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BASIC OF CROSS LAMINATED OF TIMBER AND OPTIMAL LOCATION FOR NEW CLT PLANT

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ABSTRACT

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CLT has been called the concrete of the 21st century. The analogy holds true in terms of efficiency, construction speed and potential for pre-fabricated construction. But finding an optimal place for CLT plant is very hard.

The purpose of this thesis is to provide basic information and manufacturing process of Cross Laminated timber and finding optimal place for new CLT plant.

There are possibly two optimal option can be selected for a new CLT plant and these are 'Near to sawmill' or 'Near to Elementary process'.

Key words
CLT, Environmental, Factor, Manufacturing Process, Raw Material, Sound Insulation

CONCEPT DEFINITIONS

ATFS- American Tree Farm System
CLT- Cross Laminated Timber
FSC- Forest Stewardship Council
IBC- International Building Code
IIC- Impact Insulation Class
LCA- Life Cycle Assessment
MC- Moisture Contents
SFI- Sustainable Forestry initiatives
SFM- Sustainable Forest Management
STC- Sound Transmission Class

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1 INTRODUCTION

CLT is the abbreviation of Cross Laminated Timber. CLT is an engineered wood building system designed to complete light and heavy timber framing designs. Cross laminated timber is a factory-made construction product based on a manufacturing technique developed in the late 20th century. There are numerous benefits of using engineered timber, but perhaps the most notable advantage of CLT is the remarkable speed with which solid timber structure can be erected. The programme benefits can also lead to cost saving. CLT fundamentally allows us to compete with concrete and steel. Since CLT is pre-fabricated, it is quick, easy and accurate to put up. Engineers are also very comfortable using it. Seven storage building of CLT were tested on a shake table in Japan and it survived over 14 different events of earthquakes with very minimum damage. Wood has the natural ability to adapt in making the comfort of the spaces that we build better and that's a unique property. I think there is something about CLT that captured people's imagination. This thesis will describe the CLT processes, benefits and the optimal location of a CLT plant.

2 CROSS LAMINATED TIMBER

2.1 Brief History

Cross laminated timber is a new building system in the construction industry. In some applications, CLT is more suitable than a concrete system. It's a cost competitive system and in the early 1990s, ClT was introduced by Austrian and German companies and it has gained popularity in residential and non-residential areas of Europe. After some slow years in the1990's, CLT again started gaining popularity among the people during the mid-2000's.

Nowadays CLT panels are more durable and suitable for the buildings. There are so many advantages of using CLT for buildings. Experts have shown that CLT is preferable and competitive for mid-rise and high-rise buildings. It is easy to handle the CLT panels when construction is going on. Experts also show that we don't need heavy cranes to lift the CLT panels to up. Smaller cranes are enough to lift those panels. (Greenspec 2016.)

2.2 Definition of CLT

CLT panels consist of some lumbers which are glued crosswise. There are several layers of timbers which are joined by glue for making CLT panels. Beside the glues, nails and wooden dowels can also be used to make the CLT products strong. The number of layers should be an odd number. But at least for one CLT panel we need three layers. Three to seven layers is common for CLT. But it can be more than that. And the maximum should be less than fourteen.

The thickness of every individual lumber can vary from 16 mm to 51 mm, whereas the width can be between 60mm and 240mm. If we look at the panel size, it also varies from time to time according to the manufacturers. The width of the panel size can be 2 ft. or 0.6m, 4 ft. or 1.2m, 8 ft. or 2.4m and 10 ft. or 3m. However, the length of the panel size can be up to 60 ft. or 18m. And thickness of the panel will be maximum 508mm. (Karacabeyli & Douglas 2013.)

3 KEY ADVANTAGES AND FEATURES OF CROSS-LAMINATING TIMBER

Since CLT is used for prefabrication of walls and floors, it is dimensionally stable. There are some more advantages of CLT also. CLT is ecologically friendly and energy efficiency. Sound insulation values are also quite good. The main and greatest advantage of CLT is that it takes such a short time when construction is underway.

3.1 Design Flexibility

Cross laminating timber allows the designers or architectures to make the shape of the design quite broadly according to their expectation. Because if they want they can increase or decrease the thickness of the CLT panels according their expectation. For the high rises buildings, it's so important to use the actual shape of strong materials and for the designers its quite easy to measure the shape of the panels. By using CNC machines, it is getting easier to shape the designs. Because CNC gives us actual measurement and we can cut the panels so accurately even to the millimeter. (Solid Advantages 2016.)

3.2 Cost Effectiveness

CLT is cost competitive. If we compare the cost between CLT and other elements for example, steel, concreate etc. CLT will be more cost competitive. For the high-rises buildings of residential area, CLT saves 15% in cost. For the mid-rise building of non-residential area, CLT is 15-50% cost saver. In case of educational low-rise buildings, it has (15-50) % less cost than concreate and other elements. And for the commercial low-rise building it helps us to save 25 percent of cost than other elements. (Solid Advantages 2016.)

3.3 Energy Efficiency

CLT's heating transfer system depends on the U-value. U-value means the coefficient heating transfer and it is related to panel thickness. When panels are very thick, the U-values are very low. That mean thicker panels have lower U-values. Because they have a very good insulation value, that's why they

need less insulation. Since CLT panels can be designed by CNC machine to precise the tolerance, the panels joints fit tighter and for that reason there is less possibility to flow the air inside the panels and that makes the constructed CLT panel so energy efficiency. (Solid Advantages 2016.)

3.4 Fast Installation

I can say one of the greatest benefits of the CLT is the installation is so quick and efficient. CLT panels are pre-fabricated for the specific place and even end usage. So, for working time, designers don't need to think which part should go where and they also don't need to fabricate anything at the construction site because those parts are already made before coming the construction site. They just need to lift the panels by the small cranes and it doesn't take much time.

There are some simple details for joining different part with each another. For example, floor to floor, floor to wall with steel or concreate. These are not so complicated. (Solid Advantages 2016.)

3.5 Waste reduction

One of the most important thing is to reduce the waste for an industry or organization. But it's too hard to reduce those costs or wastes, especially when building a new building. Wasting time is also common factor for making buildings, house from steel, concrete etc. But for CLT we can reduce those times easily. I already mentioned that since CLT panels are prefabricated, it's easy to install and lift the panels up and that's how it saves time. Moreover, since CLT panels are made for a final surface that's why there are less possibilities to produce waste. I had an opportunity of visiting a CLT plant in Kemi and I have seen that they made the panels so accurately for the end usage and not having extra waste. But if there is any waste somehow, manufacturers can use those waste in the prefabrication sector for different scraps, panels etc. (Solid Advantages 2016.)

3.6 Vibration performance of CLT floors

Vibration of the timber floors has been one of the most concerned matters during the last few decades. Though there is not such an acceptable kind of a well-established measurement system for the floor

vibration made of wood, but experts use some kind of system to find out the reasonable information of the vibration. Those systems are for example, footsteps of walkers, natural frequency, dumping process, acceleration, velocity etc.

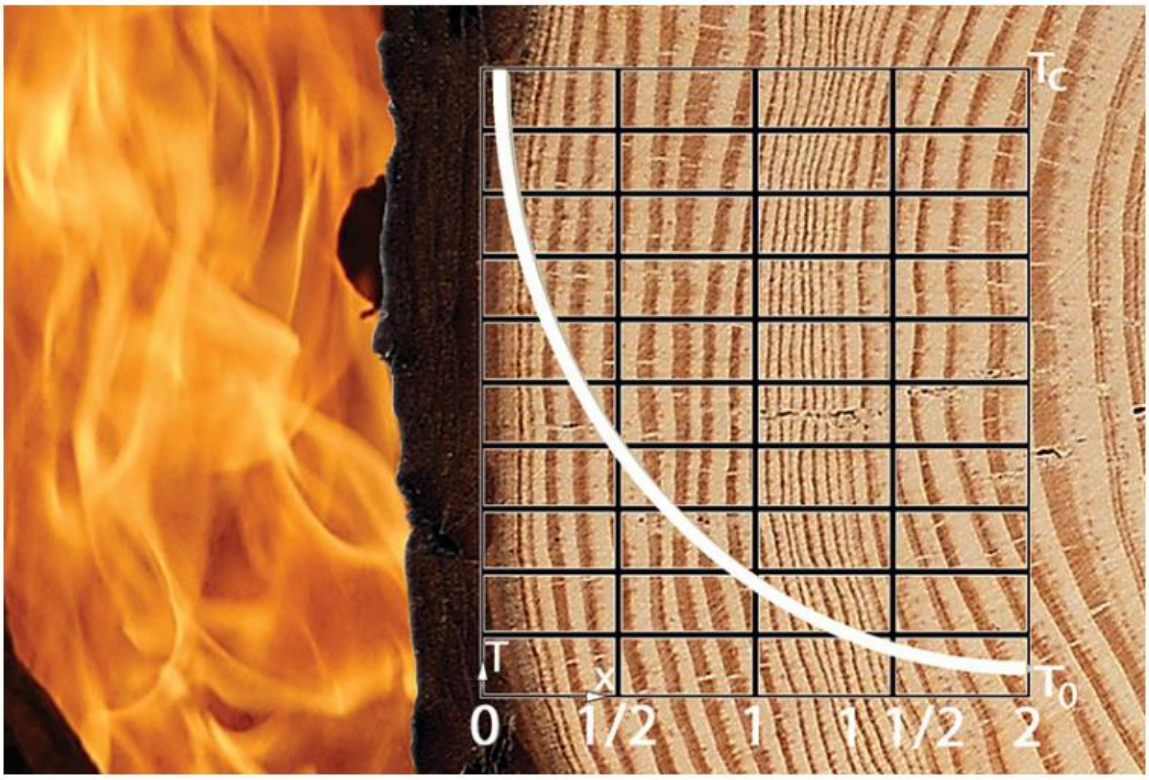
Nowadays the tendency of connecting joists is increasing in building huge span of floors. That's why it's creating a discomfort for the occupants by creating vibration. But in cross laminated timber, joists are not used. There are two kind of vibrations that can be found in the floor. If the natural frequency is more than 8-10 Hz of a floor and it's harmonic is strong, then the vibration name is transient vibration. This vibration stops so quickly. On the other hand, if the natural frequency of the floor is lower than 8-10 Hz and harmonic is strong, then the vibration is called resonance vibration.

So, we already have known about the two kinds of vibrations that can be occurred in the floors. Now, we know that the normal frequency of CLT is above 9 Hz. So according to the category of the floor vibration, CLT floors will be in the category of transient vibration. That means that it can be controlled by the shiftiness and the mass of the CLT floors. (Karacabeyli & Douglas 2013.)

3.7 Fire Resistance of Cross-laminated Timber Assemblies

It's quite good to know that cross laminated timber has great potential to provide the fire safety according to the IBC (International Building Code). IBC usually addresses such things which are related to building safety for example, public safety, fire safety, even the safety of the firefighters when rescuing in a building.

Since CLT is wood product, people assume it would be easy for the building to burn when a fire accident occurs. But the reality is quite opposite. CLT building can be stable until 30, 60, 90 minutes of fire resistance time. Tests for fire performance of CLT buildings have been carried out. The tests show that if a room of a CLT building burned with 1000 degree Celsius with the duration of one hour, the outside temperature of the CLT building will be 20 degrees centigrade. This suggest us that others room will be safe. If CLT panel surfaces exposed to fire, it cannot be easy for the fire to go other surfaces. That is one of the best properties of CLT panels in terms of fire safety. (Greenspec 2016.)



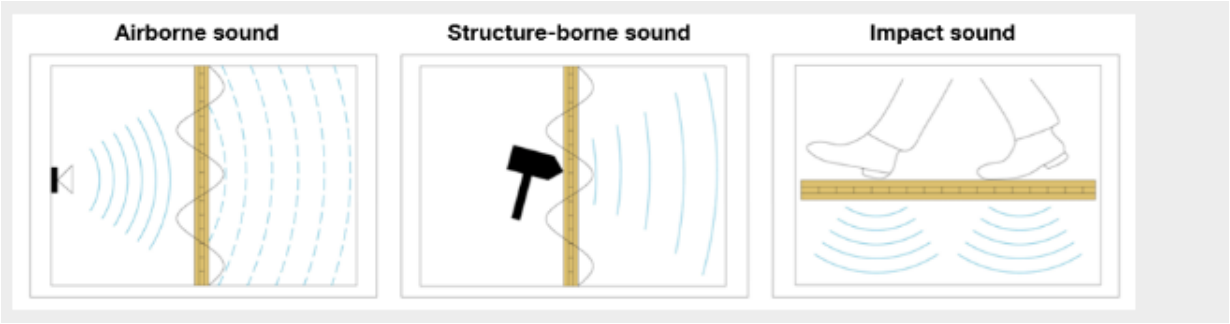
PICTURE 1. The typical temperature versus time gradient through solid timber under fire condition image courtesy of Structure magazine (Greenspec 2016).

In the Picture 1 when the gradient decrease, temperature increase. It means the higher the temperature, the lower the gradient. When the gradient was two, temperature was almost zero. But when the gradient decrease to 0.5, temperature increase almost to high position.

3.8 Sound Insulation of Cross-laminated Timber Buildings

Providing a good sound insulation system is an important aspect in a good building. So, it's very important to make a plan about sound insulation before designing the structure of a building and it should be one of the top priorities. The noise in a building can be a huge problem for the occupants.

Sound can be defined as mechanical kinetic energy which is transmitted by different media of gas, liquid and solid. These two media are called airborne sound and structure borne sound.



PICTURE 2. How Sound Effect in Different Ways (StoraEnso 2015).

3.8.1 Airborne sound

Airborne sound affects the building by making vibrations to components and these vibrations transfer to adjacent rooms in the building. The sources of airborne sounds are for example, traffic sound, vehicle horn, music, voices etc. Poor workmanship also can be a reason for airborne sound in a building. If there is a small gap between the edge of the door and the wall/floor, airborne sound can occur even though the materials provide good sound insulation (PICTURE 2). (StoraEnso 2015.)

3.8.2 Structure borne sound

Structure borne sound is the sound of running or walking, hitting the floor, moving or scraping of furniture etc. These are transmitted to elements and vibrations of airborne sound to adjacent rooms of the building. Since this is a structural sound, the designers or engineers have to be more careful about this sound problem during designing a building structure. Of course, we can reduce this structural sound problem a little by using carpet on the floor (PICTURE 1). (StoraEnso 2015.)

3.8.3 The sound insulation performance of walls or ceiling

The airborne sound insulation is measured by the transmission loss. Transmission loss(TL) is the ratio of transmitted power(TP) and incident power(IP) and it is measured by DB. So, TL= TP/IP (db.)
If the TL is greater, then the transmission of the sound through the wall or ceiling will be less.

On the other hand, Sound transmission Class (STC) is a single number rating of airborne sound insulation of a wall or a ceiling. The greater the STC the better the insulation performance of airborne sound. Similarly, Impact insulation class is defined as a single number rating of impact sound insulation of a ceiling or wall. In the same way, the greater the IIC, the better the insulation performance of impact sound. (Karacabeyli & Douglas 2013.)

3.8.4 Sound insulation of CLT walls and floor

There are two main factors of CLT which affect the insulation of CLT walls and floors. These are called mass and damping. Mass is the most effective factor amongst the other factors. The greater the mass, the better the insulation. At FPInnovation some laboratory tests showed that CLT walls and floors have damping ratio approximately 1% of critical damping system. (Hu, 2013b). there is a table which shows the elements of CLT's mass. By this table we cannot provide all the available elements of the CLT but will try to give some examples.

TABLE 1. Area mass of some CLT elements for floor and wall application (Karacabeyli & Douglas 2013).

Layer no.	**Thickness (mm)**	**Area mass (kg/m^2)**
3	**60**	**30**
3	**120**	**60**
5	**117**	**58.5**
5	**200**	**100**
7	**202**	**101**
7	**280**	**140**
8	**248**	**124**
8	**320**	**160**

We can see in the Table 1 that for every number of layer, thickness of the layers is double than area masses.

Various laboratories showed the measurements of STC and IIC of CLT walls and floors (Gagnen and Kouyoumji, 2011). Some other laboratories at FPInnovation provide the FSTC and FIIC values of CLT floors and walls (Hu 2013a).

TABLE 2. The sound insulation of CLT floors and walls (Karacabeyli & Douglas 2013)

Layer no.	Thickness (mm)	Assembly type	STC	IIC
3	95-115	Wall	32-34	
5	135	Floor	39	23
5	146	Floor	39	24
			FSTC	FIIC
3	105	Wall	28	
7	208	Floor		25

Table 2 shows us that there is no effect of IIC on the CLT wall when a CLT panel has thickness less than 115 millimetre (mm). And when thickness of a CLT panel is more than 208 mm for CLT floor, then there is no effect of FSTC.

The minimum sound insulation requirement of diminishing walls and floors are recorded by International Building Code (IBC) by the following Table 3.

TABLE 3. IBC Minimum Requirements of Sound Insulation for CLT Wall and Floors (Karacabeyli & Douglas 2013)

Assembly type	Airborne sound		Structural borne sound	
Wall	STC	50	N/A	
	FSTC	45 (field measured[2])		
Floor	STC	50	IIC	50
	FSTC	45 (field measured[2])	FIIC	45 (field measured[2])

In the Table 3, we can clearly see that for the CLT wall, the minimum STC and FSTC should be 50 and 45 field measured[2] in case of Airborne sound. Where structural borne sound doesn't have effect on the wall. But for the CLT floor, both airborne sound and structural borne sound have effect on transmission class ans insulation class in same way.

3.9 Environmental Performance of CLT

The usual materials of a building, for example, concrete, bricks, steel, masonry etc, produce high emissions of carbon dioxide into the atmosphere and these components are also energy expensive for products. The modern world is more concerned about global warming, greenhouse effects and your carbon footprint. So, whenever we try to build an industrial building, a homes or schools etc, we need to consider those factor as our first priorities. I think wood is the most preferable component for this kind of healthy building or industry in modern days. Concrete produces approximately 5% emission of carbon dioxide. That means that it is one of the dominant sources of greenhouse gas.

So, if we replace concrete, steels and masonry with wood components, it will be easily possible to reduce large amounts of carbon emissions and that will help our environment greatly. One project was carried out by SmartLam about how using CLT board saves carbon dioxide. (SmartLam 2016.)

TABLE 4. How CLT element as a product saves large amounts of carbon from destructing our environment (SmartLam 2016)

Production rate of CLT board feet (Million)	Saving carbon (Metric tons)	Avoided greenhouse emission (Metric tons)	Total benefit of Carbon (Metric Tons)
48	77,841	30,118	107,959

SmartLam's projected annual production rate of 48 million board feet of CLT represents 77,841 metric tons of stored carbon, 30,118 metric tons of avoided greenhouse gas emissions, for a total carbon benefit of 107,959 metric tons of CO2 per year (TABLE 4).

3.9.1 Life Cycle Assessment (LCA)

Life Cycle Assessment is a very important issue when environment factors come into consideration. In this present world, almost all the materials for industry deplete the resources of the earth. But trees are the only materials that grow naturally and are renewable. Whenever we think about any specific material, we must have consideration of the environment throughout their life cycle.

LCA is an international system for checking how the building materials impact on the environment and how the structure and assemblies of the buildings impact the environment over their entire life cycle. If we consider a building from 'First to last', from growing up the materials and collecting the materials to manufacturing process, designing the buildings, transportation system, air pollution, water pollution, energy using and recycling- wood materials are much better than steel, concrete, masonry and other materials especially in case of carbon footprint, global warming issues. (SmartLam 2016.)

3.9.2 Sustainability

Wood is the only material where a third party is involved who is responsible to make sure that these materials are coming from sustainable forests. These sustainable issues are effective with environment, social and economic values. There are some internationally organization who have verified this sustainability of the forests. These organizations are for example, Forest Stewardship council(FSC), Sustainable Forestry initiatives(SFI), American Tree Farm System (ATFS), Sustainable Forest Management (SFM) and so on. This sustainable system leads the manufacturers, builders, owners, designers and even distributors to verify their products or product materials from a source which follow the standard of sustainability. There are so many advantages of sustainable forestry, such as playing an important role on socio-economic issues on society, maintaining water and soil resources, balancing the capacity of forests, balancing the ecosystem and biological diversity. (SmartLam 2016.)

3.9.3 Energy Efficiency

There are many advantages of using wood for saving energy. Wood has low thermal conductivity, if we compare it with steel or concrete. For that reason, it is easy to insulate wood materials in a high standard way. Wood is a good choice for designers to design a shape of a model. Because they can meet the

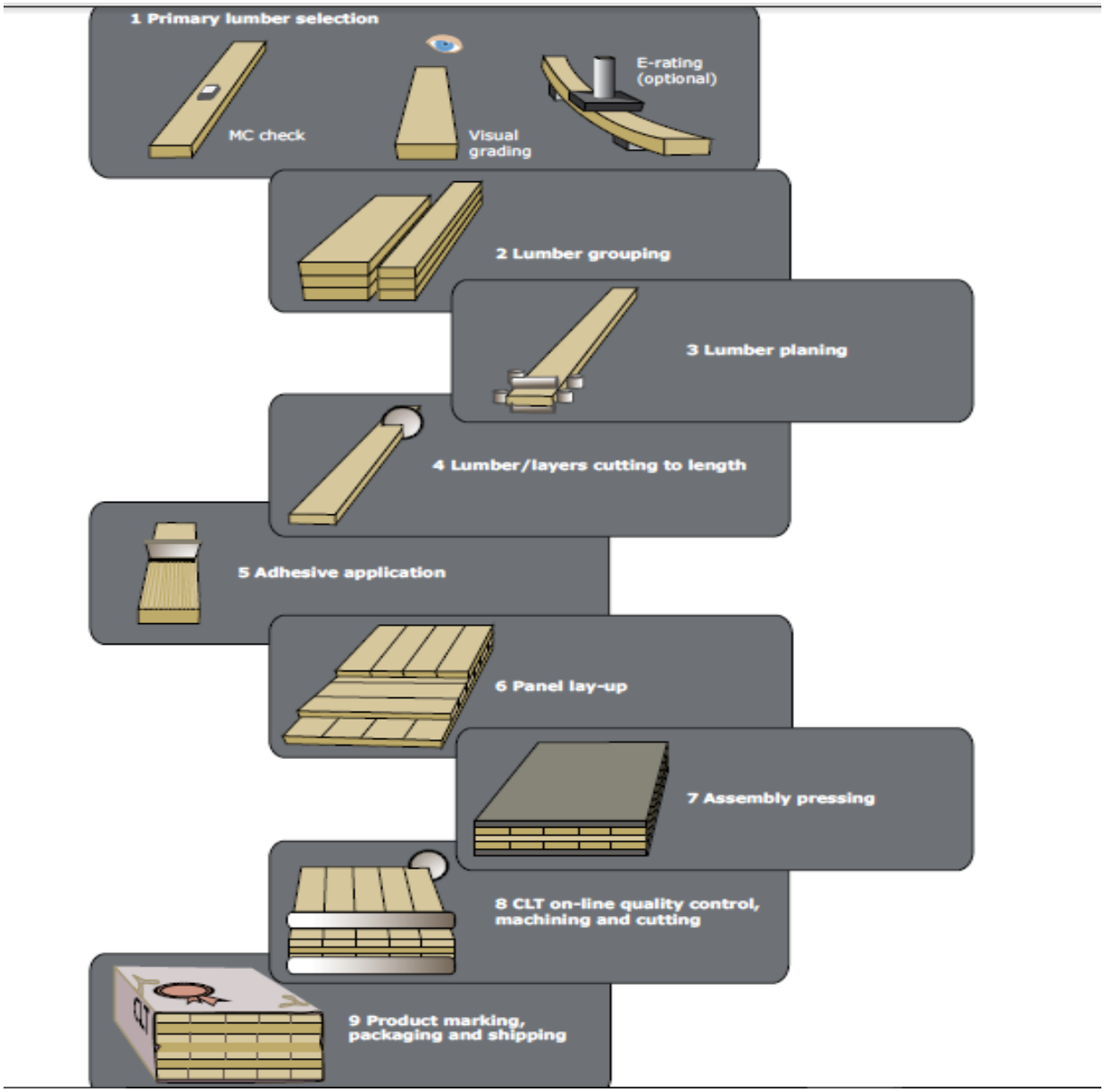
standards and zero carbon buildings. Wood has better influence on designers and manufacturers than concrete and steel. Because wood building system has low embodied energy, it is easy to save energy on installation, transportation, construction of wood materials in a building.

According to SmartLam, wood has zero waste. If they have any waste, they are delivering those wastes to fibre companies and those fibre companies use these waste as materials for other value added engineered products. SmartLam also uses those waste materials for their biomass heating system. (SmartLam 2016.)

4 MANUFACTURING PROCESS

There are several stages for making CLT products, they are selecting the lumbers, grouping the lumbers, adhesive application, laying out the panels, product cutting, pressing, and machining the surfaces and then packaging. The lumber quality and adhesive application of the panels are the successful key for CLT. Usually lumber should be dried to a moisture content 12%. Perfect moisture content makes the dimensions perfect.

There can be different types of panels, varying from manufacturer to manufacturer. Adhesive is used in the CLT as a second material. When the adhesive is completed, then the parts are pressed together to make the panel strong. There are various kinds of pressing systems, for example, electric pressing, air pressing, hydraulic, vacuum etc., depending on the thickness of the panels. (Karacabeyli & Douglas 2013.)



PICTURE 3. Manufacturing Process of CLT (Karacabeyli & Douglas 2013).

In the Picture 3, we can see the whole manufacturing process of CLT panel. It started from primary lumber selection and got finish in product packaging and shipping. All the process has been described in manufacturing process.

4.1 Primary lumber selection

There are two grades of lumber for CLT panels in Europe. These two kind of lumbers are construction grade and appearance grade lumber. So, the lumber sectors are selected according to the CLT grade. For

the appearance grade, manufacturers look at the outsides of the lumber of the panels should look great. For the adhesive application, most of the time it requires the surface of the lumber to be planed. That means that the graded lumber, which are surfaced four sided (s4s), need to be re-planed.

Packages of dried lumber should have a moisture content of 19% or less. MC (moisture contents) level for lumbers vary from manufacturer to manufacturer. It also varies from season to season. Some adhesives are more sensitive than others. Packages of lumber should be wrapped in storehouse for protection from getting wet. We have to be sure that there is enough space capacity for the packages in the storehouses. To achieve the MC and temperature, packages should be unpacked, to allow the air circulation for drying. There can also be some other things which can affect to select the lumbers. (Karacabeyli & Douglas 2013.)

4.2 Lumber grouping

Lumber preparation can follow various steps for major and minor direction of CLT. For these two direction, MC level and visual characteristics can be the considerable media. E-rating lumber is performed for parallel layers while visual characterized is performed for perpendicular layers in case of E-class CLT. But in case of V-class CLT, visual characterized lumber is used for perpendicular layers. All lumber of major strength direction should be same category and same way; all lumber of minor strength direction should be same set of category for establishing panel capacity. (Karacabeyli & Douglas 2013.)

4.3 Lumber planing

The next step after lumber grouping is lumber planing (surfacing). Lumber planing and to have clean surface is very important for effective gluing of the lumbers. If lumber planing is not done well, there can be great problem in gluing and using adhesive application on the layers of lumbers. For good gluing, the lumber's surface should be cleaned well and be fresh. Most of the time, all side of the lumber surfaces must be dimensionally uniform. But in some cases, only face and back planning may suffice when width tolerance is accepted. Usually, 2.5 mm from thickness and 3.8 mm from width of removing is required for planning the CLT lumbers. (Karacabeyli & Douglas 2013.)

4.4 Lumber or layers cutting to length

Before applying the adhesive to the lumbers or layers, the lumbers and layers should be cut into actual size. If we use the adhesive or glue in the edge of the lumbers or layers, we must cut the side of layers properly. To set the cross wise panel, they must be equal in size. If some lumbers are of different size, at that moment, the lumber should be cut to size. (Karacabeyli & Douglas 2013.)

Based on longitudinal incremental results as output of strength grading local (discrete) growth characteristics which do not meet the requirements of the strength class are cut out and the remain board segments are joined again by means of finger joints (FJs).
Finger joints enable a simple, fast and form-fit connection between elements by maximising the bond surface and minimising longitudinal losses of board material. The glued finger joint constitutes a quasi-brittle longitudinal joint between board segments which are composed to endless lamellas. In cases where these lamellas are stressed in tension parallel to grain, these stresses have to be primarily transferred by shear within the joint and between the flanks. These shear stresses are optimal for bonded joints in general. Due to the loss in cross section and the specific stress situation, finger joints have to be positioned within the clear wood zone of boards. (Brandner 2013.)

4.5 Adhesive application

Adhesive is used in the wood to make the products strong. Earlier, adhesive was only for furniture products. Modern technology is growing greatly and it creates different kinds of strong adhesive applications. To make long span wood panels, adhesive is one of the best application for the wood product. Strong adhesive makes the products stronger to carry more load. Even though furniture can be joined by nails, dowels or dovetail joints, adhesive is so necessary for veneer surface.

Adhesive is used for wood products to bond the joints. However, the main concern was that how long would the adhesive last. But adhesive applications have already passed those tests by performing their strength for the last couple of decades.

In case of CLT, adhesive is the very next step after lumber cutting step. In this step, usually the lumber is going to be joined by glue for the first time in the process. There are two kind of adhesive application in CLT and they are PUR and PRF adhesive. For applying adhesive, lumber should be set parallel and the glue comes from glue container by using an air tight system. There will be a little bit of water mist with the glue to wet the layers and this water mist happens when PUR adhesive is used. The speed of production feed is usually 18-60 m / min. (Karacabeyli & Douglas 2013.)

If the layers are already formed, the glue application will be placed on top the layers and this application provides the glue vertically over the layers. The speed will be about 24 seconds for 100 feet long layers. In the applying adhesive step, lumber should be planed on the surfaces and water should be checked properly.

Many of the time manufacturers avoid the edge gluing because of extra cost. In addition, to make an effective edge gluing, the edge of the wood plate must be so clean and fresh in advance. That is also one of the reasons why some producers do not want to do edge gluing. However, if you want to have a very effective strong CLT panel, you have to consider edge gluing even though you have to spend some extra time and money. But there are also possibilities that manufacturers also can adopt the pre-edge gluing before making CLT panels. (Karacabeyli & Douglas 2013.)

4.6 CLT panel lay up

After the adhesive step, the panel lay-up is started. In the panel lay-up step, the layers should be put one over another. It is like plywood with aligned layers in adjacent way. And the layers should be put perpendicular. That means we must put the layer crossway, kind of alternate way. However, for every wood layer, there is two faces, bark face and pith face. The bark face is the hard side of the wood lumber and the pith face is the soft side. So, the question is how do we put the layers one over another. There are three possibilities to lay up the layers. For example, bark-to-bark face, bark-to-pith face and pith-to-pith face. For the CLT sector, engineers choose to put the layers pith-to-pith face way. Because pith faces are soft, that's why layers or lumbers have a tendency to be bend or warped to pith face. So, if they put the layers pith to pith face, they can reduce the tendency of the layers to bend. Moreover, there is one more benefit to put the layers pith to pith face and that is to reduce the wane of the panels. (Karacabeyli & Douglas 2013.)

4.7 Assembly Pressing

After laying up the panels perfectly, the next step is pressing the layers vertically and horizontally. Pressing is an important step for the wood panels, especially for CLT panels. Because there shouldn't be much gaps between two lumbers and between two layers. It is quite impossible to remove these gaps without pressing tools. For the CLT manufacturing system there are two kinds of major pressing plant, they are vacuum pressing and hydraulic pressing.

Vacuum pressing is a weak pressing system, which provide only maximum 15 psi clamping pressure. Such a weak pressure is not sufficient for the CLT panels to remove the gaps between layers properly. For solving this deficiency of vacuum pressure, manufacturers can use lumber shrinkage reliefs system. And this relief shouldn't be too wide or too close. After using these kinds of reliefs, the CLT panel performance has to be checked.
Hydraulic pressing is a strong pressing system, which provide more clamping pressure than vacuum. For the vertical pressing, the recommended pressure is 40 to 80 psi (275 to 550 Kpa). If the side of the lumber already connected by the glue, then the side clamping pressure is not needed for the side of the lumbers. There are possibilities that some vertical pressure command for multiple CLT panels that the pressure can be up to 875 psi or 6 Mpa. The temperature should be more than 15 degree Celsius in terms of pressings. Because at low temperature it can take a long time for adhesive to harden. And the time of the pressing vary from 10 minutes to several hours. (Karacabeyli & Douglas 2013.)

4.8 Quality control, machining and cutting

In every industry, quality check is one of the most important issues. That's why quality control is also important in the CLT sector quality control. After assemble pressing the panel go to the quality control department. Then the panel go to the machining department where CLT doors, windows are framed by cutting accurately. The cutting department is controlled by stricter accuracy. But the parts which need to be repaired go to manufacturing process again. (Karacabeyli & Douglas 2013.)

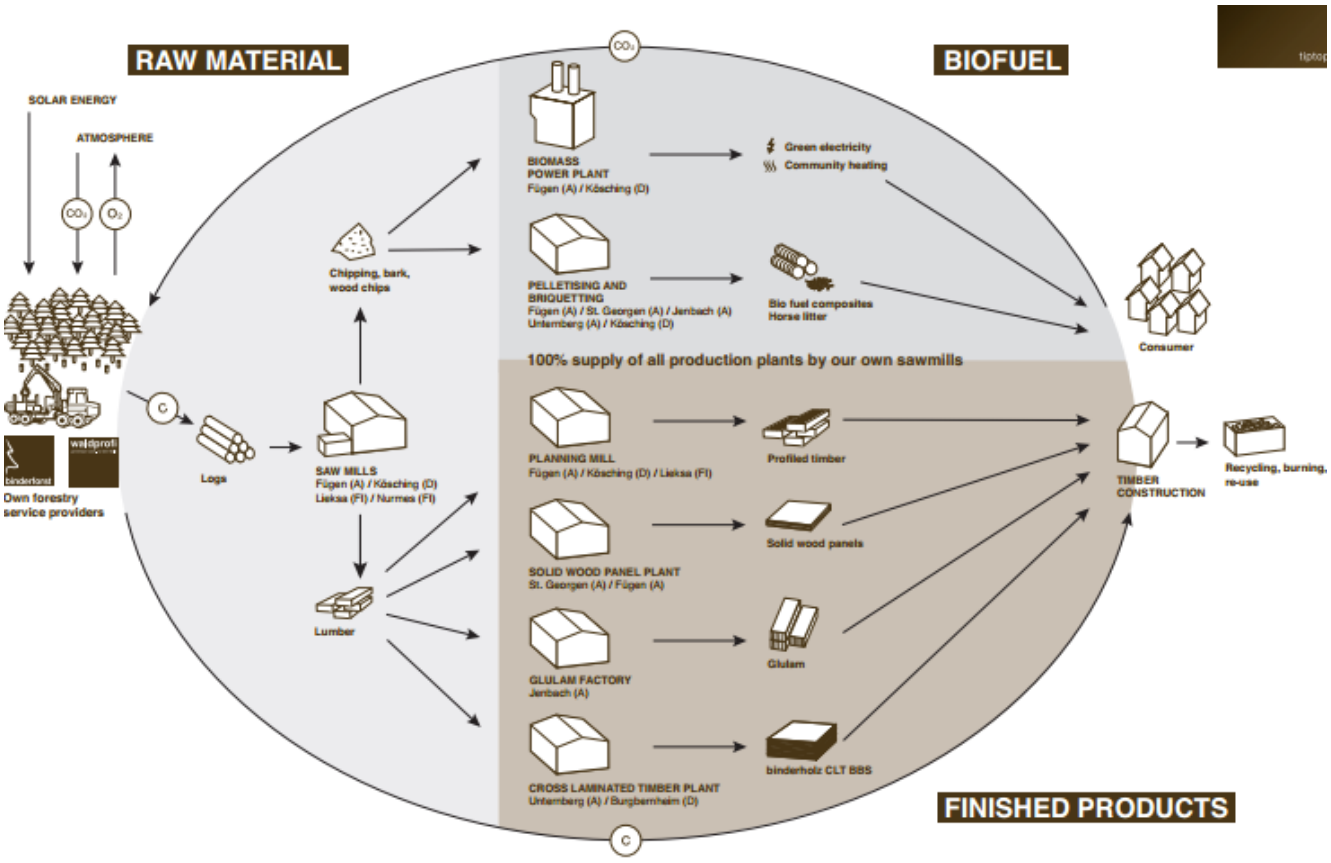
5 SELECTING CLT PLANT LOCATION

Every industry has to face the difficulties of deciding the optimal place for their factories or plants. They have to select the place after calculating the costs and benefits of different locations. It is a very crucial decision for every industry, because it is a solution which cannot be changed after taken. Every plant is not the same, so for different plants, placement or solution can be different. According to plant category, business owners or companies should try to find the optimal or perfect location. I will discuss in this section about some fundamental issues which affect the selection of the location of a plant.

5.1 Raw Material

Availability of raw materials is one of the most important factors for selecting a location of a plant. Because having raw materials near the plant means having low transportation costs. For different business or industries, there are different kind of raw materials. So, storage place of raw materials depends on the category of raw materials an industry has.

CLT's main raw material is wood. But this wood should be from a sustainable forest. So, sustainable sources of wood materials are also important issue for selecting CLT plant. Many of the forests are not verified with sustainable standard. CLT plant materials should be categorized in two steps. First step- wood logs are coming from sustainable sources and goes to sawmill. Second step- from sawmill, lumbers go to CLT plant. (Binderholz 2015.)



PICTURE 4. Process of Raw Materials (Binderholz 2015).

Picure 4 shows us how the raw material come from forests or service provider and goes to finish product. Sawmill collect the logs and send the lumbers to different mill, and sawmill also send the chipping bark and wood chips to the Biomass power plant. After processing all the lumber, goes to timber construction. Picure 4 shows us the whole process so beautifully.

Picure 4 shows us how raw material coming to sawmill and go to CLT plant. This also shows us the process of the raw material to finished product. Picture 4 is captured from 'BINDERHOLZ' CLT industry.

5.2 Logistics

Logistical costs have a huge impact on company's profit. So, for selecting the plant, logistical issues should be in great priority. Logistics costs and time also play a huge role to achieve the competitiveness. For reducing logistics cost and time, plant should be located near to suppliers and manufacturers so that they can supply and provide the component in an easy way and in less time.

Transportation is one of the most important factors for deciding a new plant location. Transportation is a part of logistics sector. Transportation costs sometimes make difference of company's profit. If plant is located far from customers or raw materials, transportation costs will go high. There are different kind of transportation systems, for example, rail ways, port, road and air. So, the plant should be located according to the benefit of the transport system. For example, if it is easier and cost competitive for getting raw materials and supplying finished goods by rail, then the plant location should be selected according to the railway line.

For CLT plant, most of the company use railway and port, because it is easier to carry lumbers by rail. The main raw materials are wood lumber which are coming from saw mills. (Binderholz 2015.)

5.3 Infrastructural resources

Of course, infrastructural factors play an important role in selecting a location for an industry. Even though it varies from industry to industry, it is undeniable fact that there needs to be a high concentration of them. Three are so many factors are included in infrastructural sectors, for example, electricity, water, gas, banking, transport facilities, communication and so on. (Plant Location 2011.)

5.4 Near saw mill

There are four steps in transferring lumber from sawmill to cross laminated timber plant. Cross laminated timber plant consists of four factories or plant. These factories are the planing mill, solid wood panel plant, glulam factory and CLT factory. So, when the necessary amount of lumbers go from sawmill to planning mill, we get profiled timber. Second step is to deliver the lumbers from sawmill to solid wood plant and we get solid wood panel. Third step is from the sawmill to the glulam factory and we get glulam. The last step is from the saw mill to cross laminated timber plant.

Since all the lumber came from the saw mill to CLT plant in four steps, and if CLT pant be located near the saw mill, logistics costs will be greatly reduced. It will be time efficient to take the lumbers to plant. (Binderholz 2015.)

5.5 Near elementary process

After making CLT board from the lumbers by using glue or nails, the CLT board go to the elementary department for pre-fabricating. In this department, all the pre-fabrication has been done by actual measurements for the construction work. So, that at the construction site, engineers don't need to do any extra work for fabrication. In the elementary process department, the plant needs to have large expensive machines. For this reason, some CLT businesses outsource this pre-fabricating department other companies who have those machines.

So, I think that for a new CLT plant, the company can outsource their elementary department for reducing machinery cost. But if any company wants to have their own elementary process along with their CLT plant, it can be possible that they can select their CLT plant near the elementary process. There are advantages of that, such as if we locate the CLT plant near to elementary building, it will be easier to transfer the big CLT board to the pre-fabrication site. And another advantage of that is in the pre-fabrication department, after fabricating the panels, most of the time there is some extra lumber that can be found after machining. This lumber needs to be transferred to CLT plant again and it will be easier to send those lumbers back to CLT plant, if the plant is located near the elementary process. (Lappia Kemi 2016.)

6 CONCLUSIONS

CLT was really a new topic for me to pick for my thesis. After getting some general information about this topic, I started to write the thesis. This thesis is based on theoretical research. Even though there is not sufficient information about this topic, still I managed to finish it up. In my thesis, I described the basics of cross laminated timber, CLT manufacturing process, benefits of using CLT, environment factor and so on. I think this thesis can be considered as a preliminary part of cross laminated timber and somebody needs to carry it more deeply to get the better understanding of the topic.

In my short research and understanding, I also tried to describe the locating of a new CLT plant. The two possible selection places were near the sawmill and elementary department. I have described the advantages of both places separately. Individual places have their individual unique benefits. So, anyone can pick any option.

Even though I cannot give the perfect and confidential solution for optimal place for CLT plant, but in my opinion the best option is to place both sawmill and elementary department near to each other so that we can put the CLT plant near to both option at the same time. And I also give the preference for the CLT plant to be put near the sawmill over the elementary process site. This is not a solution but my opinion.

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