLT manufacturer as a recess is normally required in order to embed the fixed piece. The lifting ring must be inspected frequently to ensure safety. This system can be installed on both the top and side of the panels. It is important to refer to the manufacturer's technical data in order for the design professional to determine the allowable loads and for usage and installation specifications.

Figure 24
Lifting system with self-tapping screw

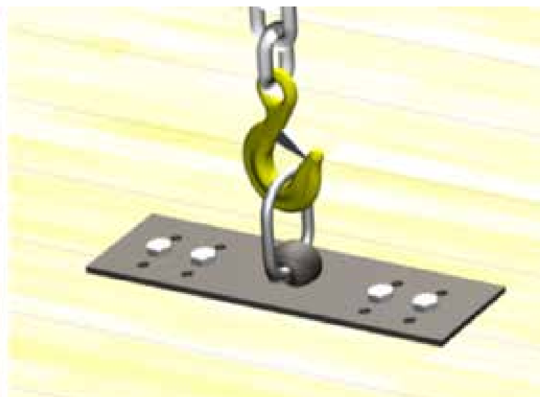
Figure 25
Screwed anchor

2.2.2 Screwed Plate and Lifting Ring

There are various lifting systems using screws or lag screws in combination with steel plates with holes. Figure 26a shows a system that uses only two self-tapping screws. This system offers very little flexibility in terms of allowable capacity.

However, it is possible to increase the number of screws in order to increase its lifting capacity. Figure 26b shows a much more flexible system. The plate has sufficient pre-drilled holes to accommodate several lag screws or wood screws. Thus, the plate provides the design professional in charge of designing the lifting systems with much more flexibility since the same plate can be used repeatedly. The steel plates, lifting ring, and lag screws should be checked regularly to ensure they have not been damaged during previous uses. Figure 26c shows a light panel being lifted. Lag screws should only be installed in a properly sized lead hole (see National Design Specification (NDS) for Wood Construction for more information) and care must be taken during installation of the lag screws to prevent stripping out of the wood. When pneumatic or electric tools are used to drive lag screws, proper calibration and maintenance of torque-limiting clutch systems is essential.

a)



b)

c)

Figure 26
Screwed plate and lifting ring (courtesy of Tergos)

2.2.3 Double-threaded Socket with Eyelet Bolt or Lifting Loop with Threaded Sleeve

Another lifting method consists of using a double-threaded socket (i.e., threaded inside and outside) together with an eyelet bolt or lifting loop. This system is screwed in plant into the panel. Similar to a lag screw, a hole with a diameter equal to 75 ~ 90% of the socket diameter must first be drilled in the wood. It is important that the design professional refers to the manufacturer's technical data to determine the acceptable installation and usage of these proprietary lifting systems.

On the construction site, the eyelet bolt (or lifting loop with threaded sleeve) is installed for lifting. Once handling is completed, the bolt is removed. The double-threaded sleeve remains in place for future use. This system can be installed on both the top and side of the panels. It is important to refer to the manufacturer's technical data to determine the allowable loads and for usage specifications.

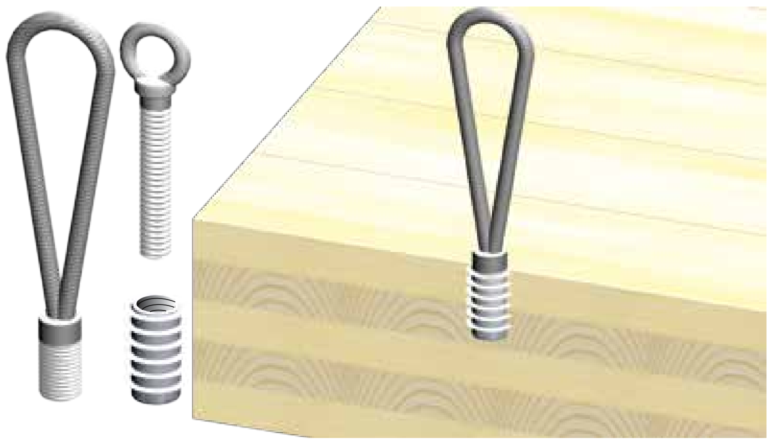


Figure 27
Double-threaded socket with eyelet bolt or lifting loop with threaded sleeve

2.2.4 Innovative Lifting System with Wood Screws and Eyelet Bolt

Some manufacturers may offer other innovative anchoring systems. An example is shown in Figure 28. Wood screws are used to screw the cylindrical steel component to the panel. This piece is usually attached on the top of the panel. However, a recess can be performed into the panel at the CLT plant in order to embed the fixed piece, thus allowing stacking of the panels during transportation. It is important to refer to the manufacturer's technical data to determine the allowable loads and for usage specifications. Again, it is important that the design professional refers to the manufacturer's technical data to determine the acceptable installation and usage of these proprietary lifting systems.

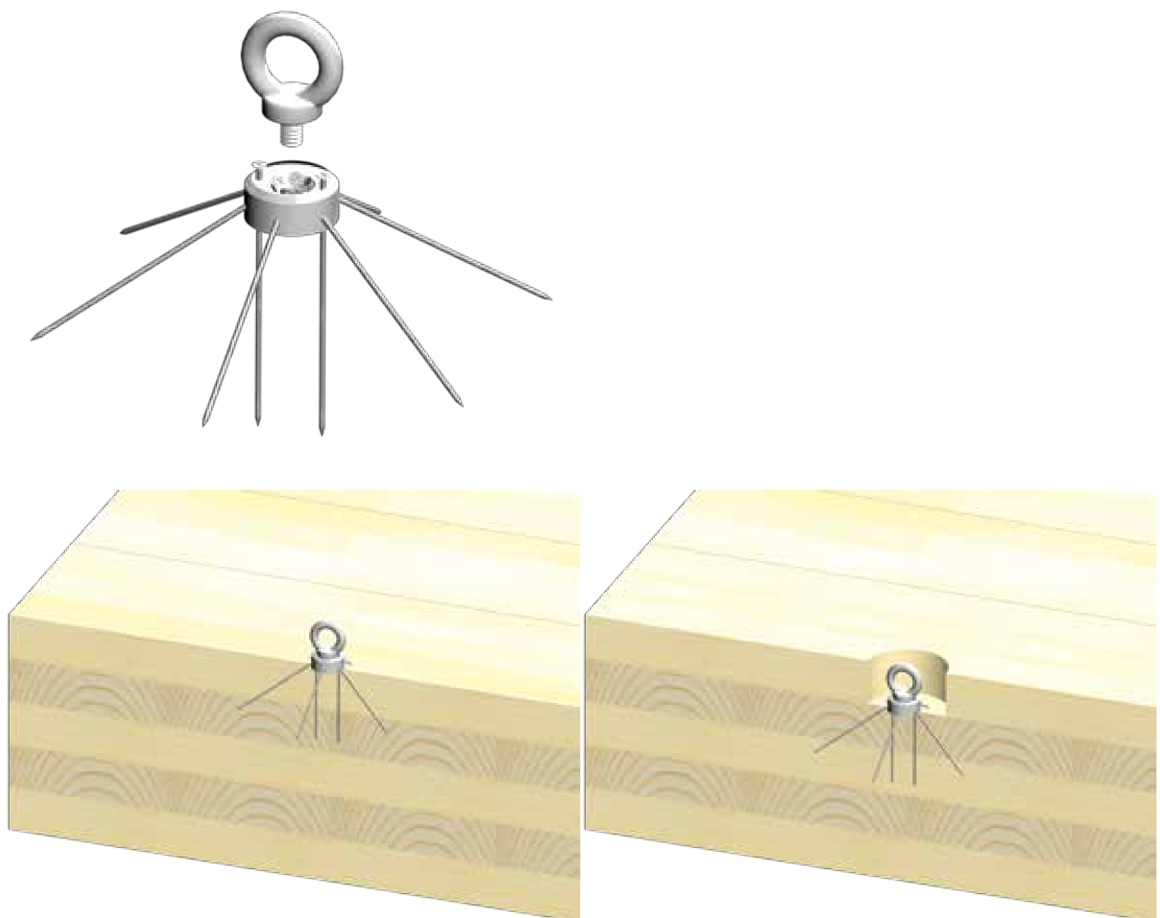


Figure 28
Innovative lifting system with wood screw (with or without recess)

2.3 Integrated Lifting Systems

The principle of using plant-integrated support parts lends speed to jobsite execution on construction sites. These systems are simple and safe. In addition, if the ceilings of buildings should remain visible, no major repair is required. However, it is better to seal the holes to ensure air tightness and to limit the spread of sound, smoke, and fire. Some examples are given in this section.

2.3.1 Inserted Rod with Soft Sling

This technique is frequently used in Europe and Canada. It consists of first drilling one hole on the top of the panel a few inches from the edge depending on the dowel bearing strength of the CLT panel (see Chapter 5). This hole, which has a diameter of about 2~3 inches (50~75 mm), is drilled at the plant by a CNC machine at a depth equivalent to about one half to two thirds of the thickness of the panel. Then, using a long drill, a hole is drilled on the side facing the axis of the hole made on the top of the panel. A steel rod with a diameter equal to that of the hole is then inserted into the hole. It is possible to use smooth rods or steel reinforcing bars. Upon insertion of the rod, a soft sling is installed and held by the rod (at the plant). The sling should be able to be positioned within the hole for easy stacking during transportation. Once the lifting and handling steps have been completed, the sling is either cut or inserted into the hole for future use. Figure 29a shows the first system.

(a)

Figure 29b shows a similar system. However, instead of drilling a hole, a groove is made on the top of the panel a few inches from the edge. The alteration is performed using a CNC machine at the plant at a depth equivalent to about one half to two thirds of the thickness of the panel. Then, using a long drill, a hole is drilled on the side. A steel rod with a diameter equal to that of the hole is then inserted into the hole. Once the panel is on the construction site, a soft sling is simply slipped under the rod; this sling can be removed once the panel is positioned. The steel bar remains in place and the hole should be sealed.

b)

Figure 29
Inserted rod with soft sling

2.3.2 Inserted Rod with Lifting Hook

The next system is once again inspired by the precast concrete construction industry. This method consists of drilling one hole on the top of the panel (re-entrant), a few inches from the edge depending on the dowel bearing strength of the CLT panel used (see Chapter 5). The diameter of this hole must be large and deep enough to allow insertion of a lifting hook, as shown in Figure 30. Then, with a long drill, a second hole is drilled at the plant using a CNC machine on the side facing the axis of the hole made on top of the panel. A steel rod with a diameter equal to that of the hole is then inserted into the hole. Once the panel is on the construction site, the hook is attached to the rod for the lifting and handling phase. The steel rod remains in place and the hole should be sealed.

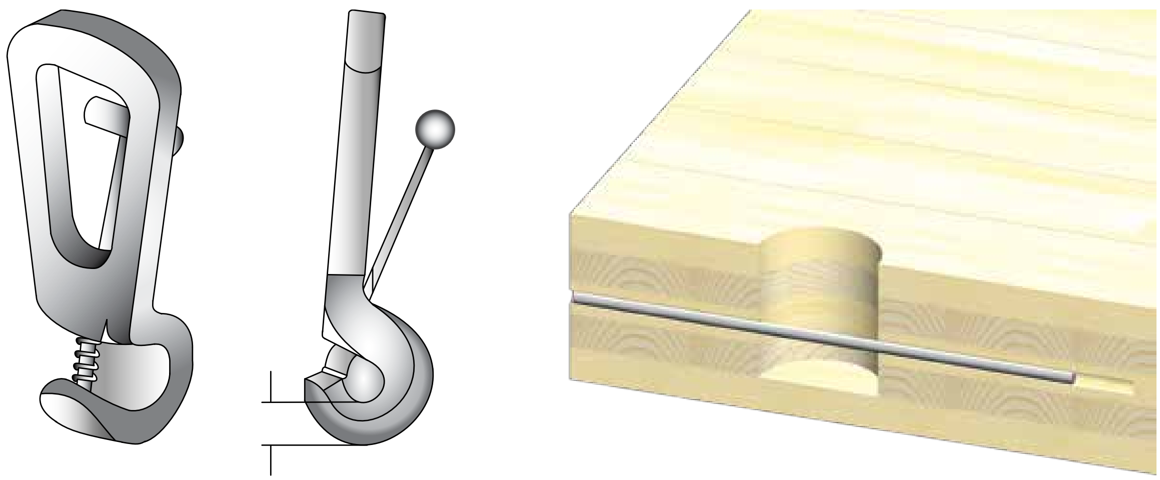


Figure 30
Inserted rod with lifting hook

3 GENERAL PRINCIPLES FOR LIFTING AND HANDLING CLT ELEMENTS

There are several types of lifting equipment that can be used on construction sites. Each has its own characteristics for lifting and handling heavy loads such as CLT panels. It is therefore essential to choose the right lifting and handling system for each type of component.

It is also of the utmost importance that lifting equipment be positioned and operated properly. Several criteria must be verified and validated prior to and during work on site. Design professionals and contractors/builders in charge of a construction project involving CLT panels need to consider certain important points. Some recommended considerations are presented in the following sections.

3.1 Lifting Station and Devices

The lifting station is undoubtedly a key location on the construction site. The lifting device must be selected and positioned according to several criteria. Certain construction sites may require more than one lifting device and some sites may need to change the type of device being used during the construction phase.

Here are some of the elements to be considered when choosing a lifting device. The device must, without limitation:

- Be able to lift all required loads for the duration of construction:
  - Types of loads may vary on the same construction site;
  - If possible, the lifting device should not be moved. However, the lifting device should be capable of being moved as jobsite and erection conditions require;
- Reach appropriate height and distance with required maximum load:
  - Appropriate range must be attained for all required distances, from point A to point B;
  - The travel path of the element to be lifted to reach the desired location must be clear of any obstacles;
- Be efficient, be able to maintain the needed working pace and be flexible, while keeping safety first.

In addition, consideration must be given to the type of land upon which the construction will be done, as well as the immediate surroundings. To avoid unplanned consequences, it is strongly recommended to inspect the site before choosing the type of device.

The grounds (slopes, streams, etc.) and the soil's bearing capacity (sand, clay, etc.) are important points to consider. As well, the stability of the operating devices must be maintained at all times. For example:

- A crane can collapse under the weight of excessive load;
- The ground can degrade under the device's bearing points;
- A device that is too close to a slope can become unstable and tip over;
- The device's range may allow it to come into contact with obstacles (e.g., buildings, trees, a second crane, power lines, etc.).

Despite all precautions that can be taken, accidents may occur. Thus, it is strictly forbidden to handle loads directly above workers or the public. Also, to avoid serious accidents, the worker in charge of positioning the slings should never stand between the load to be lifted and a fixed object, in case of load instability or improper operation during lifting. Other safety-related recommendations are available from regulatory authorities (please refer to the applicable U.S. Department of Labor, Occupational Safety and Health Administration regulations (OSHA) for more information).

3.2 Determining the Weight and Center of Gravity of CLT Elements

Before choosing the proper lifting system, it is important to know the total weight of the element to be lifted, as well as the position of its center of gravity. The whole weight of the load is considered concentrated at this center of gravity.

Although density of wood greatly varies depending on wood species (specific gravity) and moisture content, i.e., between 20 and 45 pound per cubic foot (320 and 720 kg/m^3) (Wood Handbook, 2010), it is recommended to use an average density varying between 25 and 37 pound per cubic foot (400 and 600 kg/m^3) for the calculation of the total weight of CLT elements made of softwood lumber. Note that this density is about five times lower than the density used for precast reinforced concrete elements, which is usually about 150 pound per cubic foot (2400 kg/m^3). Nevertheless, the total weight of CLT elements can be considerable. As an example, a 8 feet x 52 feet x 1 foot (2.4 m x 16 m x 300 mm) thick CLT slab weighs about 12,000 pounds (≈6 tons). We suggest verifying the CLT panel weights with the manufacturers as they will vary by species used. The following section illustrates how to calculate the weight of a CLT panel.

The total weight of a CLT slab is simply calculated as follows:

$$P = V \times \rho_{CLT} \quad [1]$$

$$V = b \times L \times h \quad [2]$$

where:

$P = CLT\ slab\ weight\ (lb.)$

$V = Volume\ of\ slab\ to\ be\ lifted\ and\ handled\ (ft.^3)$

$b = Slab\ width\ (ft.)$

$L = Slab\ length\ (ft.)$

$h = Slab\ thickness\ (ft.)$

$\rho_{CLT} = CLT\ slab\ average\ density\ (25 \sim 37\ lb./\ ft.^3)$

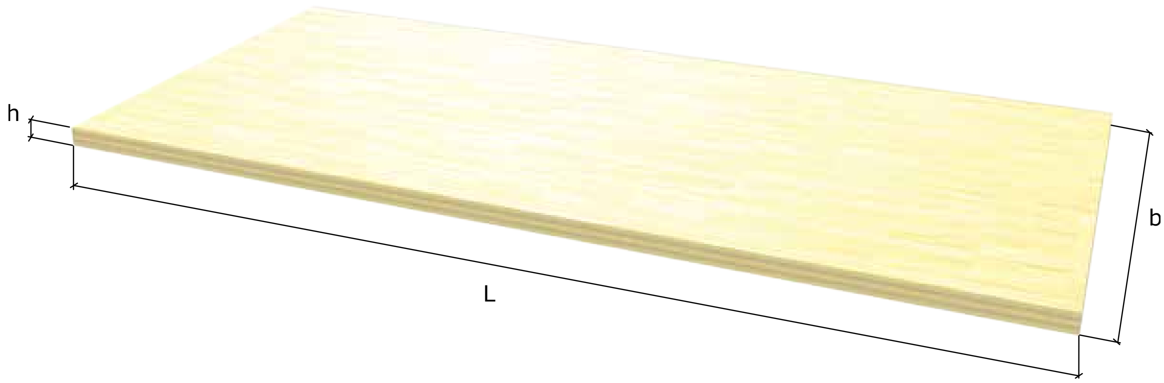


Figure 31
Calculating the weight of a CLT slab

3.3 Dynamic Acceleration Factors

3.3.1 Lifting System Used

During lifting and handling maneuvers, elements are subject to dynamic forces that must be taken into account. These forces mainly depend on the chosen system, the lifting speed, and the type of ground on which the elements are being handled.

Table 1 provides an overview of suggested lifting and handling dynamic acceleration factors for specific devices used in construction. These factors should be taken into account for the calculation of forces.

IMPORTANT: Note that the tabulated values are provided for informational purposes only. It is important to refer to normalized values, if any, as provided by the relevant authorities (e.g., States, federal, local, etc.).

Table 1
Dynamic acceleration factors (f)

Lifting Device	Dynamic Coefficient of Acceleration f
Fixed crane	1.1 ~ 1.3
Mobile crane	1.3 ~ 1.4
Bridge crane	1.2 ~ 1.6
Lifting and moving on flat terrain	2.0 ~ 2.5
Lifting and moving on rough terrain	3.0 ~ 4.0 and +

Source: FPInnovations, CLT Handbook, Chapter 12

3.3.2 Other Effects to Consider

Wind can significantly increase forces in lifting systems. CLT manufacturers, contractors and design professionals in charge of a project should consider such loads in their calculations based on the surface in contact with the wind as well as the location and height of assemblies requiring lifting.

However, it is normally unwise to lift loads when weather conditions are deemed dangerous. Prefabricated CLT elements are subject to wind movement and this phenomenon should not be underestimated.

The use of guide ropes is recommended to prevent rotation of assemblies during lifting.

Finally, it is recommended that each lifting job be performed in a single operation or in compliance with the (sequence of) operations intended by the engineer.

3.4 Asymmetrical Distribution of Load According to Center of Gravity

It is always better to fix anchors in a way to limit the eccentricity due to the center of gravity of the element to be lifted. If anchors are asymmetric with regard to the center of gravity, forces will not be equally distributed during lifting and must be calculated accordingly. Tensile and shear forces must be calculated for each component to be lifted, or the most critical elements must be taken into consideration.

Furthermore, to limit the tilt and sway of panels during lifting and handling, it is possible to use a spreader system. Simply align the center of gravity of the element as calculated exactly facing the hook installed on the spreader beam to prevent rotation. Figure 32 shows the appropriate method. However, if the lifting of an element is done without a spreader beam, which is often the case in CLT construction, it is important to check the balance of the load when lifting. Wind can also swing and spin the load.

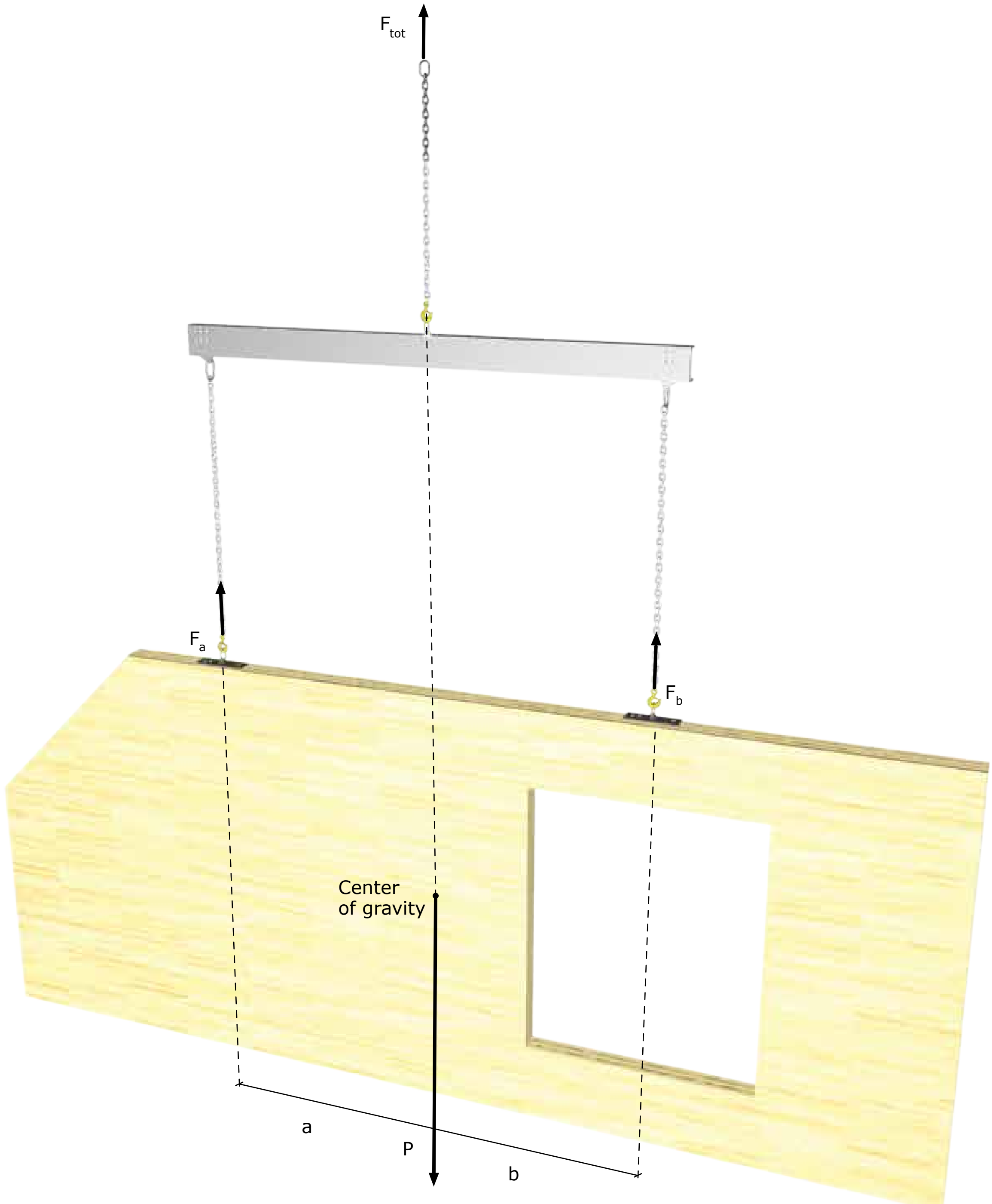


Figure 32
Element lifted with a spreader system

For example, the next equations are used to calculate forces in two anchors placed asymmetrically to the center of gravity of an element that is being lifted with a spreader system. The center of gravity required for determining measures "a" and "b" may be given by the CLT manufacturer when CAD software and CNC machines are used.

$$F_a = \frac{P \times b}{(a + b)} \qquad [3]$$

$$F_b = \frac{P \times a}{(a + b)} = P - F_a \qquad [4]$$

3.5 Determining Forces According to Lifting Angles

When a spreader system, similar to that shown in Figure 32, is not used for lifting assemblies, it is necessary to adjust forces in the anchors by taking into account the lifting angles. In this case, the inclination angle of the cables or slings will vary depending on their length.

The adjustment is done by evaluating the coefficient of angle z. A range of coefficients z is presented in Table 2 according to the inclination angle β. Refer to Figure 34 for more details about angles. These coefficients are used in the Equation 5 presented later in this Chapter.

Table 2
Coefficient of lifting angle (β)

Cable Angle β (1)	Angle α (2)	Angle Coefficient z (3)
0°	0°	1.000
7.5°	15°	1.009
15°	30°	1.035
22.5°	45°	1.082
30°	60°	1.155
37.5°	75°	1.260
45°	90°	1.414
52.5°	105°	1.643
60°	120°	2.000

(1) It is strongly recommended to limit β to 30°
(2) $\alpha = 2 \times \beta$
(3) $z = 1/\cos \beta$

3.6 Determining Load Distribution According to the Number of Effective Anchors (Suspension in Several Effective Points « N »)

It is common practice to use only two anchor points when CLT wall or beam elements are handled on the construction site. In these cases, it is normally sufficient to determine forces in the two anchors (N = 2) according to the position of the center of gravity, the lifting system, and the lifting angle.

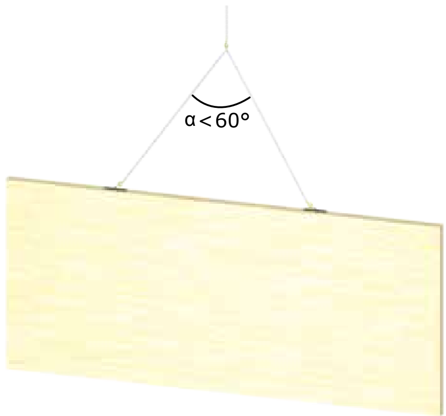
However, for floor and roof slabs, or for long wall assemblies, the use of three or four anchors is generally required. Thus, if more than two anchors are used, it may be impossible to accurately determine the load applied to each anchor, even when anchors are positioned symmetrically to the center of gravity. Indeed, there is no guarantee that the load will be perfectly symmetrical to the center of gravity or that the slings will be exactly the same length. It is therefore strongly suggested to correctly establish the maximum forces by using only two effective anchors (N = 2).

In special cases, for example, when the loads are not precisely known, or the element is irregular in shape, each anchor should be calculated so as to be capable of supporting the total load of the assembly (N = 1).

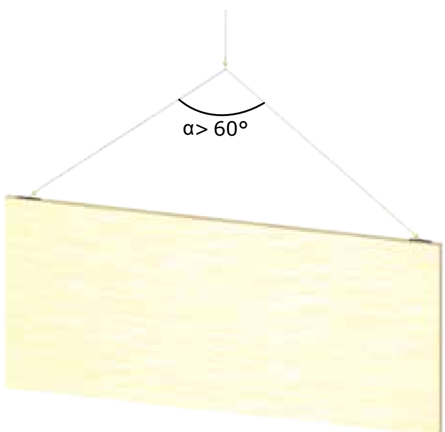
Furthermore, to ensure proper distribution of forces in each anchor considered to be effective, it is important to use systems with minimal friction. The use of free spreaders, pulleys, or shackles helps reduce unwanted friction.

Note that, in all cases, it is recommended not to use excessively long slings so as to avoid instability or to create high angles when lifting. Also, if assemblies that require lifting and handling are too long, the use of a spreader system might be a better option, as it will limit the length of the slings.

Figures 33 to 40 present typical cases of CLT element lifting and the number of effective anchors suggested in the calculations.



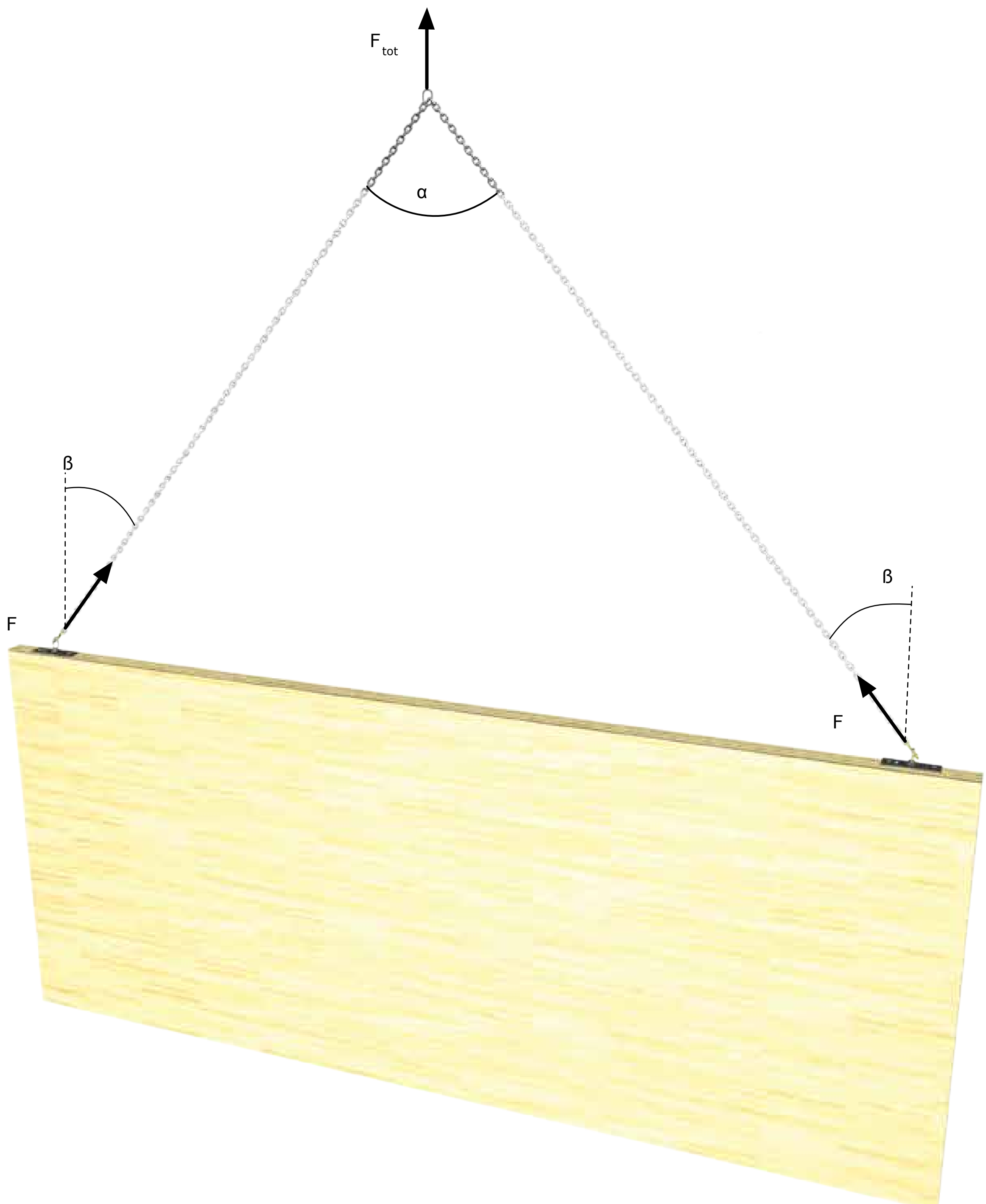
Proper angle



Angle too sharp

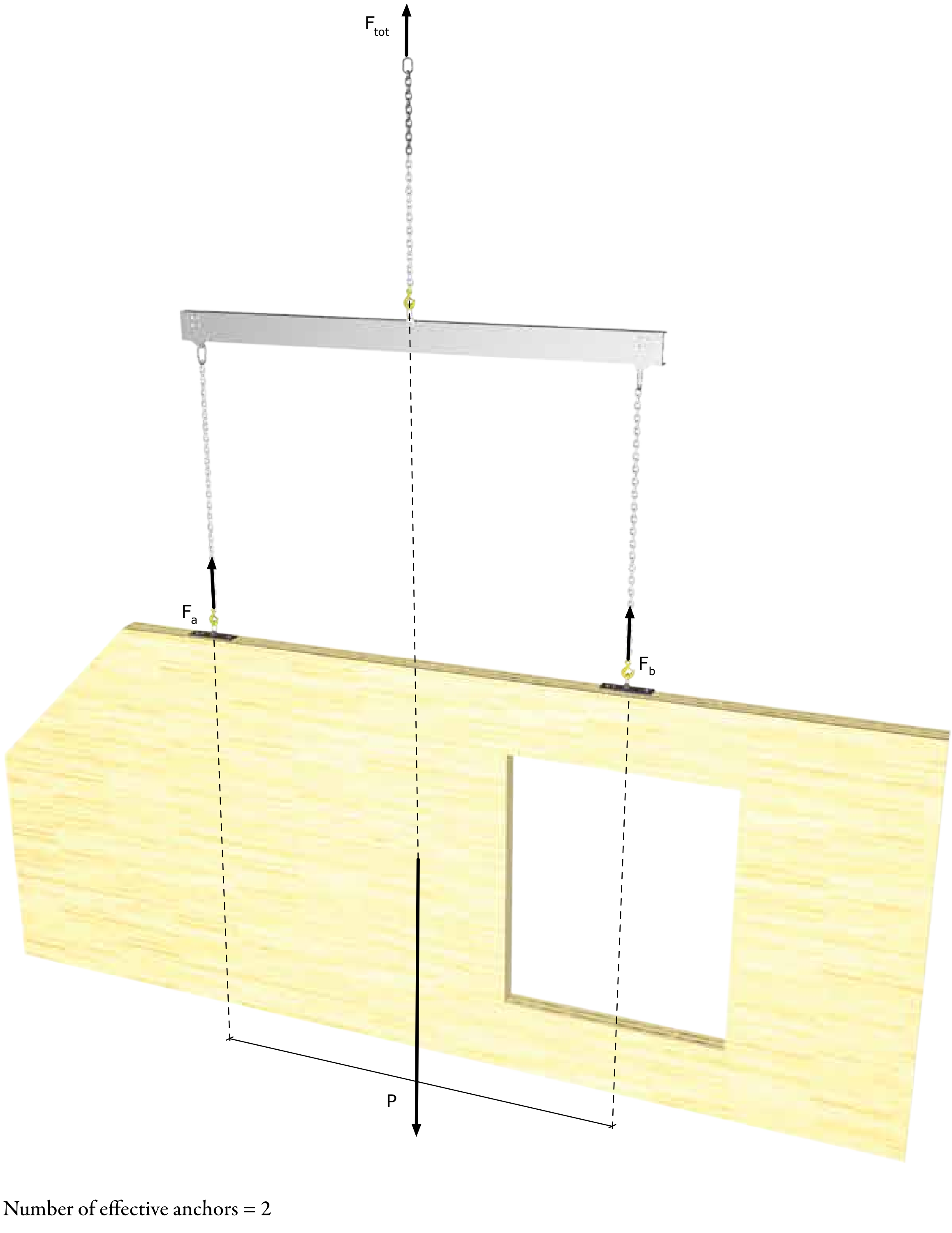
Better performance using spreader

Figure 33
CLT wall lifted with two slings symmetrically positioned – good and bad practices



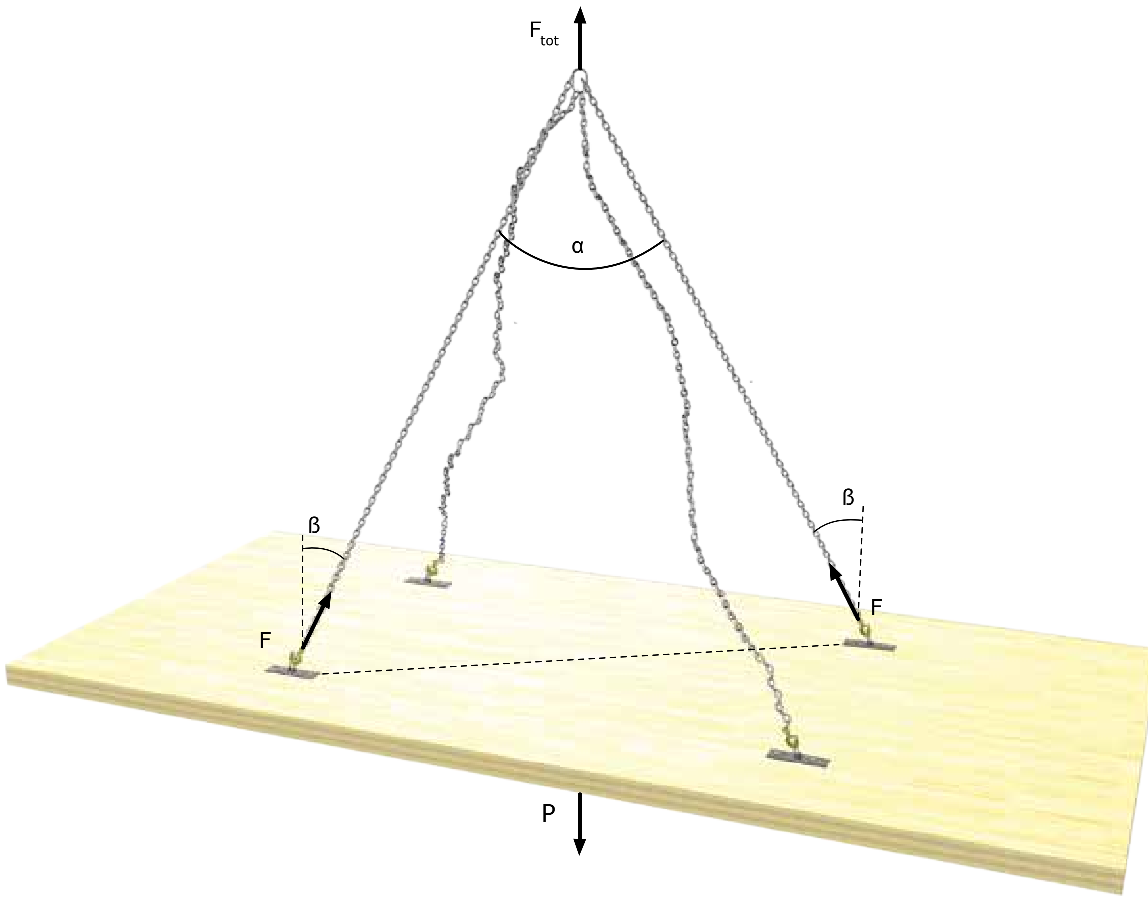
Number of effective anchors = 2

Figure 34
CLT wall lifted with two slings symmetrically positioned with F_{tot} in line with the center of gravity (N = 2)



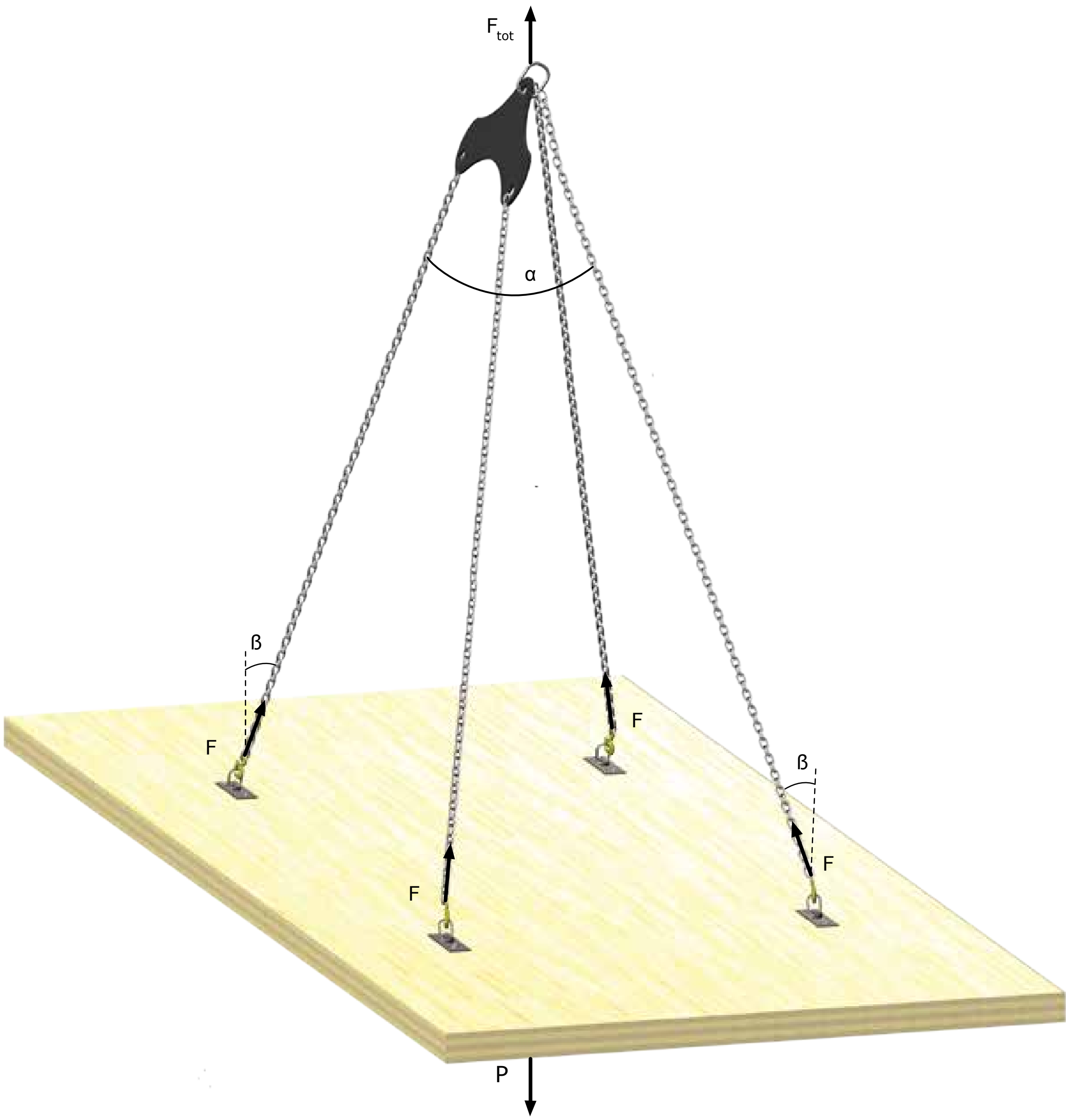
Number of effective anchors = 2

Figure 35
CLT wall lifted with two slings asymmetrically positioned with F_{tot} in line with the center of gravity, with single spreader (N = 2)



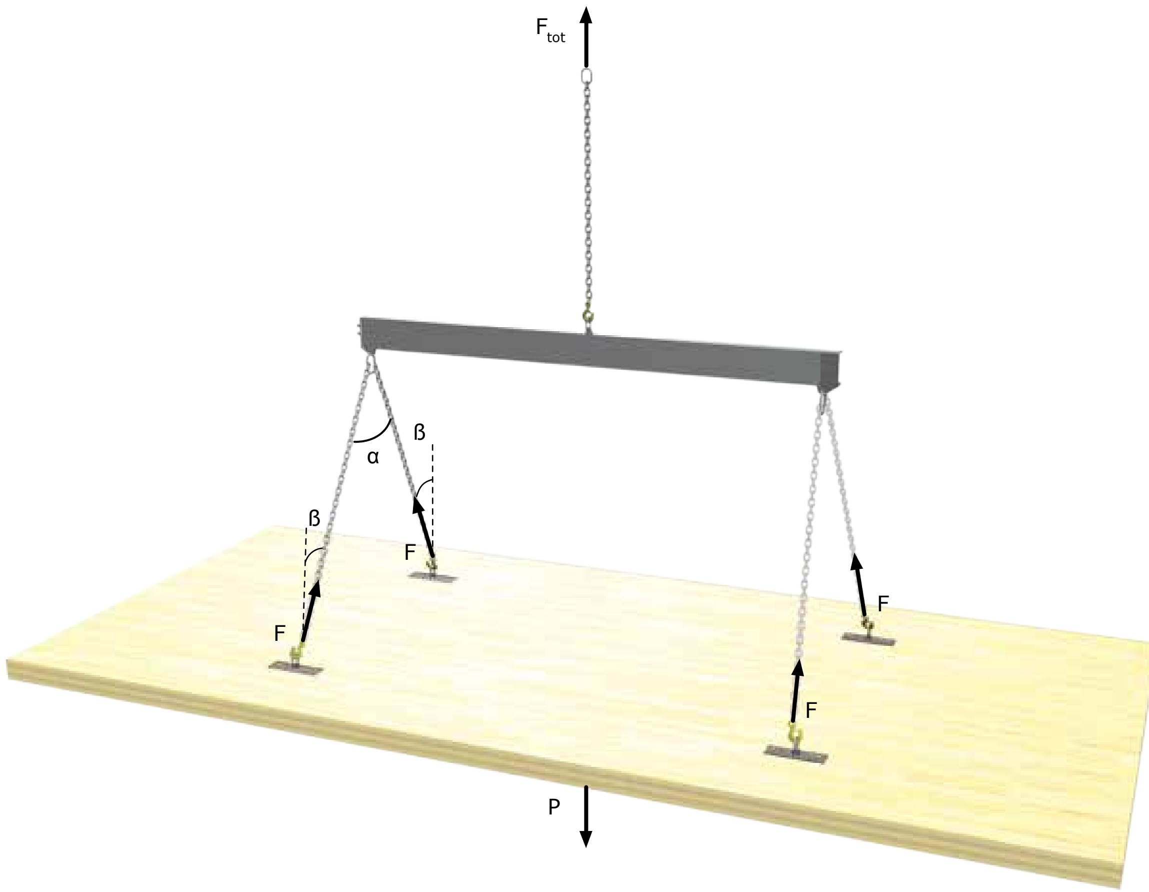
Number of effective anchors = 2

Figure 36
CLT slab lifted with four slings symmetrically positioned to the center of gravity, without spreader and without compensation system (N = 2)



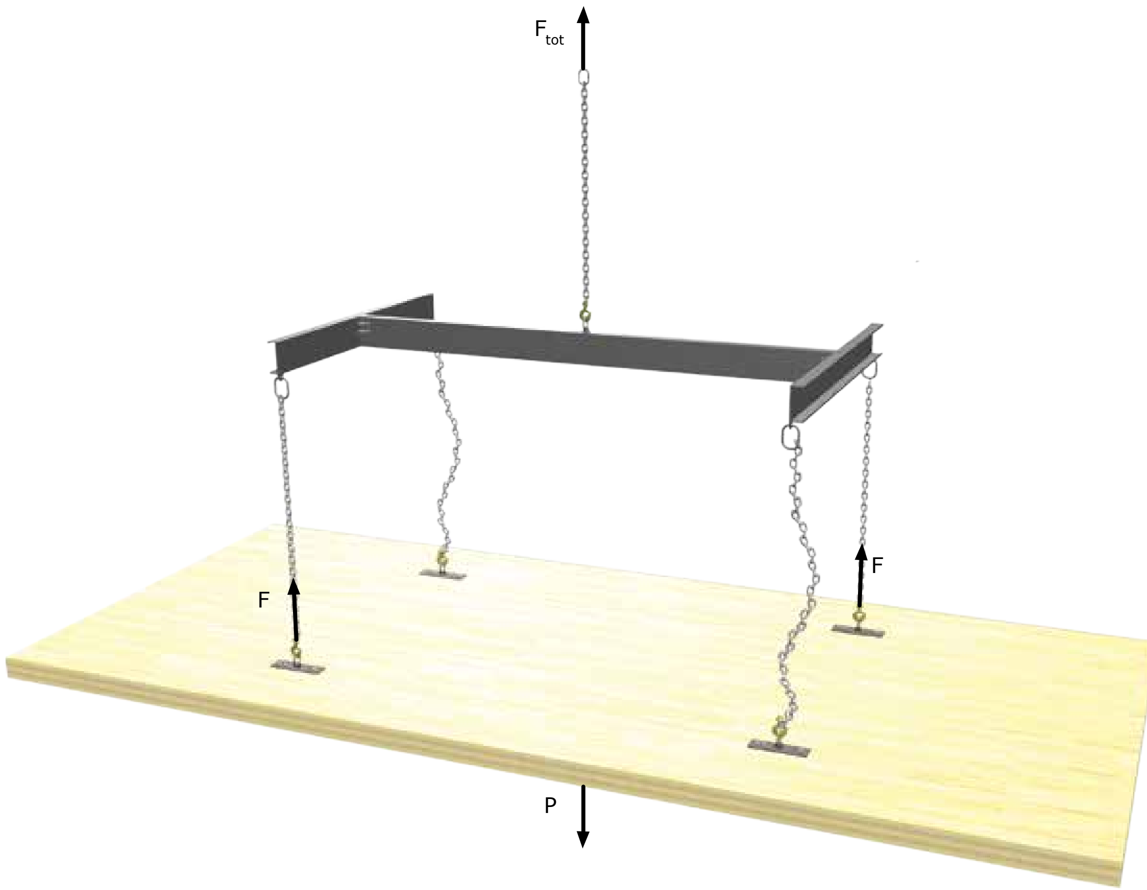
Number of effective anchors = 4

Figure 37
CLT slab lifted with four slings symmetrically positioned to the center of gravity, with compensation system (N = 4)



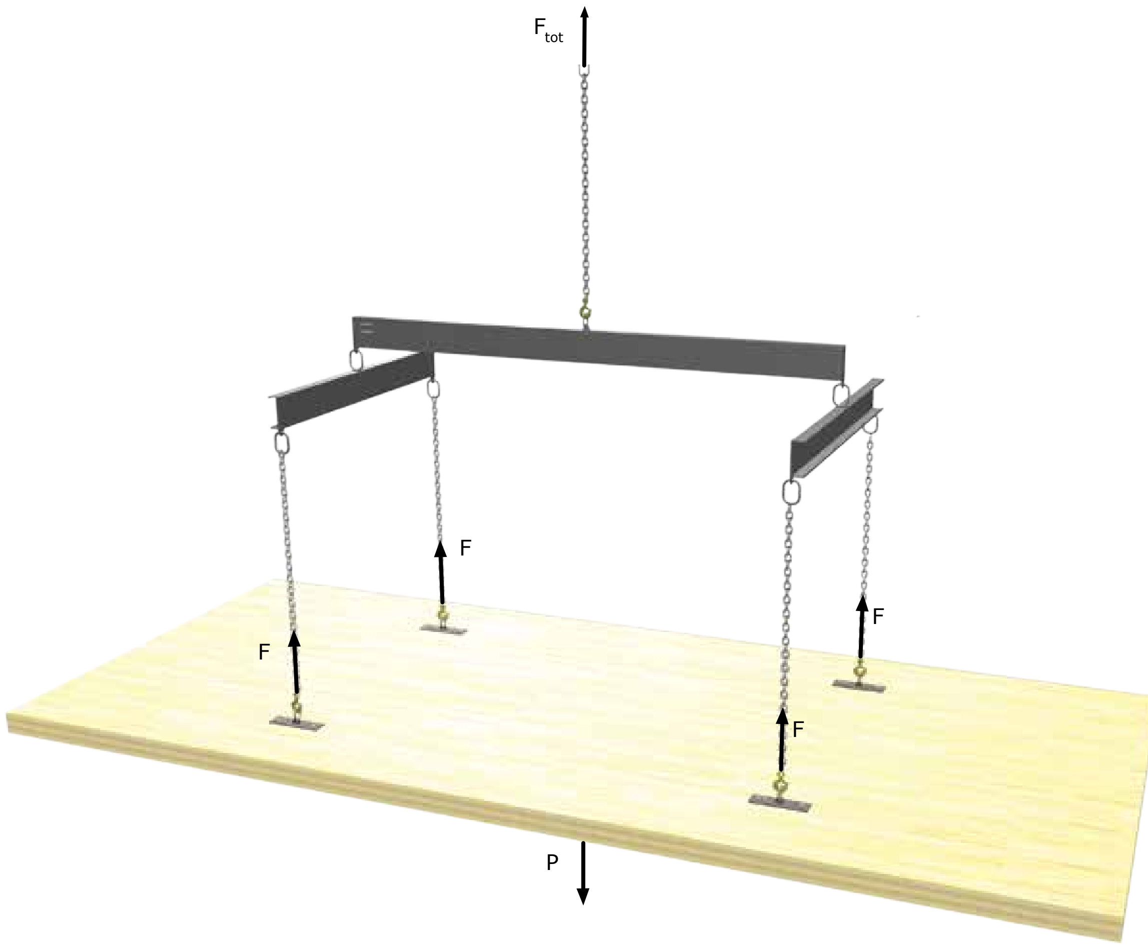
Number of effective anchors = 4

Figure 38
CLT slab lifted with four slings symmetrically positioned to the center of gravity, with single spreader (N = 4)



Number of effective anchors = 2

Figure 39
CLT slab lifted with four slings symmetrically positioned to the center of gravity, with single spreader, with three fixed spreaders (N = 2)



Number of effective anchors = 4

Figure 40
CLT slab lifted with four slings symmetrically positioned to the center of gravity, with single spreader, with three free spreaders (N = 4)

3.7 Calculation of Forces Resulting from Lifting with Anchors

The maximum forces resulting from lifting using anchors must be evaluated at each stage of lifting and handling. The maximum unfavorable value will determine the design of the lifting systems.

For example, different lifting systems can be used in the plant and on site (e.g., travelling crane in the plant vs. stationary crane on construction site). Furthermore, a component can be raised and handled in several stages and with slings of different lengths. Also, if the same lifting systems are used more than once during handling between the plant and its final destination, it may be required to use an oversize anchor to accommodate the effects of repetition.

For loads that require lifting with slings placed symmetrically to the center of gravity, force per anchor is calculated as follows:

$$F_i = \frac{F_{tot} \times f \times z}{N} \qquad [5]$$

where:

F_i = Resultant anchor force (lb.)

F_{tot} = P=Total weight of assembly to be lifted (lb.)

f = Dynamic acceleration factor (Table 1)

z = Angle coefficient (Table 2)

N = Number of effective anchors (see Figures)

Finally, tensile and shear stress in anchors can be established based on the lifting angle. The anchoring system can then be correctly designed by the design professional or by the manufacturer.

Important notes:

- If anchors are not symmetrical to the center of gravity, the resultant forces must be adjusted by using the appropriate static equations (see Equations [1] and [2]).
- Other effects such as wind may significantly influence load movement on lifting systems.
- If the same lifting system if used more than once during the same handling/lifting operation, it may be necessary to adjust the allowable anchor capacity to account for previous stressing of the system.
- It is important to ensure that the calculated and provided capacities of anchorage systems are compatible.
- Laboratory tests may be required (e.g., when proprietary lifting devices are used).

4 OTHER ACCESSORIES AND MATERIALS

Numerous construction accessories and materials are required on a construction site. In this section, in addition to items and tools normally required in conventional wood construction, we suggest the following products, tools, and accessories that may be useful or essential on a construction project using CLT panels.

4.1 Fire-resistant "Rope" (Fibrous Caulking Material) and Joint Sealing Tapes

To ensure proper sealing of CLT panel joints (i.e., floor-to-floor or floor-to-wall joints), it is recommended to use products that are specifically intended for this purpose. There are a variety of acceptable products on the market.

Typically, the proposed products should perform the following in-service functions:

- Help reduce sound transmission through floors and walls;
- Ensure effective protection against fire and hot combustion gasses;
- Improve energy efficiency by reducing heat loss and by limiting air flow (for CLT elements that are part of the enclosure).

Intersecting fire resistance rated assemblies may need to have the joints or intersection protected by a fire resistance joint system complying with ASTM E1966.

Fire

Fire-resistant materials used to seal joints and openings are typically flexible. Some products are made from noncombustible mineral fiber inserted into a fiberglass wire netting. These materials must provide effective protection against fire and hot combustion gases.

Acoustics

Acoustic membranes or tapes are specially designed and formulated to effectively stop sound transmission between walls and partitions. Some suppliers also indicate that the tapes are used to control the vibrations of floor slabs (damping).

Air

To ensure air tightness, polyethylene foam-type products are often used on concrete foundation joints and on the roof. Other types of membranes (e.g., rubber-based) can be used.

Figures 41 to 43 show some examples of tight joints between CLT elements.

Figure 41
Sealing joint between floor, wall, and connectors

Figure 42
Joint between floor and wall with semi-rigid membrane

Figure 43
Joint between two floor slabs with flexible membrane

4.2 Adjustable Steel Shoring

During frame assembly, it is crucial to have the right tools at hand. Figure 44 shows adjustable steel shoring for assuring that walls are plumb. Shoring can be adjusted with screws or with steel dowels that can be placed at frequent intervals. This instrument is essential to ensure a precise angle of installation. The fastening at both ends is done with screws. If the CLT panels are to remain visible, repairs may be required when the operation is complete.

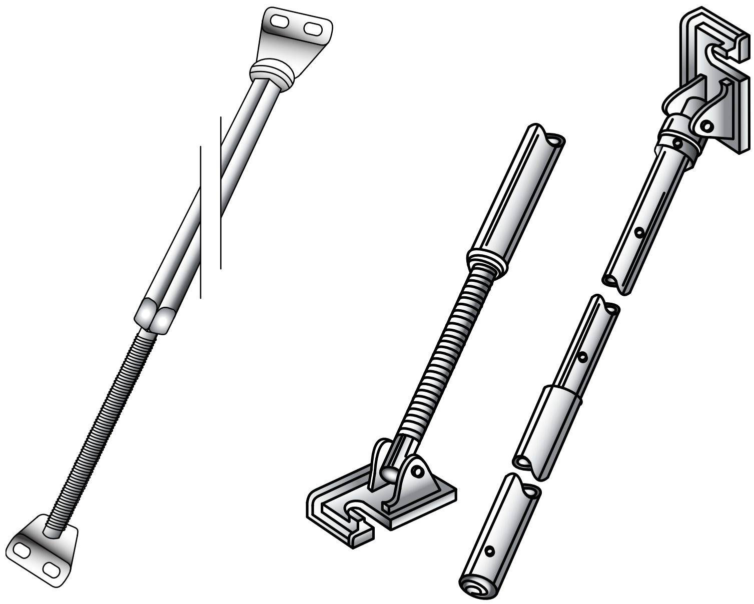


Figure 44
Adjustable shoring for walls

4.3 Beam Grip with Ratchet and Hooks

Figure 45 shows a beam grip with ratchet and hooks. This instrument is primarily used to bring the CLT panels together once they are supported and juxtaposed. It is necessary to use this type of instrument to ensure that there is proper contact between wall, floor, or roof panels. Figure 45 shows a beam grip being used to bring two floor panels together. It can be noticed that the forged hooks have been driven in line with the exterior walls that will be subsequently installed. If the floor must remain visible, it is essential to position the beam grip strategically so as not to mark the wood.

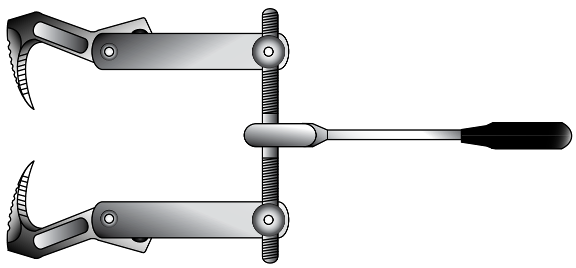


Figure 45
Beam grip with ratchet and hooks

4.4 Beam Grip with Ratchet and Screw Plate

The beam grip can also be used to ensure proper contact between two panels that are installed perpendicularly. Instead of hooks, the beam grip is used with two perforated plates. The beam grip is screwed onto the CLT wall and roof elements. The clamping is then performed and the panels are screwed to one another using self-tapping screws or other systems (refer to Chapter 5 for more information). Tightening will ensure proper contact between the elements to limit air infiltration and sound transmission. Note in Figure 46 the weatherproofing membrane used at the junction of the panels.

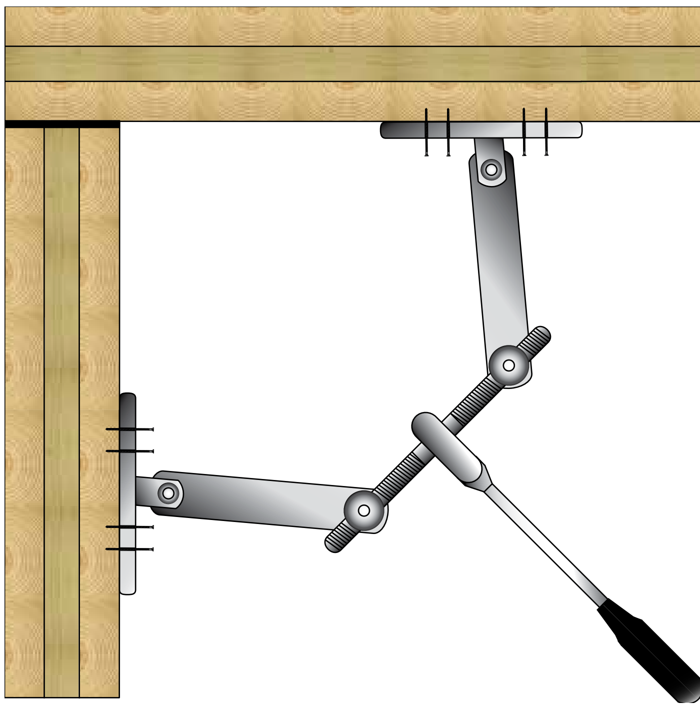


Figure 46
Beam grip with ratchet and screw plate

4.5 Manual Winch with Cables or Slings

Instead of a beam grip, a hand winch attached to cables or slings can be used to bring the CLT panels together. Figure 47 shows the system in use. Steel plates are installed on the panels with screws or lag screws. A flexible sling is used as the link between the winch and the plate. Once proper contact has been made between the panels, they are assembled using self-tapping screws or wood screws (refer to Chapter 5 for more information).

Figure 47
Manual winch used with soft slings

4.6 Steel Shims and Cement-based Grout with no Shrinkage

It is sometimes necessary to use steel shims of different thicknesses under CLT walls, at the junction of concrete foundations, for them to be perfectly square. Once the wall has been properly installed and is at a right angle, the gap is usually filled with a cement-based grout. It is imperative to use a waterproof membrane at the base between the concrete and the wood to limit the migration of water into the wood.

Figure 48
Junction between concrete foundation and CLT walls with steel winch and cement-based grout without shrinkage

5 TRANSPORTATION OF CLT ELEMENTS

Before undertaking the design of a CLT building, consideration must be taken with regards to the transportation of the prefabricated CLT elements. Transporting CLT panels can be costly and, depending on the size of the element, may require specialized transportation services. It is important to understand that the transportation of CLT panels may involve the design professional, the contractor/erector and the CLT manufacturer; therefore, the information that follows is intended to address the concerns of each of these team members as it is applicable.

As shown in Chapter 1, CLT panels can be quite large. Typical panel widths are 4 ft. (1.2 m), 8 ft. (2.4 m) and 10 ft. (3 m) while maximum lengths are dependent on the press type and may reach 60 ft. (18 m). As well, panels can be quite heavy. Because of the potential size and weight of the elements, there are two main factors regarding transportation that must be considered when planning CLT elements: highway regulations and construction site limitations.

5.1 Standard Weights and Dimension Regulations

In the United States, vehicle weights and dimensions fall under the Federal Motor Carrier Safety Regulations (FMCSR) and are regulated by the Federal Motor Carrier Safety Administration (FMCSA).

While each of the States may have varying rules and regulations for weights and dimensions, the FMCSR have been adopted by all States and take precedence over any individual State regulations. Under the Motor Carrier Safety Assistance Program (MCSAP) and the Safety Management System (SMS), the FMCSA allows certain roads and bridges to be restricted from truck travel if the size and weight of such roads and bridges will not safely accommodate commercial vehicles. Keep in mind that States are allowed (and many do) to set more liberal or more stringent weight and dimension restrictions within their jurisdictions and may also require special permitting for loads considered over dimensional or those that exceed the maximum allowable gross vehicle weight rating. The motor carrier being selected should have previous experience in safely securing and transporting flatbed shipments and efficiently handling cross border traffic. Motor carriers may be called upon to deliver in any State within the United States, so they must have operating authority in the U.S. territory and be familiar and comply with State and federal regulations governing interstate motor carriers.

It is also recommended that the motor carriers' Compliance, Safety & Accountability (CSA) record be reviewed prior to contracting for the movement of products. A motor carrier's safety record is available online through FMCSA's website and can be searched by either the motor carriers name or their assigned Department of Transportation (DOT) number.

In Canada, vehicle weights and dimensions (W&D) fall within provincial jurisdictions and limits vary from province to province. However, the provinces and territories have agreed on National Standards for the weight and dimension limits of heavy vehicles used in interprovincial transportation. These are contained in a Federal/Provincial/Territorial Memorandum of Understanding (MOU). Under the terms of the MOU, each of the provinces and territories will permit vehicles which comply with the appropriate weights and dimensions described in the agreement to travel on a designated system of highways within their jurisdiction. Keep in mind, however, that the provinces are allowed (and many do) to set more liberal W&D within their jurisdictions. More information on the MOU may be obtained by visiting the Council of Ministers Responsible for Transportation and Highway Safety website.

5.1.1 Dimension Limits

In terms of dimension limits, here are the main points with regard to road vehicles (according to dimensional limits applicable to the U.S. territory, which are slightly more restrictive than Canadian limitations):

- Vehicle height, including load, is limited to 13'6" (4.11 m);
- Vehicle width, including load but excluding load covering or securing devices, cannot exceed 8'6" (2.6 m);
- Semi-trailer length, including load, cannot exceed 53' (16.15 m).

The FHWA website discusses in detail the size and weight limitations of commercial motor vehicles.

Figure 49 presents these limits in a graphical format.

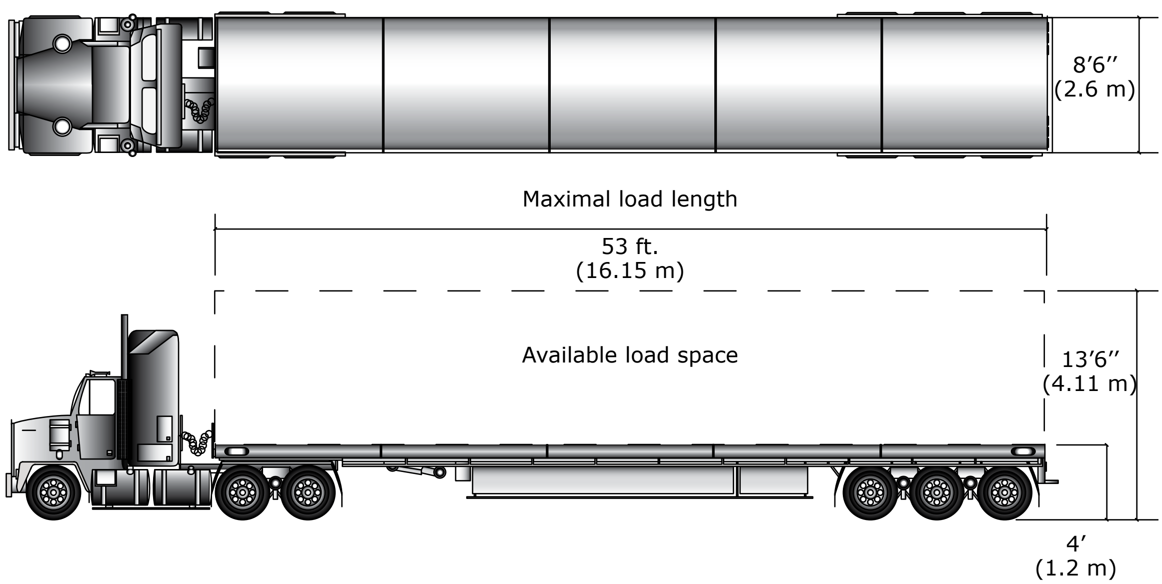


Figure 49
Available load space on a flatbed semi-trailer

Exceptions

Some States allow what are called over dimensional loads to be hauled with special restrictions and permitting. Over dimensional loads (or OD loads as they are commonly referred to) generally require a minimum of the following:

1. OD loads may consist only of indivisible products. Definitions and exceptions to this rule may be found by visiting the FHWA website.
2. OD loads may, in most cases, only be transported during daylight hours.
3. Special vehicle markings are typically required with placards or banners showing oversized or over width loads.
4. Special permits must be ordered from each State well in advance with specific routes traveled being strictly adhered to.

5. Some OD loads may require a safety escort service to lead and, in some cases, follow the OD load, depending on the required routes to be traveled.

Motor carriers with experience transporting OD loads are responsible for obtaining the proper markings, permits and any safety escorts to comply with all federal, State and other municipality rules and regulations.

The majority of CLT panels will be transported by the use of a flatbed semi-trailer (Figure 50). These trailers have the advantage of being open on all sides, which facilitates loading, and having a continuous deck space from front to back. Given that the normal height off the ground of the deck of a flatbed semi-trailer is about 4'11" (1.51 m) (at the front of the trailer, which is the highest point), this permits load heights of 8'6" (2.6 m). Overall, this means that a CLT load, comprised of one or more elements, must fit into a box with a height of 8'6" (2.6 m), a width of 8'6" (2.6 m), and a length of 53' (16.15 m) if it is to be transported by a flatbed semi-trailer. This type and size of trailer is the most commonly utilized in the United States while some motor carriers still have 48' (14.6 m) length trailers in their fleet. It is recommended, when ordering a truck, to be specific about your length requirements.

For taller structures, drop deck (also called step deck) semi-trailers can also be used. However, as can be seen in Figure 51, unlike flatbed semi-trailers, the deck of a drop deck is not continuous. A drop deck flatbed with smaller 255/70R22.5 type tires (but still using normal axle hubs and brakes) can be used to allow a 9'10" (3 m) tall load on the rear 42' (12.8 m) section and a 8'6" (2.6 m) tall load on the front 11' (3.35 m) section.

Other semi-trailers with even more load height are available, such as double drop decks (Figure 52), but they can be difficult to load, and the deck is divided into three sections with the lowest section having a length of about 29'6" (9 m) and a deck height of 1'9" (0.55 m), allowing products of up to 11'8" (3.56 m) in height.

Although all of these semi-trailer types can be as long as 53' (16.15 m), many are 48' (14.63 m) in length. The dimensions given here are presented as guidelines.

IMPORTANT: It is important that you check with your transportation provider to verify the dimensions of their vehicles before going forward with any transportation plan.

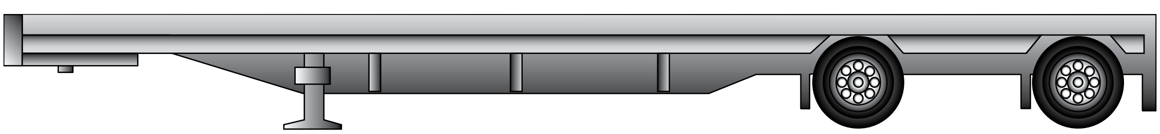


Figure 50
Flatbed semi-trailer

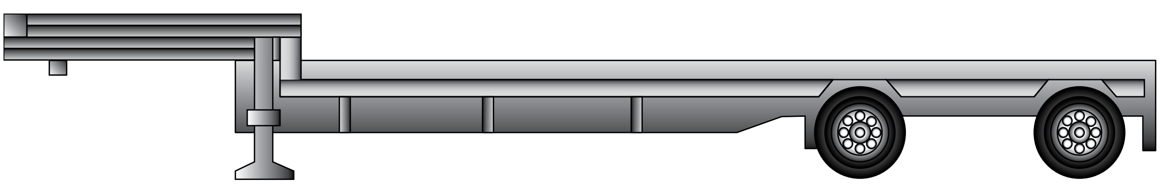


Figure 51
Drop deck semi-trailer

Figure 52
Double drop deck semi-trailer

5.1.2 Weight Limits

When it comes to weight limits, the situation is more complex since the CLT panels may be crossing the U.S./Canada border and weight limits and axle configurations vary between the United States and Canada. Legal Gross Vehicle Weight (GVW) is the weight of the vehicle and its load. Legal GVW varies not only by province in Canada, as previously mentioned, but also by the type of vehicle, the number of axles on the vehicle, and the distance between the axles. Nonetheless, a simplified picture can be drawn. When delivering within Canada, 6-axle semi-trailer combinations (e.g., a tandem drive tractor with a 3-axle semi-trailer) can be used in every jurisdiction although at different allowable GVWs. In the United States, tractor/semi-trailer combinations are limited to 5 axles.

Table 3 presents the maximum payloads authorized with 5- and 6-axle flatbed combinations by jurisdiction, taking into account the typical tare weights for these units (14.5 t {29,000 lb.} for a 5-axle unit and 16 t {32,000 lb.} for a 6-axle unit) and the legal GVW in each jurisdiction. It should be kept in mind that these are only guidelines. It may be possible to have higher payloads with some of the superlight trailers available on the market. Also, trucks are limited in the amount of weight that different individual axles or axle groups can carry. With odd-shaped loads, it is often difficult to distribute the load properly between axles and thus the legal GVW cannot be obtained while maintaining legal axle or axle group weights.

Table 3
Maximum payloads by jurisdiction for 5- and 6-axle tractor/semi-trailer combinations (t)

Jurisdiction	5-axle Combinations	6-axle Combinations
United States	23.3 (46,600 lb.)	N/A
MOU*	26.5	32
Atlantic Provinces and Quebec	28.5	35
Ontario†	28.5	36.6

* Manitoba, Saskatchewan, Alberta and B.C. limits all follow the MOU
† Although higher GVW may be allowed in the regulation, we have included the highest practical GVW

5.1.3 Other Canadian Legal Configurations

Quebec also allows the use of 4-axle semi-trailers while Ontario allows 4- and even 5-axle semi-trailers with much higher payloads. Given that these vehicles cannot travel outside their jurisdictions, we have not presented payload maximums for these types of units. As well, the Canadian MOU allows the use of 8-axle B-train units (a tractor pulling two semi-trailers; see Figure 53) at a GVW of 62.5 tons. However, the length of both trailers combined is 65'7" (20 m), with a lead trailer typically having a deck length of 32' (9.75 m) and a rear trailer with a deck of 27'10" (8.5 m). Because each trailer unit articulates separately (steering and suspension systems), a load cannot span from the deck of the lead unit to the rear unit. As such, the longest panels that super B-trains can accommodate are 32' (9.75 m). Typical tares are in the range of 18 t (36,000 lb.), so loads of up to 44.5 t are possible. Gross vehicle weight in the U.S. is 80,000 lb. or 40 t.

Different possible configurations are also available in the United States, the most common being spread tandem axle semi-trailers. In these configurations, the space between the two axles of a tandem group is increased from the standard 48 inches to a space reaching up to 121 inches.

Figure 54 presents a typical U.S. motor carrier flatbed with spread axle configurations and a 53' trailer

Figure 53
Super B-train flat deck combination

Figure 54
U.S. motor carrier flatbed

5.2 Oversize and Overweight Permits

In every U.S. and Canadian jurisdiction, oversize and overweight permits are required when the dimensions or weight of a vehicle exceed the normal limits permitted by legislation. Larger CLT panels may exceed these dimension limits and a truckload of panels may also cause the vehicle to exceed the legally allowable Gross Vehicle Weight. Keep in mind that these permits are only available for indivisible loads.

The regulations, permitting, and logistics of oversize and overweight transportation are quite complex. The planning and organization of such hauls is best left to the CLT manufacturers and transport companies that specialize in this type of work. If it is determined that CLT elements do not fit in the standard legal dimensions or weights described in Section 5.1, it is important to contact one specialist. For more information on oversize and overweight permitting, refer to local State or provincial authorities. A complete understanding of the size and weight limits as well as State by State lists may be obtained on the U.S. Federal Highway Administration website.

5.3 Construction Site Limitations and Considerations

Transporting CLT elements to the construction site is only part of the challenge. The construction site itself may have restrictions that are more limiting than weights and dimension regulations. First off, the contractor, working in conjunction with the CLT manufacturer and their selected transport company, must ensure that the route from the plant to the construction site will allow movement of the truck, including its load, without any obstacles being in place that would interfere with the transport of the CLT panels. This is especially critical for oversize loads.

A common problem at construction sites occurs when a long trailer arrives and the width of the driving space (which was fine for a shorter truck) does not allow enough clearance for the off-tracking of the rear trailer wheels when a short radius turn is needed. Moving a fence, a shed or piles of materials, for example, to make driving space changes can disrupt and delay deliveries and increase costs.

This can be a challenge when working in tight urban areas where the space for storing building materials and the allowance for turns is very limited. The off-tracking is a function of the sum of the squares of the vehicle combination wheelbases so an extra-long trailer will intrude inward on a tight turn much more than shorter wheelbase trailers. A data chart and other methods to estimate off-tracking (SAE J 695) are available to the Society of Automotive Engineers.

Awareness of local city regulations and pre-planning to match construction site challenges are advisable to ensure a smooth efficient delivery without delays and cost overruns.

5.4 Other Transport Considerations

It is a large advantage for the design professional working in concert with the CLT manufacturer to design the loads to fit on normal equipment, which allows the option to use for-hire carriers to deal with long distance one-way hauls where many loads must arrive and be staged at a jobsite within a close period of time. It also reduces the vulnerability by having access to replacement vehicles when a specialized vehicle has downtime and to deal with swings in demand.

When normal flatbeds are used, it is generally best to lay the load horizontally for easiest tarping and to have the load center as low and stable as possible for safety and load security. Tarping and load tie-down requirements must take into account the fact that federal safety regulations limit the height at which workers can work without a fall restraint system to 10’ (3 m) off the ground and that many drivers are not willing to climb up high to manually tarp a difficult load because of the safety risk.

Having each lift of CLT wrapped in a waterproof package can be helpful as long as it has a way to drain trapped water and breathe out condensation at the bottom in case the wrapping gets damaged during handling or in case there is an air void that allows condensation to accumulate. It is best to also have a physical tarp over the load as the primary protection against rain, ice and debris.

In addition to the general standards described here, U.S. federal law includes provisions, exemptions, and variations applicable to particular States, routes, vehicles, or operations. For more details, please consult 23 CFR Part 658, available on FHWA's Office of Freight Management and Operations website.

6 POSITIONING OF MATERIALS ON CONSTRUCTION SITE AND PROTECTION AGAINST WEATHER

6.1 Positioning of Materials on Construction Site

Once the materials have been delivered to the construction site, wood-based building materials must be stored properly if they are not used immediately. Good planning is essential to ensure that materials have the necessary space and proper logistics control during construction as there are costs associated with handling each piece or shipment.

If panels must be placed temporarily on the ground prior to use, great care must be taken to protect them against weather elements and vandalism. The panels must be installed on skids at least 6 inches above the ground; skids must be in sufficient numbers to protect panels from water runoffs and appropriate tarpaulins should be used to protect them from direct exposure to the elements.

Figure 55 shows CLT panel packs in the process of being unloaded from a truck for storage on site. The packs are completely wrapped (six faces) and are deposited on wood skids to protect them from water runoffs. Although this packaging practice may be adequate, it is recommended that high-quality tarpaulins are also used. Every effort should be made to ensure that the packs remain sealed since, if there are openings, water could infiltrate and become trapped. Therefore, the bottom of the wrapping must be slit at the jobsite to permit any moisture that may become entrapped to escape. Also, CLT bundles should be stacked properly to avoid overloading the lower assemblies. Skids must be properly aligned to ensure load transfer from one bundle to another.

Figure 56 shows a truck platform left on construction site. It will be recovered on the next trip. This can reduce costs by allowing independent scheduling of transportation and unloading.

Finally, it should be noted that the stacking of the panels on the construction site should match the planned installation sequence when possible. Unnecessary handling leads to additional costs and risks of accidents or damage.

Figure 55
Storage on construction site – individually wrapped bundles stacked on lumber skids

Figure 56
Truck platform left on construction site – it will be recovered on the next trip

6.2 Construction Load on Frame

Stacking and storage of CLT elements or other heavy materials must be made while taking into account the maximum anticipated loads for the building. If assemblies need to be placed on the construction frame, ensure that the provisional loads do not exceed the engineer's expected loads during construction.

It is recommended that CLT slabs be placed flat on the frame so they are not exposed to winds. Skids in sufficient numbers and at regular intervals should be placed between panels (see Figure 57).

Figure 57
CLT slabs temporarily stored on a floor

6.3 Temporary Protection During Construction

As indicated in section 6.1, the wood components should be protected as much as possible against the elements during frame set-up operations. The CLT components are primarily intended for use in dry conditions with limited exposure to water, so they should be protected from direct rain, snow and ice, especially from long exposure to these elements. Otherwise, the wood may become discolored or dirty during construction.

In addition, due to the hygroscopic nature of wood, CLT panels may vary slightly in size during construction due to swelling if exposed to the elements and problems can occur at joints. For example, connections can be difficult to perform on the construction site, especially if accuracy is important.

There are some effective techniques used to provide adequate protection against weather elements during frame set-up operations. Figures 58 to 60 show techniques used mainly in Europe to protect components from the weather during construction. While these erection techniques are not commonly used in the United States, there could be applications where such protection could be beneficial.

Figure 58
Use of a temporary tarpaulin (courtesy of Fristad Bygg, Sweden)

Figure 59
Use of a water-proof tarpaulin outside scaffoldings – Germany

Figure 60
Use of an adjustable tent – Sweden

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Special Publication SP-529E

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