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REPORT

FCLT PROJECT | RESEARCHES ON CLT

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Introduction

Cross Laminated Timber (CLT) was developed in Austria and Germany around the year 1990. Initially, it was meant to be a product that could address the amount of waste wood produced by mills. Few years later, there was a joint research effort between the wood industry and academia in Austria, the goal of which was to develop the CLT as we know it today.

It has only been several years since the demand for this type of timber raised. The main factors contributing to this fact were the lack of knowledge of CLT's performance and capability as a heavy construction material. However, due to the recent pro-environmental inclinations and activities, CLT has been gaining popularity as a construction material choice for both residential and non-residential purposes in Europe. Compared to other materials such as concrete and steel, CLT brings several advantages in relevance to environmental performance, such as carbon sequestration, reduced emissions and increased cost effectiveness. (Stauder 2013, 1 [MGB 2012])

As CLT has been becoming more and more popular, research efforts have taken place across the world. The following tables show examples of some research done on CLT. Most of the publications are post-2010, therefore the following tables represent recent research efforts. The title is followed by a number in square brackets, which indicates where the publication was found. The references that are being referred to can be found in References chapter. The tables are sorted by last column to the right, general subject. This column indicates what the research efforts were focused on, sometimes in a more general sense in order to provide better and more comprehensive overview.

Table of the researches on CLT

AUTHOR	TITLE	PUBLISHED	DATE	GENERAL SUBJECT
Rikard Öqvist, Fredrik Ljunggren, Anders Ågren	On the uncertainty of building acoustic measurements – Case study of a cross-laminated timber construction [1]	Luleå University of Technology – Division of Sound & Vibration, SE-971 87 Luleå, Sweden	April 2012	Acoustic performance
Luigi Pagnoncelli, Alessia Gadotti, Antonio Frattari, Laura Moran	Acoustic performance of cross-laminated timber system (CLT): in situ measurements of airborne and impact sound insulation for different configurations [2]	Conference: 40th IAHS World Congress on Housing: Sustainable Housing Construction, At Funchal, Madeira, Portugal	Dec 2015	Acoustic performance
Nicolas Jacquier, Ulf Ame Girhammar	Evaluation of bending tests on composite glulam–CLT beams connected with double-sided punched metal plates and inclined screws [1]	Division of Structural and Construction Engineering – Timber Structures, Luleå University of Technology, SE-971 87 Luleå, Sweden	July 2015	Bending tests
Masoud Sadeghi, Marco Ballerini, Ian Smith, Enrico Pedrotti	Bending Properties of Connections in Cross Laminated Timber [2]	University of Trento, Italy; University of New Brunswick, Canada	May 2015	Connections – bending properties

AUTHOR	TITLE	PUBLISHED	DATE	GENERAL SUBJECT
Pouyan Zarnani, Pierre Quenneville	New design approach for controlling brittle failure modes of small-dowel-type connections in Cross-laminated Timber (CLT) [1]	Department of Civil and Environmental Engineering, Faculty of Engineering, University of Auckland, 20 Symonds St., CBD, Auckland, New Zealand	Sep 2015	Connections – design approach
J. Schneider, Y. Shen, S.F. Stiemer, S. Tesfamariam	Assessment and comparison of experimental and numerical model studies of cross-laminated timber mechanical connections under cyclic loading [1]	Construction and Building Materials journal, Volume 77, 15 February 2015, Pages 197–212	Jan 2015	Connections (mechanical) testing and modelling
Nicolas Jacquier, Ulf Ame Girhammar	Tests on glulam–CLT shear connections with double-sided punched metal plate fasteners and inclined screws [1]	Division of Structural and Construction Engineering – Timber Structures, Luleå University of Technology, SE-971 87 Luleå, Sweden	Oct 2014	Connections tests
Aivars Vilguts, Dmitrijs Serdjuks, Leonids Pakrastins	Design Methods of Elements from Cross-laminated Timber Subjected to Flexure [1]	Riga Technical University, Azenes Str.16, Riga, LV 1048, Latvia	Sep 2015	Design methods
T. Uibel, H.J. Blaß	Edge Joints with Dowel Type Fasteners in Cross Laminated Timber [7]	Universität Karlsruhe, Germany	Aug 2007	Edge joints with dowel type fasteners – load carrying capacity
R. Steiger, A. Gülzow, D. Gsell	Non-destructive evaluation of elastic material properties of CLT [2]	Dubendor, Switzerland	Oct 2008	Elastic properties evaluation

AUTHOR	TITLE	PUBLISHED	DATE	GENERAL SUBJECT
Barber, David	Fire Safe Design of Exposed Mass Timber in Buildings [7]	Presentation: 2015 Mass Timber Research Workshop, Forest Products Laboratory (FPL), Madison, Wisconsin	Nov 2015	Fire - design
Andrea Frangi, Mario Fontana, Erich Hugi, Robert Jubstl	Experimental analysis of cross-laminated timber panels in fire [1]	Fire Safety Journal (research conducted in Switzerland + Austria), Volume 44, Issue 8, November 2009, Pages 1078–1087	Aug 2009	Fire performance
Joachim Schmid, Jochen Köhler, Jürgen König	Fire-exposed cross-laminated timber-modelling and tests [2]	WCTE – World Conference on Timber Engineering 2010	Jan 2010	Fire performance
Laura E. Hasburgh, Keith J. Bourne	Forest Products Laboratory Research on the Fire Performance of Cross Laminated Timber [7]	Presentation: 2015 Mass Timber Research Workshop, Forest Products Laboratory (FPL), Madison, Wisconsin	Nov 2015	Fire performance
Dionysios I. Kolaitis, Eleni K. Asimakopoulou, Maria A. Founti	Fire protection of light and massive timber elements using gypsum plasterboards and wood based panels: A large-scale compartment fire test [1]	Construction and Building Materials journal (research conducted in Greece), Volume 73, 30 December 2014, Pages 163–170	Oct 2014	Fire performance – using gypsum plasterboards and wood based panels

AUTHOR	TITLE	PUBLISHED	DATE	GENERAL SUBJECT
Zhiqiang Wang, Meng Gong, Ying-Hei Chui	Mechanical properties of laminated strand lumber and hybrid cross-laminated timber [1]	Construction and Building Materials journal	Nov 2015	Hybrid CLT – mechanical performance
Lin Wang, Hua Ge	Hygrothermal performance of cross-laminated timber wall assemblies: A stochastic approach [1]	Department of Building, Civil and Environmental Engineering, Concordia University, 1455 de Maisonneuve, Montreal, QC, H3G 1M8, Canada	Dec 2015	Hygrothermal performance
Ruth McClung, Hua Ge, John Straube, Jieying Wang	Hygrothermal performance of cross-laminated timber wall assemblies with built-in moisture: field measurements and simulations [1]	Building and Environment journal (research conducted in Canada)	Oct 2013	Hygrothermal performance
Sam Glass	Hygrothermal Performance of Mass Timber Construction	Presentation: 2015 Mass Timber Research Workshop, Forest Products Laboratory (FPL), Madison, Wisconsin	Nov 2015	Hygrothermal performance
Marjan Popovski, Johannes Schneider, Matthias Schweinsteiger	Lateral load resistance of cross-laminated wood panels [2]	WCTE – World Conference on Timber Engineering 2010	Jan 2010	Lateral load resistance
Olivier Perret, Arthur Lebée, Cyril Douthe, Karam Sab	The Bending–Gradient theory for the linear buckling of thick plates: Application to Cross Laminated Timber panels [1]	International Journal of Solids and Structures	Feb 2016	Linear buckling

AUTHOR	TITLE	PUBLISHED	DATE	GENERAL SUBJECT
A. Hassanieh, H.R. Valipour, M.A. Bradford	Load-slip behaviour of steel-cross laminated timber (CLT) composite connections [1]	Centre for Infrastructure Engineering and Safety School of Civil and Environmental Engineering, UNSW Australia, Sydney, NSW 2052, Australia	March 2016	Load-slip, connectors efficiency, composite system of steel beam and timber slab
Cameron Stauder	An analysis of the Austrian industry and ideas for fostering its development in America [4]	Austria – Fachhochschule Salzburg: University of Applied Sciences	Sep 2013	Market analysis
Chul Choi, Cho-Rong Yuk, Ji-Chang Yoo, Seog-Goo Kang	Physical and Mechanical Properties of Cross Laminated Timber Using Plywood as Core Layer [2]	JOURNAL OF THE KOREAN WOOD SCIENCE AND TECHNOLOGY 43(1):86-95	Jan 2015	Mechanical properties using plywood as core layer
Reinhad Brandner	Production and Technology of CLT: A state-of-the-art Report [2]	Graz, Austria	May 2013	Production and technology processes, quality assurance
E.I. Saavedra Flores, K. Saavedra, J. Hinojosa, Y. Chandra, R. Das	Multi-scale modelling of rolling shear failure in cross-laminated timber structures by homogenisation and cohesive zone models [1]	International Journal of Solids and Structures	Dec 2015	Rolling shear failure

AUTHOR	TITLE	PUBLISHED	DATE	GENERAL SUBJECT
Van De John W. Lindt, Pouria Bahmani, Mikhail Gershfeld, Giraj Kumar Kandukuri, Doug Rammer, Shiling Pei	Seismic Retrofit of Soft-Story Woodframe Buildings Using Cross Laminated Timbers [7]	New Developments in Structural Engineering and Construction, Yazdani, S. and Singh, A. (Eds.), ISEC-7, Honolulu, June 18 –23, 2013; 6 p.	2013	Seismic design
Marjan Popovski, Erol Karacabeyli	Seismic behaviour of cross-laminated timber structures [2]	WCTE – World Conference on Timber Engineering 2012, Auckland	July 2012	Seismic performance
John Van De Lindt, M Omar Amini, Douglas R. Rammer, Philip Line, Marjan Popovski	Developing seismic performance factors for cross laminated timber in the United States [2]	11th Canadian Conference on Earthquake Engineering (research conducted in USA + Canada)	July 2015	Seismic performance
Forest Products Laboratory	Development of Seismic Performance Factors of Cross-Laminated Timber (CLT) [7]	USA - USDA Forest Service, Forest Products Laboratory, Madison, Wisconsin, Research In Progress FPL-RIP-4719-022	2014	Seismic performance
Shiling Pei, Marjan Popovski, John W. van de Lindt	Seismic design of a multi-story cross laminated timber building based on component level testing [2]	WCTE – World Conference on Timber Engineering 2012, Auckland	July 2012	Seismic performance and design of multi-storey cross laminated timber building

AUTHOR	TITLE	PUBLISHED	DATE	GENERAL SUBJECT
Ario Ceccotti, Carmen Sandhaas, Minoru Okabe, Motoi Yasumura, Chikahiro Minowa, Naohito Kawai	SOFIE project – 3d shaking table test on a seven-storey full-scale cross-laminated timber building [3]	Earthquake Engineering & Structural Dynamics journal	May 2013	Seismic performance-suitability of multi-storey x-lam structures for earthquake-prone regions
Renhard Bradner, Philipp Dietsch, Julia Dröscher, Michael Schulte-Wrede, Heinrich Kreuzknger, Mike Sieder, Gerhard Schickhofer, Stefan Winter	Shear Properties of Cross Laminated Timber (CLT) under in-plane load: Test Configuration and Experimental Study [2]	Conference: INTER 2015, At Sibenik, Croatia	Aug 2015	Shear properties
Yuan Li, Frank Lam	Low cycle fatigue tests and damage accumulation models on the rolling shear strength of cross-laminated timber [7]	Journal of Wood Science	March 2016	Shear strength (rolling) of CLT
R. Stürzenbecher, K. Hofstetter, J. Ebergardsteiner	Structural design of Cross Laminated Timber (CLT) by advanced plate theories [1]	Institute for Mechanics of Materials and Structures, Vienna University of Technology, Karlsplatz 13/202, 1040 Vienna, Austria	April 2010	Structural design
Johan Vessby, Bertil Enquist, Hans Petersson, Tomas Alsmarker	Experimental study of cross-laminated timber wall panels [5]	European Journal of Wood and Wood Products	Feb 2009	Structural performance

Conclusion

CLT is a type of timber which can serve as an alternative building material for concrete, masonry and steel construction. Especially countries with sufficient supply of wood can benefit from this type of construction material. In Europe, the cross-laminated timber industry has been growing from year to year.

As can be observed from recent research efforts, the majority of those are focused in fire performance, seismic performance, performance of different types of connectors and fasteners, hygrothermal performance, acoustic performance and design. Seismic performance research has yielded interesting results, as it is suggested that buildings constructed by using CLT have better seismic performance than buildings made of traditional construction materials. This could be very relevant to countries with high seismic activity.

CLT also provides benefits where it is not expected – fire performance. Mass timber actually performs quite well in terms of fire performance, as in fire, the outer layer of the panel forms a charred layer which protects the core of the panel from burning for an impressive duration. In buildings, the fire performance can be easily enhanced by introducing automated sprinkler systems.

As CLT becomes more and more popular, the increased number of research efforts aid in introducing this relatively new material to the general public and in providing better understanding of CLT performance related to its ability to withstand the basic elements – fire, earth, wind and water.

References

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[6] T. Uibel, H.J. Blaß. 2007. *EDGE JOINTS WITH DOWEL TYPE FASTENERS IN CROSS LAMINATED TIMBER.* Available at: http://holz.vaka.kit.edu/public/52.pdf

[7] Forest Products Laboratory. Available at: http://www.fpl.fs.fed.us/products/publications/