Hybrid Cross Laminated Timber Plates (HCLTP)

FINAL REPORT

Title of the research project	**Hybrid Cross Laminated Timber Plates**
Coordinator of the project	prof. dr. Boštjan Brank

BASIC PROJECT DATA

Project period	15.4.2014 – 15.3.2017
Contact information of the coordinator (institute/unit, address, telephone, fax, e-mail)	University of Ljubljana, Faculty for Civil and Geodetic Engineering Jamova 2 1000 Ljubljana +386 1 47 68 594 +386 1 425 06 81 bostjan.brank@fgg.uni-lj.si
URL of the project	http://www.hcltp.com

FUNDING

Total budget in EUR	831.000,00
Public funding from WoodWisdom-Net Research Programme:	Total funding granted in EUR by source:
Austria Federal Ministry of Agriculture, Forestry, Environment & Water Management (BMLFUW)	99.900,00
Finland Tekes – the Finnish Funding Agency for Innovation Academy of Finland (AKA)	[-] [-]
France Ministry of Agriculture, Fisheries and Forestry Resources (MAAF) French Environment and Energy Management Agency	[-] [-]

(ADEME)	
Germany Agency for Renewable Resources (FNR)	244.500,00
Ireland Department of Agriculture, Food and the Marine (DAFM - CoFoRD Programme)	[-]
Norway The Research Council of Norway (RCN)	[-]
Slovenia Ministry of Education, Science and Sport (MIZS)	336.800,00
Sweden Swedish Governmental Agency for Innovation Systems (VINNOVA)	[-]
Switzerland The Commission for Technology and Innovation (KTI; in the Federal Department of Economic Affairs FDEA)	[-]
United Kingdom The Forestry Commissioners (FC)	[-]

Other public funding:

[Name of the funding organization, Country]	[amount in EUR]
[Name of the funding organization, Country]	[amount in EUR]

Other funding:

CBD d.o.o., Slovenia	29.200,00
Studiengemeinschaft Holzleimbau, Germany	10.500,00
Vienna University of Technology, Austria	11.100,00
Stora Enso GmbH, Austria	45.000,00
Ledinek d.o.o., Slovenia	45.000,00
Černivšek Jože s.p., Slovenia	9.000,00

PROJECT TEAM (main participants)

Boštjan Brank, PhD, Professor	Sex (M)	University of Ljubljana	Slovenia
Iztok Šušteršič, BSc, Project manager	Sex (M)	University of Ljubljana	Slovenia
Andjelka Stanić, BSc, Researcher	Sex (F)	University of Ljubljana	Slovenia

Bruno Dujič, PhD, Managing director	Sex (M)	CBD d.o.o.	Slovenia
Wolfgang Winter, MSc, Professor	Sex (M)	Vienna University of Technology	Austria
Simo Aicher, PhD, Academic Director	Sex (M)	Organization	Germany
Thomas Demschner, BSc, R&D Manager	Sex (M)	Organization	Austria
Gregor Ledinek, BSc, Managing director	Sex (M)	Organization	Slovenia

DEGREES (if relevant)
Degrees earned or to be earned within this project.

Year	Degree	Sex (M/F)	Name, year of birth and year of earning M.Sc., D.Sc., etc. Degree	University	Supervisor of thesis, supervisor's organization
2015	BSc	M	Rok Soklič, 1983 2015	University of Ljubljana	doc. dr. Tomo Cerovšek, University of Ljubljana
2017	Master	M	Jaka Brezočnik, 1989 2017	University of Ljubljana	prof. dr. Boštjan Brank, University of Ljubljana

PROJECT SUMMARY REPORT

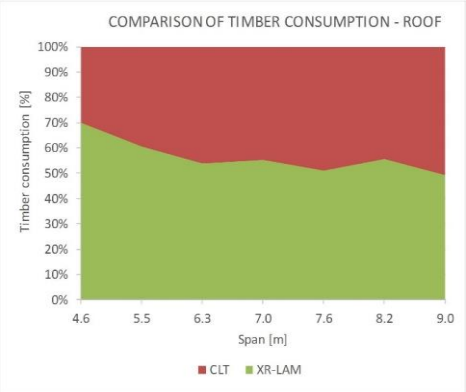
A summary of the project, preferably one page only

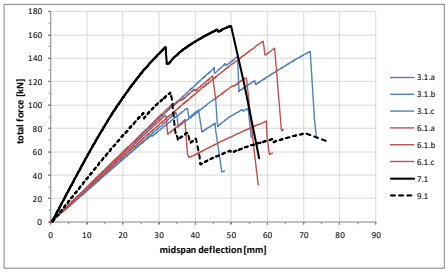
The project was focused on developing, optimising, producing and testing new, upgraded types of cross laminated timber plates. The plates were to be supported with a production line. The new plates, so called hybrid crosslam plates, would be optimised in terms of material use, production cost and other specific conditions (spans, fire resistance, seismic design, outer climate etc.) that would allow for their more effective and economic use. As the quantity of yearly cut timber in Europe is slowly reaching its maximum, its price is consequently rising, making conventional Xlam less competitive on the market on one hand and more straining on the forest of the other. A consortium of seven partners from three European countries, both from the academic and industry sector, was established to fulfil the task.

Two new types of plates were developed; new Xlam plates with glued-in timber ribs and their further upgraded version with and additional concrete layer. On one hand the ribbed-type plates ensure a rational use of material for bridging larger spans. On the other hand, such plates are optimal for building's outer walls, allowing for insulation and a façade system to be installed easier and at lower costs. The new production process development is crucial to ensure that the new product's production costs are kept on the same level as conventional Xlam and therefor ensure a better price performance than the current solutions on the market.

The new ribbed Xlam plates with an additional concrete layer bonded with an affordable connection system were also developed and produced. The aim of such plates is, apart from increasing their load bearing capacity, to enhance their sound insulation properties which often cause problems especially in multi storey and multi apartment buildings and possibly use them as final elements of roof assemblies with concrete serving as a weather protection layer. The concrete layer can also offer a stiff membrane floor response, which is necessary for an efficient seismic design of buildings and eliminates problems with stress concentrations perpendicular to grain in timber.

Over forty large scale and thirty small scale elements were produced (on a prototype production line), experimentally tested and numerically analysed. The new elements use 30-50 % less timber than their conventional counterparts. It was concluded that the elements behave as numerically predicted, or even better, offering even more robustness and a higher safety factor. The production line project was developed to a practically production-ready phase, offering the possibility to enter the market in the near future.





1.1 Introduction

1.1.1 Background

Describe the background of the project and the basic problem that it sought to address.

Cross laminated timber (Xlam or CLT) started its mass production about 15 years ago. Over time it has become one of the most used products in the timber construction industry with its worldwide use growing exponentially. The currently produced Xlam plates, however, still have lots of room for improvement that would allow for their more effective and economic use under different conditions. The aim of this project was the development of new types of cross laminated timber plates, so called hybrid crosslam plates, which could be optimised for specific conditions.

1.1.2 Objectives

Describe the project objectives.

- Development of finite element models for new types of plates
- Parametric study of various material and geometry combinations (timber, glue, concrete, rib spacing and dimensions, plate thickness and layer combinations, rib pre-stressing etc.)
- Experimental testing of theoretically-optimised prototype setups (walls, slabs)
- Experimental testing of individual plate components (i.e. shear connection stiffness and strength)
- Building physics analysis of new plate and wall setups
- Architectural analysis of new wall and slab setups, crossings, details (finalisation, façade etc.)
- Development of a new production line of Xlam-ribbed plates with incorporated ribs (focusing on lamella assembly and pressing process – either hydraulic, pressure or vacuum)
- Optimisation of new products and their production
- Derivation of design principles suitable for technical approvals
- Product marketing strategy development and cost optimisation

1.2 Results and discussion

Main achievements of the project, quality, innovativeness, industrial relevance and contribution to competitiveness, environmental and societal impact.

Calculation and structural design of hybrid timber plates;
New types of cross laminated timber plates were developed, modelled and optimised. A plate with integrated timber ribs and a ribbed plate with an additional concrete layer. Both products use 30-50 % less timber for equal or higher performance than conventional CLT, making them more competitive on the market.

Building physics analysis of the new plates;
The new types of plates were, apart from structural analysis, also modelled for the transmission of moisture, checked for condensation, thermal insulation etc. Architectural integration was foreseen with the appropriate floor-wall intersections. This is very important as the architectural aspects are crucial for a successful integration into the building practice.

Production of specimens;
The plates that were developed and numerically optimised were then also produced on a prototype press. Forty-three specimens of different types with, spans and cross sections were produced. A prototype production press was made which was capable of producing specimens up to 4 m x 1,5 m in floor plan with 28 cm high ribs. It allowed for vertical and side pressing of specimens, ensuring a strong, rigid and robust bond between the ribs and the compression plate.

Experimental tests.
All the large-scale specimens were tested for four-point out of plane bending and wall buckling. In addition, also 30 small-scale specimens were made to investigate the effects of rib gluing beforehand. The testing has shown that the new plates behave even better than expected, offering a more ductile failure mechanism and a more robust and resilient design.

Preparation of production line plan.
The prototype press was further upgraded and developed into a full production line plan with a production capability of 300 000 square meters per year. The press is capable of full 3D pressing (vertical, side, longitudinal) hence ensuring a very robust connection of the ribs to the compression plate.

1.3 Conclusions

The most important contributions to the state-of-the-art, derived from the results and discussion.

New, upgraded types of cross laminated timber plates were developed, using a ribbed concept. It allows for a 30-50 % material reduction at the same load carrying capacity, a higher fire safety and better acoustic performance. It also reduces the cost of the outer envelope as it eliminates the need for a façade substructure. The experimental behaviour shows the new plates fail in a more ductile manner, hardly seen in timber structures and demonstrate a higher wall vertical resistance and more controlled buckling behaviour with a 30 % material reduction. The developed production line is capable of yearly producing 300 thousand square meters of ribbed plates in three shifts. The new product is ready to be implemented into production.

1.4a Capabilities generated by the project

Knowledge generated in the project / outcomes of the project, such as unpublished doctoral theses, patents and patent applications, computer programs, prototypes, new processes and practices; established new businesses; potential to create new business opportunities in the sector.

The ribbed cross laminated plates are protected with a patent. The project also resulted in one diploma work and one master thesis. A prototype press was made during the project and a new production line process was developed. The project products were developed to a high technology readiness level, enabling their market implementation in the near future. As the results show the new product performs substantially better than its conventional counterpart, it has the potential to gain a large market shade.

1.4b Utilisation of results

Give a brief description of how the results of the research and development have been used and/or what is the exploitation plan or plans for transferring the results into practice.

Talks with the industry to establish a production for the new ribbed elements started even before the project was finished. Several existing cross laminated timber producers are interested in the product, hence we expect is will be available on the market in a couple of years.

1.5 Publications and communication

a) Scientific publications

For publications indicate a complete literature reference with all authors and for articles a complete name. Indicate the current stage of the publishing process when mentioning texts accepted for publication or in print. Abstracts are not reported. Indicate the five most important publications with an asterisk.

1. Articles in international scientific journals with peer review

A. Stanić, B. Brank, J. Korelc, On path-following methods for structural failure problems, Computational Mechanics 57: 1-26, 2016

**Stanić A, Hudobivnik B, Brank B (2016). Economic-design optimization of cross laminated timber plates with ribs, Composite Structures, Volume 154, 15 October 2016, Pages 527-537*

2. Articles in international scientific compilation works and international scientific conference proceedings with peer review

Brank B, Stanić A, Hudobivnik B (2015). Simulations of wrinkling of bi-layer composite, Proceedings of the 3rd International Conference on Buckling and Postbuckling Behaviour of Composite Laminated Shell Structures, Braunschweig, 5.-27.3.2015, page 40.

Brank B, Stanić A, Korelc J, Ibrahimbegović A (2015). Tracing equilibrium paths of structures with evolving cracks, Proceedings of the ECCOMAS 2nd International Conference on Multi-scale Computational Methods for Solids and Fluids, 10.-12. 6. 2015, Sarajevo, BiH, 36-37.

**Šušteršič I, Brank B, Dujič B, Brezočnik J, Gavrić I, Aicher S, Dill-Langer G., Winter W, Fadai A, Demschner T, Ledinek G (2016). Hybrid cross-laminated timber plates (HCLTP) - numerical optimisation, modelling and experimental tests. WCTE (World Congress in Timber Engineering), Vienna, 22.-25.8.2016*

**Šušteršič I, Less is more – optimized ribbed CLTs – the future. Proceedings of the 22. Internationales Holzbau-Forum IHF 2016, December 2016, Garmisch.*

3. Articles in national scientific journals with peer review

B. Dujič, I. Šušteršič, S. Aicher (2016). Manj je več: prihodnost križno lepljenih plošč, Ventil, oktober 2016, 69-74.

Lavrenčič M, Brank B, Šušteršič I (2016). Porušni mehanizem križno lepljenih lesenih rebrastih plošč = Failure mechanism of crosslaminated timber ribbed plates. Gradbeni vestnik, dec. 2016, letn. 65, str. 267-276.

4. Articles in national scientific compilation works and national scientific conference proceedings with peer review

B. Dujič, I. Šušteršič, S. Aicher (2016). Manj je več: prihodnost križno lepljenih plošč. Zbornik koference Zgradbe prihodnosti, Cerknica, Slovenija, oktober 2016.

5. Scientific monographs

[-]

6. Other scientific publications, such as articles in scientific non-refereed journals and publications in university and institute series

Brank B (2016). Hybrid cross laminated timber plates, Swedish Wood Building Council & Silent Timber Build seminar, Stockholm 28.-29.4.2016, http://silent-timber-build.com/events/

a) Other dissemination
Such as text books, manuals, user guidelines, newspaper articles, TV and radio programmes, meetings and contacts for users and results.
Dissemination of results to industrial partners and industrial partners dissemination within the company.

A lecture at the Croatia Green Building Council seminar in Zagreb, Croatia. Lecture title: "Sustainable wooden construction in green buildings" (Iztok Šušteršič, 20.3.2015).

A lecture at the Green Building Council Slovenia seminar in Celje, Slovenia. Lecture title: "The development of contemporary technologies in timber construction" (Iztok Šušteršič, 23.4.2015).

**A lecture at the Slovenian research council consultation held at the Slovenian State council. Lecture title: "The vision of a cross laminated timber production in Slovenia" (Iztok Šušteršič, 19. 6. 2015).*

A lecture at the 3rd conference of timber construction. Lecture title: "New technologies in massive timber construction" (dr. Bruno Dujič, 26. 10. 2016).

1.6 National and international cooperation

Give a brief description of the cooperation/ networking (partnership between the project participants and how this has developed; industrial involvement; synergies of industrial and research expertise; Has the project collaborated with similar projects in the WW-Net countries or other regions, or established new links with/ between local or international organisations involved in the respective research field? Describe how these partnerships have supported the project.
National vs. transnational aspects in the project; added value for the project and its impacts which result from transnational cooperation.

The project involved seven partners from three countries. Universities from Slovenia and Austria, a German institute, two SMEs and a medium size company from Slovenia, and a large company from Austria. The consortium was, hence, quite diverse and at the beginning rather challenging to coordinate as small and large companies, institutes and universities have different work principles. As one would expect, on one hand the academia is more interested in the project's scientific aspects and on the other hand the industry cares more for the final results, new product efficiency, added value and the possibility of implementation into production. Overall, the HCLTP project has bridged this gap very successfully, resulting in both in-depth scientific papers considering specific finite element model behavior, a large experimental testing series with a detailed element behavior analysis, as well as a production line development and a new product practically ready for industrial implementation.
Additionally, the HCLTP project had established a close collaboration with the Wood Wisdom Silent Timber Build (STB) project which focused on the acoustic aspects of timber structures. The projects had complemented each other, with the STB giving valuable input for the approach to acoustic design of the elements developed within HCLTP and the later supporting the STB team with structural advice. Cooperation with another Wood wisdom project, EU-Hardwoods for the building sector. The HCLTP ribbed plates were also produced and analyzed for the cases with hardwood ribs, contributing additional information to both the projects.
The national cooperation was running smooth from the beginning. The international had a few problems at the beginning as the national funding and official start of the project was not simultaneous, causing some delays in the first year.
In general, having a wide variety of partners from different countries at the same table can result in both brilliant academic ideas which can end up as market products with a high added value. It is, however, very important that the coordinator can recognize and organize the potential that is at hand and efficiently combine it to work in synergy.