FACTA UNIVERSITATIS
Series: **Architecture and Civil Engineering** Vol. 13, N° 1, 2015, pp. 57 - 64
DOI: 10.2298/FUACE1501057C

INNOVATIVE STRUCTURAL CLT SYSTEM IN PROJECTING AND BUILDING OF STUDENT HOUSES

UDC 728.54

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Abstract. *The University campuses represent a dominant type of organization of the living activities of students. Buildings and common features, were usually built, in a classical manner. This means that majority of the student living complexes was built in the massive and skeletal structural systems of concrete and steel. This paper deals with the possibilities, advantages and examples of an innovative structural system, named CLT or XLAM system. The XLAM system was developed in Germany around 12 years ago and it has been rapidly spreading in most European countries such as Austria, Switzerland, Italy and Nordic Countries. It is a European innovative timber based material in which timber boards, made of domestic timber species are assembled in layers and glued together crosswise in order to form massive timber wall and floor panels characterized by significant mechanical properties. Such type of structural system can serve as a models for construction of residential, commercial and student facilities in Serbia.*

Key words: *CLT-cross laminated timber, student houses, examples*

1. INTRODUCTION

The CLT system (in which CLT stands for cross-laminated solid timber boards) was developed in Switzerland, Austria and Germany around 12 years ago and it has been rapidly spreading in most European countries such as Italy and Nordic Countries. In the early 2000s construction with CLT increased dramatically, partially driven by the green building movement, but also due to better efficiencies, code changes, and improved marketing.

The CLT is a European innovative timber based material in which timber boards, made of home-grown timber species (mainly Spruce) are assembled in layers and glued together crosswise in order to form massive timber wall and floor panels (Figure 1).

Received May 12, 2015 / Accepted May 28, 2015
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The cross lamination method produces a material with high stability, good mechanical properties, good thermal insulation and a good behaviour in case of earthquake or fire.

The CLT system can be used for single unit housing and multi-storey buildings. The construction process is very quick and feasible even for non-highly-skilled manpower. The CLT panels are strong and stiff whatever is the timber quality, therefore they allow the use of medium-low grades of domestic sawn timber.

An important factor has been the perception that CLT is a ''not light'' construction system. European producers have followed a proprietary approach to manufacturing with European Technical Approval (ETA) reports that allow them to operate, however there are efforts under way to develop a European (EN) standard. Typical building types include multi-family apartment, buildings and educational buildings. The countries leading in the use of CLT are: Austria, Germany, Switzerland, Italy, Sweden, Norway, and the UK with 0,3 million m^3 constructed in place and a 0,6 to 1,0 million m^3 forecast for 2015. New plants are soon to be built in Sweden, Australia and North America. CLT is also known as X-lam ('cross lam') and 'massive timber' (Boellaard and Lootens. 2007).

In the last decade many business residential and school buildings was carried out across Europe by using this technology, such as already mentioned. Classic structures of student houses in masonry or skeletal system of construction can be successfully replaced by CLT technology from the reasons given below.

Fig. 1 Typical cross-section of CLT panel (http://www.trada.co.uk)

2. CLT SYSTEM: GENERAL PERFORMANCES

Environmental performance: CLT has better characteristics than concrete and steel systems in several aspects of environmental performance. Some of them are renewability of timber, recyclability, recoverability, carbon storage, etc.

Fire performance**:** CLT assemblies can inherently have excellent fire-resistance due to the thick cross-sections which, when exposed to fire, char at a slow and predictable rate. Demonstration tests by IVALSA on a 3-storey CLT building: Fire room was protected by gypsum board, and room contents (and later the CLT wall panels) burned for 1 hour without fire spread to adjacent rooms or floors (Frangi, A., Fontana, M., Hugi, E., 2009).

Acoustical Performance**:** It is possible to exceed code requirements for floors and walls. The acoustical performance of CLT has been rated as sound class B and A in Europe. Exterior walls: R_w= 47 to 52 dB (85 mm panel +150 mm insulation) (min. 43), partition walls: R_w= 65 to 75 dB (min. 50), ceilings: up to L_{nw}= 40 dB (max. 53), where, R_w is weighted sound reduction index and L_{nw} is weighted normalized impact sound pressure.

Vibrations: The low damping ratio (about 1% critical damping ratio) is one of the weaknesses of CLT floors. We have to take in account that the higher floor frequency, means easier vibration control, and the lower damping, means the lower comfort of human to the vibrations. Damping to a large extent is affected by the degree of integration of the floor to the surrounding structural parts, especially by the addition of partitions. Increasing of the damping ratio through CLT product design and CLT floor construction details will make CLT floor systems more cost-effective and better positioned to compete with concrete slabs.

Thermal Performance: European sources often suggest that CLT provides thermal mass for a building, which can be associated with heating and cooling energy reductions. CLT has the same fundamental thermal properties as the timber from which it is made. In terms of heat capacity and thermal resistance timber is average among building materials. Values for CLT are improved simply through the virtue of its thickness.

Seismic Performance: Three-and 7-storey full-scale CLT buildings were tested by IVALSA (Trees and Timber Research Institute of Italy) in Japan on the largest shaking table in the world (Figure 2). The buildings performed remarkably well even when subjected to severe earthquake motion like that of the devastating Kobe earthquake (M 7,2 and a=0,8-1,2 g). In the case of the 7-storey building there was no residual deformation at the end of the test. The maximum inter-storey drift was 40 mm (1,3%),while the maximum lateral deformation at the top of the building was only 287 mm. (Frangi 2006).

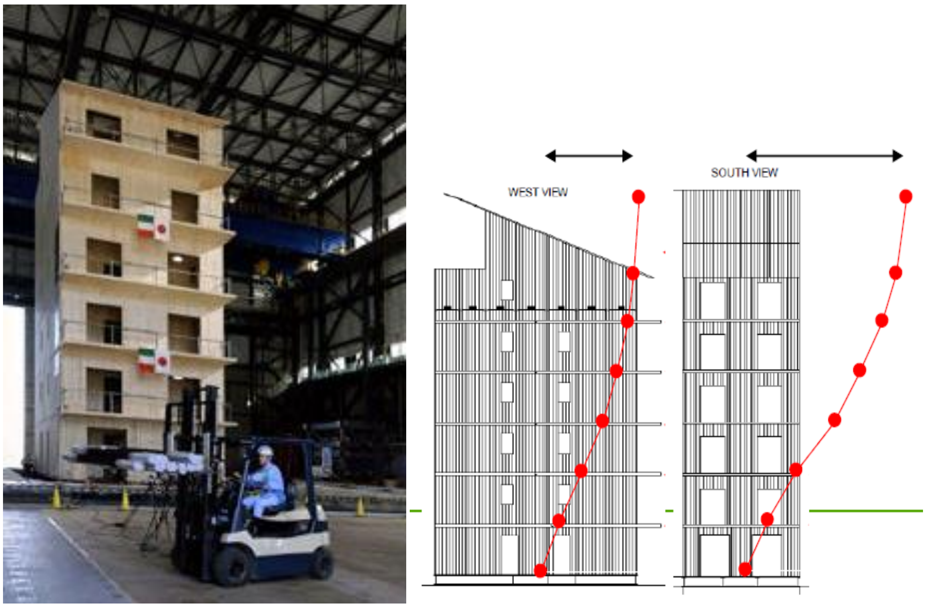

Fig. 2 Seismic performance testing in Japan (http://www.klh.at)

The CLT buildings showed ductile behavior and good energy dissipation. Such behavior was mainly influenced by the mechanical connections used.

Weather Protection: Wall elements may be protected with vapour barriers. Long-term weather exposure is not desirable. One should try to avoid wetting at any time and CLT should be used at a safe distance above ground level. Optionally, a tent can be used to provide a dry and comfortable construction environment. The tent moves up with the building. Simpler protection systems consist of scaffolding and wrapping around the building.

3. Construction and Building Features of CLT System

CLT as a building system has some structural features that architects and engineers may find attractive. It comes from the fact that panels can be used for all assemblies just by varying the thickness. Furthermore, it is possible to achieve, long spans:

- spans up to 7,5 m with no beams or columns (e.g., 230 mm 7-ply floor),
- ,,cassette'' floors allow longer spans. Cassette is also suitable for cantilever
- applications,
- the span can go up to 20 m if "folded" structural CLT systems are used,
- longer spans require glulam columns or beams and trusses,
- floors can be put directly on columns without carrying beams because of the effective potential of spreading point-loads,
- stability is gained out of the diaphragm action of the wall to floor connections,
- dimensional stability and static strength in all directions are provided due to cross lamination process (perpendicular: 1 to 2 mm tolerance for the panels (0,2 mm/m per percent of wood's equilibrium moisture content (10 to14% equilibrium moisture for 35 to 65% relative humidity), parallel: negligible change),
- settlement effects are negligible (e.g., 20 mm for 7-storey building after 1 year),
- high axial load capacity for walls due to large bearing area,
- high shear strength against horizontal loads,
- high buckling capacity,
- feasibility for high-rise construction: There is ongoing work in Europe aimed at targeting high-rise construction.

In terms of assembling and prefabrication, CLT has all the features of prefabricated buildings plus some specific advantages:

- Rapid construction time: Fast construction is probably one of the main attributes of CLT. Team of 2, 4, or 8 carpenters plus one or two mobile crane operators are typically employed in Europe. Some advantages include lower capital cost, faster project turnaround and potential insurance benefits due to fast and safe erection,
- This stability plus the use of CNC routers allows pre-installed windows and cladding. Pre-installed piping, electrical and insulation are also possible. These installations can be placed in the cavity between the plasterboard and the CLT panels,
- Safe: As most work occurs off-site at the factory,
- Less demanding of skilled construction work: The erection of the structure mostly requires carpentry skills and power tools. Only mobile cranes are used.
- Less waste: Little waste is produced,
- Less disruption to neighbours: It is a quick and quiet process, and takes up less space, making it suitable for infill sites and/or additions.

4. EXAMPLES

The following examples of structures built in Europe, in CLT system, illustrate the previously mentioned advantages and characteristics of this innovative construction technology in timber. The basic data on the structures are given (a number of floors, purpose, quantities of used timber material and construction period (Falk, A. 2005)).

Murray grove is townhouse with eight floors of timber structure–the tallest habitable timber building in the world area floors 2 to 8, 2,352 m^2, CLT 950 m^3 (Walls: 128 mm, Floors: 146 mm).

Architects and structural engineers are already working on timber buildings that will be considerably taller. An unusual feature is the cross-laminated timber (CLT) panels used as load-bearing walls and floor slabs. There are no beams or columns anywhere and the structure is being created in walls with relative ease. The building was assembled using a unique structural system pioneered by KLH in Austria, using timber strips glued together (using formaldehyde-free adhesive) in perpendicular layers to form the panels.

Fig. 3 Murray grove Residential: 1+8 stories London, England/2008, (KLH catalogues http://www.klh.at)

Fig. 4 Växjö, Sweden/2008,Residential: 1+7 stories (last as duplex), 4 buildings, 10,700 m^2, CLT 4,800 m^3(KLH catalogues http://www.klh.at).

The Scientia Academy is a new school, meeting the needs of the growing student population of the Burton on Trent area, built on the old Belvedere Park site. A hybrid structure was selected as the optimum design, using cross laminated timber (CLT) and structural steelwork to create flexible and open learning spaces.

Fig. 5 The Scientia Academy in the area of Staffordshire (www.xlam-alliance.com)

Fig. 6 Norwich open academy: 3 stories, UK/ 2010, floor area 9500 m^2,
CLT 3600 m^3, 18 weeks
(KLH catalogues http://www.klh.at.).

5. CONCLUSION

The University campuses represent a dominant type of organization of the living activities of students. Buildings and common features, were usually built in a classical manner. This means that majority of the student living complexes are built in the massive and skeletal structural systems of concrete and steel. The innovative structural system, named CLT or XLAM system, developed in Germany around 12 years ago, made from timber boards assembled in layers and glued together crosswise in order to form massive timber wall and floor panels, characterized by significant mechanical properties can serve as model for construction of residential, commercial and student facilities in Serbia.

Acknowledgement: This paper is a part of the scientific-research project: "Construction of Stu-dent hostels in Serbia at the beginning of 21st century", approved by the Ministry of Science and technological development of the Government of the Republic of Serbia, in Belgrade, January 2011. Project manager, Prof. Ph D Nikola Cekić, Grad. Eng. of Arch. The Faculty of Civil Engineering and Architecture of the University of Nis. Project number: TR 36037.

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INOVATIVNI SISTEM GRADNJE U UNAKRSNO LEPLJENOM DRVETU PRI PROJEKTOVANJU I GRADNJI STUDENTSKIH DOMOVA

Univerzitetski kampusi predstavljaju dominantan oblik studentskog stanovanja. Zgrade koje čine kampuse su najčešće građene na klasičan način u skeletnom ili zidanom sistemu, primenom čelika i betona kao osnovnih materijala. Ovaj rad daje pregled konstrukcijskih mogućnosti, prednosti i konkretne primere gradnje u inovativnom sistemu zasnovanom na upotrebi drveta kao materijala, poznatom pod nazivom unakrsno lepljeno drvo (CLT or XLAM system). Tehnologija unakrsno lepljenog drveta je razvijena u Nemačkoj, pre oko 12-ak godina, ali se njen ubrzani razvoj vezuje i za ostale evropske zemlje kao što su Austrija, Švajcarska, Italija i Nordijske zemlje. Ova evropska inovativna tehnologija gradnje zasnovana na upotrebi drveta tako da se drvene daske određene širine ređaju u međusobno unakrsnim slojevima i spajaju lepkom odgovarajućih svojstava i na taj način dobijaju odgovarajući masivni zidni paneli i monolitizirane međuspratne drvene konstrukcije značajnih mehaničkih svojstava.Ovakav sistem gradnje, sa stalnim rastom primene u razvijenim zemljama, može poslužiti kao model novog sistema koji bi se sa punim opravdanjem koristio prilikom projektovanja konstrukcija stambenih, poslovnih i studentskih objekata u Srbiji.

Ključne reči: *unakrsno lepljeno drvo, studentski domovi, primeri*