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Application of Cross-Laminated Timber in Construction Engineering

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Abstract. Against the backdrop of the global “carbon peak and carbon neutrality” goals, the construction industry is shifting from high-carbon to low-carbon development, and the innovation and application of green building materials have become crucial breakthroughs. As an engineered wood product made of multi-layer orthogonal grain wood, Cross-Laminated Timber(CLT) has core advantages of light weight, high strength, low-carbon sustainability, and good prefabrication compatibility. This thesis explores CLT’s application in construction engineering. It first details CLT’s material characteristics(definition, structural composition, key performance indicators like mechanics, fire resistance, thermal performance, and durability) and compares it with traditional building materials. Next, it discusses the key aspects of CLT’s manufacturing process and quality control measures. Subsequently, the thesis sorts out CLT’s application scenarios across different building types and components, analyzes its key technologies and innovation directions, and finally forecasts future development trends. The study concludes that CLT holds broad application prospects in green buildings. However, to further promote its adoption in construction projects, it is essential to overcome limitations related to raw material supply and production costs.

Keywords: CLT, Construction, Material Properties

1. Introduction

Driven by the global goal of "carbon peak and carbon neutrality", the construction industry is facing a key change in the transformation from high-carbon construction to low-carbon, and the innovation and application of green building materials have become the core of breakthroughs. Traditional buildings have long relied on high-energy materials such as concrete and steel, and their carbon emissions in the whole life cycle account for more than 30% of the world's total emissions, and there are pain points such as long construction period and high resource consumption. As the core representative of modern engineered wood materials, CLT breaks through the defects of "anisotropy" of traditional wood with its unique structure of multi-layer orthogonal texture superposition, which not only retains the natural advantages of wood, but also has excellent engineering characteristics such as prefabricated equipment.

From the perspective of international practice, the application of CLT has formed a mature system, with Europe as the birthplace, Germany and Austria through EN 16351 and other standards

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and specifications, and a large number of multi-storey CLT residential and public buildings have been built. North America expands CLT application to high-rise buildings with more than 10 floors, and Canada also achieves a 90% prefabrication rate, shortening the construction period by 40% compared to traditional buildings. On the other hand, although multi-layer CLT pilot projects have appeared in Shanghai, Beijing and other places, they still face significant bottlenecks. High-quality structural wood relies on imports (European spruce) to account for more than 70%, the localization of fire and corrosion prevention technology is insufficient, and the market has doubts about CLT's seismic performance, resulting in the industrialization process lagging behind the international level [1].

In this context, this thesis analyzes the core properties of CLT such as mechanics, fire resistance, and durability based on the materials, manufacturing, design, and application of CLT in construction engineering, and clarifies its differentiated advantages from traditional building materials. Secondly, combined with typical cases at home and abroad, the application mode and key technologies of CLT in residential, public buildings and modular buildings are summarized, and finally the direction of material innovation and technology upgrading is put forward for bottlenecks such as raw material supply standard system and market cognition.

From the perspective of theoretical significance, sorting out the correlation mechanism between CLT material properties and building applications can further improve the theoretical system of engineered wood buildings and provide a theoretical basis for subsequent correlation. In terms of practice, this study can provide detailed technical reference for the application of CLT in different building types such as multi-storey residences, public buildings, and modular buildings, which will help promote the industrialization of domestic wooden buildings and promote the greener, more environmentally friendly and efficient development of the construction industry.

2. Cross-Laminated Timber material properties

2.1. Mechanical property

CLT's excellent mechanical properties are the basis for its use as a structural material, including flexural strength, compressive ability, shear strength, and stiffness [2]. Due to the alternation of slab directions, orthogonal laying makes the material have a more balanced performance in both directions (horizontal and long) directions. In terms of one-way performance, its compressive strength and flexural strength in the grain direction are better than those of traditional solid wood, and it can withstand large vertical loads. In terms of orthogonal performance, due to the orthogonal grain structure, the shear strength and crack resistance of CLT in the horizontal grain direction are significantly improved, which effectively solves the defect of "anisotropy" of traditional wood and makes its force performance in different directions more balanced [3]. The joint performance has a significant impact on the overall stability of the CLT structure, and the synergistic stress performance between CLT and metal connectors (such as screws and bolts) is directly related to the bearing capacity and resistance performance of the structure.

2.2. Fire resistance

CLT has certain natural fire resistance properties, and will form a "carbonization layer" during the combustion process, which can effectively delay the transfer of heat, thereby buying time for the evacuation and fire rescue of personnel in the building [4]. The carbonization rate of wood without flame retardant treatment is about 0.6mm/min, during which the components can still meet the

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requirements of integrity, bearing capacity, and thermal insulation [5]. Of course, different thicknesses of CLT have different fire resistance limits. For example, a large amount of data from Europe, North America and other regions shows that 120-150mm 5-layer CLT can reach the fire resistance limit of 1.5 hours in fire resistance tests that meet international standards, and some can even reach 2 hours [6]. If scientists want to further improve the fire resistance of CLT, they can also take some fire prevention measures, such as applying fireproof paint or coating fireproof boards (such as gypsum board).

2.3. Thermal performance

The thermal performance of CLT is good, and its thermal conductivity is about 0.13-0.17W/(m· K), which is much lower than that of steel (50W/(m· K) and concrete (1.5W/(m· K)). This means that CLT buildings can better maintain stable indoor temperatures, reduce energy consumption for heating in winter and cooling in summer, and meet the energy-saving requirements of green buildings.

2.4. Durability

In terms of durability, CLT's corrosion resistance can be improved by treating wood with preservatives to inhibit the growth and reproduction of mold, rot bacteria, and other microorganisms. For pests such as termites, physical or chemical protection (such as insect repellents) can be used. In addition, the orthogonal structure of CLT makes it have good stability in environments with large temperature and humidity changes, which can effectively reduce the warping and deformation of components [7].

3. Manufacturing process of Cross-Laminated Timber

3.1. Raw material selection and pretreatment

The selection of CLT raw materials needs to meet certain requirements, and the tree species suitable for making CLT mainly include European spruce, pine and domestic larch, etc., which need to meet the structural grade wood standards. During the pre-treatment of raw materials, the wood is first sawn and processed to the specified width and thickness. Then dry treatment is carried out to control the moisture content of the wood between 12% and 18% to avoid the deformation of the CLT components due to changes in moisture content during subsequent use. Finally, it is necessary to remove defects from the wood to remove cracks and other defects that affect the strength of the components to ensure the quality of raw materials.

3.2. Core manufacturing process

The core process of CLT mainly includes three links: gluing and batching, hot press forming and post-processing. In the stage of gluing and embryos, automatic gluing equipment is used to apply glue, and the thickness of the glue is controlled at 0.15-0.2mm to ensure that the adhesive can play a full role. The embryo assembly is carried out according to the principle of orthogonal superposition to ensure that the grain direction of each layer of wood is vertical, and the grain direction of the surface wood is consistent with the stress direction of the component, so as to improve the mechanical properties of the component. Hot pressing is a key link in CLT manufacturing, and the hot pressing parameters need to be reasonably adjusted according to the number and thickness of

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CLT, usually the hot pressing temperature is 100-120 degrees Celsius, the pressure is 0.8-1.2MPa, and the hot pressing time is determined according to the thickness of the component, for example, the hot pressing time of 5 layers of CLT is about 30-40min. The post-processing mainly includes trimming, drilling and surface treatment, the trimming process ensures the dimensional accuracy of the components, the drilling process reserves holes for the installation of subsequent connectors, and the surface treatment improves the surface quality and durability of the components by sanding, painting anti-corrosion coatings, etc [8].

4. Application scenarios and cases of Cross-Laminated Timber in construction engineering

4.1. Residential building

In the field of residential buildings, CLT is widely used. In terms of multi-storey apartments, the "T3 Salmon Creek" project in Vancouver, Canada, is a typical case, which is a 6-storey CLT residence with a prefabrication rate of up to 90%, which greatly shortens the on-site construction time and improves construction efficiency. Among low-rise villas, there is a CLT demonstration in Hangzhou in China, using 3-story CLT wall panels and floor slabs, which shortens the construction period by 50% compared with traditional concrete villas, and residents subjectively respond to it, with better living comfort and environmental performance.

4.2. Public buildings

CLT is also widely used in public buildings. In terms of school architecture, a school in Norway is a 5-story CLT teaching building, which can meet the requirements of earthquake resistance of 8 degrees, providing a safe and comfortable learning environment for academics. In public buildings such as libraries and exhibition halls, a CLT library in Munich, Germany, uses long-span CLT roof panels to achieve column-free space design, providing readers and visitors with open activity space, and also demonstrating the application potential of CLT in long-span buildings [9].

4.3. Modular construction

Modular construction is one of the important areas of CLT application. In terms of temporary resettlement housing, CLT modular housing is widely used in Japan after natural disasters such as earthquakes and floods, which can quickly provide housing security for the affected people after natural disasters such as earthquakes and floods. In the field of sojourn construction, such as RV camps and homestays, CLT modules are lightweight, easy to transport and install, and can adapt to the needs of different venues, providing passengers with a unique living experience.

5. Development and prospect of Cross-Laminated Timber

5.1. Material innovation direction

In the future, the innovation of CLT materials will mainly focus on three directions: localization, modification and hybridization. In terms of localization, the processing technology of domestic larch and fir and other native tree species will be further optimized, the utilization rate of local wood will be improved, and the dependence on imported wood will be reduced. In terms of modification, the dimensional stability of CLT is improved through heat treatment technology, and a new anti-corrosion modified CLT is developed to solve the compatibility problem between preservatives and

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adhesives, and improve the durability of CLT. In terms of mixed materials, develop composite components such as "CLT + steel", such as CLT floor slabs and concrete laminated layers, to give full play to the advantages of different materials and improve the bearing capacity and comprehensive performance of components.

5.2. Sustainability outlook

In terms of recycling, after the dismantling of CLT buildings, their components can be recycled and reused, such as cutting into small CLT components for other small buildings, or as biomass fuel for energy recovery, so as to achieve resource recycling and meet the requirements of sustainable development. In the future, with the continuous development and improvement of CLT technology, its application in construction engineering will be more extensive, making important contributions to promoting green, low-carbon, and sustainable development in the construction industry.

6. Conclusion

As a new type of green building material, CLT has shown broad application prospects in the field of construction engineering with its advantages of light weight, high strength, low carbon sustainability, and good prefabrication and assembly [10]. It has important application value especially in multi-storey residences, public buildings and modular buildings. However, the current domestic CLT application still faces many challenges and bottlenecks, such as insufficient supply of raw materials, high cost, imperfect standard system, and low market awareness.

In order to promote the further development of CLT in domestic construction projects, priority should be given to promoting the research and development of localized CLT in the future, improving the utilization efficiency of local wood, reducing the cost of raw materials, accelerating the improvement of CLT-related standardization systems, and providing clear guidance for engineering design and construction. At the same time, the government should introduce relevant policy support measures to create a good policy environment for the development of CLT. It is believed that through joint efforts, CLT will strive to be the core material of modern wooden buildings in our country and provide strong support for the transformation, upgrading and sustainable development of the construction industry.

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