**Course Name: Building Materials as a Cornerstone to Sustainability**

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**Lecture 02**

Cross Laminated Timber

Dear students, so in our ongoing process of learning and understanding about alternate building materials, today we will look at an alternate building material called as cross laminated timber. It is an upcoming building material and it is a very useful and versatile material. In today's class, we will look at cross this building material, I will introduce this material to you, its composition, what are the advantages of using this material and the most important thrust area of this course which is its environmental benefits. We will also look at its limitations, its application in the building industry along with building examples. Now the building professionals worldwide are increasingly considering alternates to timber because of a relatively small manufacturing energy input and the perception that when substituted for other materials, timber has carbon benefits. For sustainable construction of residential and mixed use buildings, researchers have identified cross laminated timber CLT as an emerging structural system.

Cross laminated timber or CLT is an engineered timber product which is characterized by its plate like structure creating a quasi rigid composite material. Typically, it consists of an uneven number of layers; say 3 layers, 5 layers or even 7 layers. Each layer is composed of adjacent boards oriented at a 90 degree angle to one another. This design allows CLT to efficiently support loads both in plane and out of plane.

This figure illustrating the product and an application exemplifies its versatile use. While cross laminated timber may seem like a modern innovation, its fundamental design draws inspiration from traditional joinery and carpentry practices. Despite its ancient roots, CLT has gained prominence in contemporary construction for its strength, sustainability and adaptability in various architectural applications. Let us now look at the composition. Now, a typical cross laminated timber product comprises an odd number of layers of timber or structural composite panels which is stacked crosswise and bonded together using structural adhesives such as polyurethane, phenol resorcinol, formaldehyde, emulsion polymers, melamine formaldehyde amongst others.

The width to thickness ratio of the individual layers must exceed 4 and the timber used should range from 40 to 300 millimeters in width and 6 to 45 millimeters in thickness. This figure highlights that for a three layer CLT, the transverse layer thickness varies from six to 16 millimeters. In the composition of cross laminated timber, various structural composite panels like laminated veneer lumber; laminated strand lumber, oriented strand board and others are utilized as layer contributing to the overall strength and stability of the cross laminated timber product. If we look at the requirement of engineered wood market- In terms of its application between the years 2019 and 2027, we can see use of engineered wood in the construction industry between 2019 and 2027 has shown an extremely steep hike.

The predicted use of engineered wood in the furniture market between 2019 and 27 again is an extremely steep requirement. In flooring it is not so much and in packaging it is not so much whereas in other applications there is adequate requirement of engineered wood. What we also see is the quantity requirement of engineered wood in furniture and construction is extremely high. And since there is a market with a requirement of engineered wood, CLT is a very good option. Let us look at the advantages of using CLT.

Now, cross laminated timber presents a multitude of advantages that make it a highly favorable choice for large scale construction projects. One of its key benefits is its suitability for large-scale endeavors where its prefabricated nature streamlines the construction process. Despite being lightweight, CLT is exceptionally strong, providing structural integrity while reducing overall load on the building. Additionally, CLT demonstrates superior acoustic properties, enhancing sound insulation and creating a conducive indoor environment. Its commendable fire and seismic protection attributes further contribute to the safety of the structure.

So, to summarize CLT can be prefabricated, it is very strong yet it is a lightweight material, it has very good acoustic properties and has good fire and seismic protection properties. Also, CLT exhibits external thermal performance which aids in energy efficiency and creates comfortable living or working spaces. The fast and easy installation of CLT components accelerates project timelines reducing construction duration. An environmentally friendly option, CLT generates minimal waste on site, aligning with the sustainable construction practices. The material's inherent design flexibility allows architects and builders to create innovative and aesthetically pleasing structures.

Furthermore, CLT boasts low environmental impacts as it is often sourced from sustainably managed forest contributing to the overall eco-friendliness of construction projects. Hence, the strength of CLT as a good thermal performance material which is

fast and easy to install at the same time generating no waste on site makes it a material which has low environmental impacts. Let us now look at the environmental benefits of CLT. Cross laminated timber stands as a noteworthy contributor to sustainable construction practices, primarily due to its impressive carbon sequestration capabilities. Acting as a long-term carbon repository, CLT effectively binds significant airborne carbon dioxide, playing a pivotal role in mitigating emissions.

Further, cross laminated timber distinguishes itself with low emissions during production, outperforming traditional materials such as brick, cement, steel and glass. The manufacturing process of cross laminated timber is marked by commendable energy efficiency, consuming less energy compared to alternatives. Emphasizing a circular lifestyle, CLT showcases sustainability from production to end of life scenarios, where recycling or energy production minimizes waste aligning with responsible and environmentally conscious construction methodologies. So, in total the environmental benefits of CLT include carbon sequestration. So, it acts as a long term carbon bank.

It binds a large amount of airborne carbon dioxide in it and it helps in mitigating the emissions effectively. It has very low emissions because CLT's production results in fewer carbon dioxide emissions as compared to many other materials. It is an energy efficient material. Because the manufacturing process of CLT requires less energy than most of the conventional building materials. It has a circular life cycle which means CLT demonstrates sustainability throughout its life cycle including recycling or energy production, minimizing waste and promoting a circular economy.

So this is how it works. When trees absorb carbon dioxide when they grow but what stops when they mature? Then if we cut them down, we can replant and maintain the carbon cycle. But using the timber to build a house creates a long term carbon store. The point is we cannot use timber in its actual form because that would mean cutting a lot of forests. So CLT is a way of engineering timber allowing us to build large number of homes.

So lots of carbon can be stored. Its carbon sequestration property is one of the most important properties that make it a sustainable building material. Let us now look at the limitations of CLT. While cross laminated timber presents notable advantages, it is important to acknowledge certain limitations in its application. One of the key considerations is the higher cost associated with cross laminated timber compared to other conventional materials.

This may impact the overall project budgets and therefore, this could act as a deterrent. Additionally, meticulous planning of utilities, electrical and plumbing system is essential

as alterations post construction can be very challenging once the construction has commenced. The prefabrication of panels to specific sizes contributes to higher transportation costs in the construction site. Further, weather protection measures are crucial during both the delivery and construction phases to prevent potential damage to cross laminated timber panels. Lastly, preventive measures are necessary to guard against insect infestation, highlighting the importance of implementing protective measures throughout the construction process.

Despite these limitations, thoughtful planning and careful execution can help navigate these challenges and leverage the many benefits CLT offers in sustainable construction. In a gist, the limitations of CLT include its high costs as compared to other conventional materials. This can be reduced if en masse production of CLT is commenced which will be based on demand and that is in the hands of designers. One must plan entire building detailing carefully to incorporate all the services otherwise it becomes very difficult to incorporate these at a later stage. Transportation cost can be high because the panels are prefabricated in a factory and not on site.

This can also increase the embodied carbon and embodied energy. There are certain limitations to post construction alteration because it is not easy to alter the building once the construction has started. It needs protection from the weather and insect infestation needs to be handled with proper protective measures. Let us look at the applications of cross laminated timber. Now, cross laminated timber finds versatile application in construction offering sustainable solutions for various structural elements.

In the context of floors, CLT is commonly employed in post and beam or post and panel configurations supporting single span systems or two directional spans with a thin concrete tapping topping slab. CLT's large panels make it an efficient choice for roofs enabling quick enclosure of structures against inclemental weather. The panels can also form cantilevered overhangs without additional reinforcement and span up to 40 feet, particularly beneficial in low snow load regions. As an ideal material for walls, CLT panels serve both load bearing and non-load bearing purposes, utilizing the dimensional stability of altering wood layers for long spans with lightweight panels. CLT extends its utility to shear walls and diaphragms, providing effective lateral load resistance, although consultation with structural engineering teams is essential for adherence to codes and standards.

Finally, CLT showcases its efficiency in elevator cores and shafts, offering quick erection, load-bearing support and the potential for a two-hour fire resistance rating without the need for a dry wall finish. In total, use of cross-laminated timber is found to be suitable in floors, in roofs and as wall elements, also as shear wall elements and as

shafts but is not limited only to these. Let us now look at building examples using cross laminated timber. This CLT house is a residential project in China by Unknown Works. Now, in this residential project which spans about 153 square meters, this was completed in the year 2022 by the architectural firm Unknown Works.

Cross laminated timber emerges as a strategic choice for its flexibility, cost effectiveness and sustainability. The architects employ a creative design approach developing a kit of prefabricated structural panels in CLT. This innovative method facilitated an efficient on-site assembly accomplished within an impressive four-day framework. So, the time frame was only 4 days. The CLT panels after being insulated and coated in textural render were painted in a vibrant banana yellow contributing to a distinctive stepped rear extension and cube front approach.

The international use of colour and form not only adds a bold and unique character to the residential typology but also reflects the architect's innovation in CLT. Another building example that we will see is the Avoti Timber Office. So, in this case study of an office project spanning about 1086 square meters in Latvia, the architects from made architect showcases a thoughtful and efficient design approach. The building utilizes a glued wooden post and beam system, enhancing stability with CLT panels in walls and floor slabs. The design emphasizes a compact, protrusion-free structure, ensuring an efficient, warm surface and minimizing the risk of thermal bridges.

The heating and ventilation system is intentionally kept simple, reducing operational risks and costs while promoting natural air exchange within the office space. Overall, a holistic design strategy focuses on operational efficiency, aligning structural, thermal and HVAC systems for a streamlined and cost-effective solution tailored to the specific needs of the office typology, which shows an exemplary use of CLT. The climate responsive geometry, structure, integrated HVAC systems, renewable materials, zero VOCs and low carbon dioxide footprint. The blend of abstract simplicity and clever details sets an example for the building industry as it proves that it is possible to have climate responsive building which has structurally integrated services system with the use of renewable materials giving a high indoor air quality and which has low carbon dioxide footprint. What better example of sustainability than this? So, in summary Cross laminated timber stands out as a versatile and sustainable building material which is used in different scales and typologies as depicted in various building example.

Its plate like structure composed of layers bonded with structural adhesives offers strength in multiple directions. CLT finds applications in floors, roofs, walls, shear walls, diaphragms, elevator cores and shafts. It showcases its adaptability in various construction elements. The advantages of CLT such as suitability for large scale projects,

prefabrication, lightweight strength and environmental benefits contribute to its widespread use. However, limitations including higher costs and careful planning requirements needs consideration.

Environmental advantages like carbon storage and low emissions highlight its sustainable nature. Case studies by Unknown Works, which is a residential project and a building with glued wooden post beam system, exemplify the application of CLT in real world scenarios, emphasizing its thermal efficiency, simplicity in HVAC and a holistic design approach for operational efficiency. CLT continues to play a pivotal role in modern construction practices offering innovation across diverse building scales and typologies. As such a versatile material with the only so-called limitation for an architect that the building has to be detailed out completely to incorporate every single services aspect because it is difficult to alter buildings which are built with CLT. A good material, a very carbon negative material, a material which can store carbon and literally save the world.

Today we saw about cross laminated timber and its use in architecture. Today we will stop the class here and we will continue with yet another alternate building material in the next class. Thank you.