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CROSS LAMINATED TIMBER – EUROPEAN EXPERIENCES

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Abstract:

The European success story of Cross Laminated Timber (CLT) started more than one decade ago in many small capacity simple workshops in the Alps of Europe. Currently, Europe has over one dozen CLT manufacturers (>350,000m³/y) which are extremely specialized, starting with eco-type (glue-free) to full glue applications, narrow (<1.25m) to large (< 3m) free size panels, short (<5m) to long (16.5m), handmade-to-fully automated lines able to produce engineered elements for walls, roofs, and floors. Traditionally CLT was delivered to the carpenters able to prepare cut-to-size elements for building construction which included the insulation layers, preparation of connectors, windows, doors etc. New CLT mills use CNC portal equipment working with their own architectural design departments that are able to shape the raw panels to the final construction element at the production site which also includes insulation, fire protection, finishing layers, windows, and doors. The final CLT delivery is a sophisticated ready-to-install product. Simplified working steps at the construction site allows for building erection that are much faster than traditional construction methods. However, this requires unique logistics, construction equipment, and trained workers in CLT construction. In Scandinavia and Central Europe the national building codes were forced to accept the new generation of multiple story buildings made from CLT, which now exceed 10 stories with a target of 20 stories. New challenges for earth quake, noise, fire, and summer heat protection were requested by owners and authorities. The European Norm (prEN 16351) drafted in 2011 is specialized for CLT. Intelligent solutions for the implementation of self-contained heat storage and generation; and indoor air conditioning are in development for the next generation of CLT based passive-energy houses. North America is the next logical market for pilot CLT construction projects and production facilities which will be based on the European experiences.

Key words*: Cross Laminated Timber (CLT); X-Lam; multistores wood buildings.*

Technical basis

The building regulations of CLT are issued by national approval from the construction authority such as the German Institute for Construction Technology (DIBt) or the European Technical Approvals (ETA). The approvals include minimum requirements for the products, the control mechanism and the designation. Furthermore the approvals include regulations and recommendations in regard to the structural, fire protection (analysis of load bearing structures) and thermal design of the building. For design of CLT based buildings the allowing for the specifications of the approval according to the national design standard DIN 1052 or the European design standard Eurocode 5-1-1 are requested or to fulfil. As a rule according to DIN 1052 the Service Classes 1 or 2 as well as a predominantly statically loading are available (Studiengemeinschaft Holzleimbau 2010).

Wood preservation and service classes for CLT

Cross Laminated Timber are permitted only for the Service Classes 1 and 2 in accordance to DIN 1052/2008, Design of Timber Structures - General Rules and Rules for Buildings, or DIN EN 1995-1-1/2010, Eurocode 5: Design of Timber Structures - Part 1-1: General - Common Rules and Rules for Buildings. The expected moisture content does not exceed 20% thus attack through fungi can be excluded. Preventive constructional measures in buildings are usually sufficient (Studiengemeinschaft Holzleimbau 2010).

Auxiliaries for CLT

Usually polyurethane (PUR) or melamine – urea - formaldehyde adhesives (MUF) are used as well as in smaller quantities polymer of isocyanates (EPI). The percentage of resin ranges from 0.1% (EPI) to 0.5% (PUR) in weight.

The formaldehyde emissions are established in accordance with the European standard draft prEN 16351/2011, Timber structures – Cross-Laminated Timber – Requirements, with reference to DIN EN 717-1, Wood-based Panels - Determination of Formaldehyde Release - Part 1: Formaldehyde Emission by the Chamber Method (Studiengemeinschaft Holzleimbau 2010).

Fire protection concept

For height buildings is the Classification 5 (buildings with a fifth level not higher than 22m) to be fulfilled. The fire resistance of 90min as well as fire behaviour of the building material must fulfil certain requirements at least like the Fire Resistance Class A2 (mineral materials).

A case study was done for a 7 story building in down town area in Vienna. In order to fulfil all the requirements a compensation concept was examined by experts of the Technical University, Vienna and the Construction Authority of Vienna.

The concept is an encapsulation of the load bearing wooden structure by mineral materials to prevent inflammation. The fire duration is calculated in accordance to the standard temperature curve where the same fire impact like with the normal (nature) fire is assumed.

In case of an encapsulation of 30 minutes of the load bearing wooden structure with materials from the Fire Resistance Class A2 a fire load can be excluded. The report mentions the importance of encapsulating all cut outs and gaps. All installations are routed in the facing shell. Another option would be the installation of a sprinkler system where the fire load also can be controlled (Teibinger 2008).

Multi story timber construction

Functionally efficient showcases are the 6 - story building in Vienna's Wagramerstrasse (completed 2012). Another residential complex with 255 apartments is also in Vienna's Mühlweg. This building complex is still European largest residential complex built in a timber/masonry mix (Binderholz-Bausysteme, Subsidised Residential complex in an innovative timber and timber/ masonry mix, Wagramerstrasse, Vienna, A, 2012) (completed 2008). Another 7- storey building is located in central Berlin (completed 2008) and a 8 storey building in Bad Aibling (close to Rosenheim) completed 2011. Also in UK a 9 - storey free standing residential building near the centre of London was constructed entirely in wood (completed 2010). Also a residential complex in Milan open a new era of the CLT use and confirmed the quick building speed of a 9 - stores (27m) with 124 apartments in about one year (to be completed by mid-2013) (HZB14 2013).

Earthquake safety of buildings

The seismic performance of the CLT constructions was tested in a full scale (3 and 7 storey building) building by the Trees and Timber Research Institute (IVALSA) Trient in Italy on the world largest shake table in Miki, Japan. As the results show very little deformation due to the ductility of the wood and especially by the energy dissipation of the mechanical connectors. (FPInnovations - Forintek Division - Canada's Wood Products Research).

Due to the ductility of the wood elements in combination with adequate mechanical connections the building's capacity to dissipate energy is comparably high to common materials such as concrete (Binderholz-Bausysteme, Earthquake safety of BBS buildings 2010).

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The earthquake tests at the "Laboratorio Nacional de Engenharia Civil" (LNEC) in Lisbon, organized by the Technical University in Graz (February 2012) showed very clear results. A building with 8 floors survived 32 earthquake tests with no severe damage.

The test was carried out within two days. 75 sensors were installed to measure the deformations of the CLT and the connectors. A simulated earthquake with the magnitude of 7.3 (according the measurement of Richter) no damages were noted. In total 32 earthquakes were simulated whereat fasteners and connectors were partly removed. The final result showed very little damage (www.proholz.at 2012).

Timber Tower and Chanels

Environmental friendly and economical effective wind turbines made out of wood. The timber tower with a height of 100m saves about 300 tons of sheet steel. The processing of wood saves energy, the material stores about 400 tons CO_2. There has been built one tower with a height of 25m in Waffenensen, Germany in 2010 as a pilot project. The tower serves for a simulation and further optimization for much higher towers (up to 100m) in the near future. The current tower has a turbine with power of 1.5MW.

The panels for the pilot tower were entirely prefabricated (including the connections and surface cladding) at the factory. For the transport standard trucks can be used. To transport a timber tower with a height of 100m about 10 trucks are required.

First, the inside construction including multiple components such as light installations, cable system and the grid connectors and the operating platforms were constructed. Surrounding the inside structure the panels were attached. The weight of the power turbine on top is carried by the panels. The splices of the panel surface sheeting are welded by using an integrated elevator system (www.timbertower.de 2013).

In Melbourne timber+DESIGN currently designing a 10- story building which should be built starting 2014. This is a new dimension not only in Australia but also in UK and Central Europe.

Building physics

Sound Insulation

Due to the crosswise composition of the CLT an acoustic light and in the same time stiff to bending exists. To reduce sound transmission flexible facing shell are used. For ceiling it is common praxis to decouple the facing shell from the construction. (Studiengemeinschaft Holzleimbau 2010).

Thermal insulation (winter/summer)

Due to the solid construction and therefore higher thermal capacity a balanced indoor climate can be assured.

Following are the example of spefic values from CLT of 470kg/m³ made from spruce in accordance to DIN 4108. Heat conductance: λ_R= 0.13W/mK.

Specific thermal capacity c = 2.10kJ/kgK conductibility of temperature a = $1,317x10^{-7}$m²/s (www.binderholz-Bausysteme.com 2012).

Allmost all companies provide prooved build ups for wall, floor and roof constructions.

Under standardized moisture content (m.c.) of 12% result in a thermal conductivity for CLT of 0.11 to 0.13W/mK. An average value of 12% is assumed for wood m.c., whereby less than 12% wood m.c. should be expected in external walls during the relevant winter months. With less wood m.c., the actual thermal conductivity value reduces further. The Austrian standard ÖNORM EN 12524 specifies a rated thermal conductivity of 0.13W/mK for wood in the relevant bulk density range. (www.clt.com 2013).

Airtightness

The airtaightness depends upon the amount of layers and how they are glued together.

Most of the CLT- producers have approved the airtightness of their products which ist especially relevant for the 3 and 5 layer compositions.Basically with 5 layers all producer have approved the airtightness. Stora Enso also glues the boards sidewise which gives already a airtightness with 3 layers. Most of the companies have tested and confirmed the airtaightness by the Wood Research Austria (HFA), German Institute for Construction Technology (DIBt) or the European Technical Approvals (ETA) (www.clt.com 2013).

The wind and airtightness of a building envelope (wall, ceiling and roof panels) are essential for several impacts such as indoor climate, noise load, indoor atmosphere and energy demand in of a building. In common frame structure buildings the airtightness from inside is given by semipermeable sheet and the windtightness from outside given by windproof sheeting. CLT constructions do not need this additional sheeting by using a 5 - layer structure. Due to this fact most of the taping with special tapes can be omitted. Additionally, dividing the structural layer from the insulation and other layers makes the construction methods much easier compared to timber frame buildings where the vapour barrier is very crucial und must be carried out with high precision by skilled people (www.clt.com 2013).

Inadequate airthightness may cause deposition of condensation in the structure, reduced thermal protection and low surface temperature which results in poor living quality. If condenstation occurs in the structure of the building the structure can be damaged, mold formation happens at increased moisture contents. Most of the insulation material have reduced thermal transmittance in case of high moisture (Riccabona 2008).

The windtightness of a building is as important as its airtightness. Inadequate windtightness can cause similar phenomena like with inadequate airtightness.

Earthquakes in L' Aquilla, Italy

2009 the earthquakes in L`Aquilla in the Abruzzi have devastated a vast amount of buildings and infrastructure. About 300 people were killed and 70.000 people were left homeless. The earthquake had a power of 6.3 on the Richter scale and very few buildings resisted the multiple skakes. The few which are still standing must be prooved if further use is reliable and approveable.

In the meantime the homeless people were sheltered in tents to have a "roof" above theire head. Accordingly, the government of italy was forced to build new houses before the winter arrives.

150 basements, supported by posts and reinforced by concrete were built. On this basements the buildings for each 25 to 30 apartments were contracted according 100 points system. 10 points were given for the realization time, 25 points for the costs and 65 points for the technic such as energy efficieny, sustainability, architecture, interior design, efficieny and resitents concentration per area. The wood construction systems (CLT, frame building systems) won the competition.

CLT construction was delivered by BinderHolz Bausysteme, Unternberg, Austria and prefabricated by Schafferer Holzbau, Matrei, Austria. The ready elements (including part of the installations, insulation and cladding on the outside.

Within a construction time of 80 days thirty 3 - story building with approximately 27.000m² living area were handed over to the people. The costs per m² are about € 1.200 and including the external costs about € 2.400. About 6.300m³ of CLT was used for this project.

Additionally it must be mentioned that the use of wood in earthquake vulnerable areas has several advantages compared to concrete or steel. Due to the fact that ductile and lighter materials can absorb earthquake shakes in a higher degree wood has the weight of 1/6 of concrete and nearly 1/20 of steel. This was approved already in several full scale tests at different laboratories.

Big players for CLT

In Austria there are basically five big CLT producer besides several small companies producing special CLT constructions (curved panels, different wood species etc.).

The big players are CLT (Stora Enso), BinderHolz Bausysteme, KLH, MM CrossPlan and Hasslacher with a total capacity of about 300.000m³/y CLT.

CLT and BinderHolz Bausysteme have already standarized thicknesses to full cm such as 6,8,9,10,12,14,15,16,18,20 etc. up to 40cm.

The maximum length of the produced is mostly about 16 to 18m and the max. width about 2.95m to 3.5m.Various types of presses are in use. Besides the hydraulic press the vacuum press is very common for large scale presses.

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