United States Department of Agriculture

Final Report

Title:	**Low Environmental Impact Design for High Strength Light Frames Constructed of Small Diameter Woody Stems and Other Wood Residue**

Sponsoring Agency	NIFA	**Project Status**	COMPLETE
Funding Source	Mcintire Stennis	**Reporting Frequency**	Final
Accession No.	201152	**Project No.**	IND011524MS
Project Start Date	10/01/2009	**Project End Date**	09/30/2014
Reporting Period Start Date	10/01/2009	**Reporting Period End Date**	09/30/2014
Submitted By	Christy Rich	**Date Submitted to NIFA**	02/18/2015

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Recipient Organization

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Performing Department

Forestry & Natural Resources

Non-Technical Summary

Worldwide, there is an urgent need for low-cost housing and durable domestic and school furniture. Many forests are overstocked with small-diameter trees that pose both a fire and a health hazard to the forest. The purpose of this project is to solve furniture and housing problems in disadvantaged areas through the use of wood waste and small-diameter tree stems.

Accomplishments

Major goals of the project

Goal: To provide direction for design for structural wood products with low environmental impact; specifically use of round mortise and tenon joints in light timber frames and furniture constructed of small diameter woody stems and other wood residue. Objectives: 1.Determine the structural capacity of joints, members, bracing, cross frames, side frames, three-dimensional building frames and furniture constructed with round mortise and tenon joints. 2.Determine dimensional stability of members and joint components. 3.Develop manufacturing system for modular light timber frame products. 4.Assess product sustainability and end-of life disposal. Publications: Prepare journal articles on the fabrication of light building frames constructed with round mortise and tenon joints that utilize small diameter tree stems as the basic material of construction. It is anticipated that a manual will be developed and published illustrating the construction of equipment and the fabrication of furniture based on round mortise and tenon joint construction. It is expected that this manual will be directed primarily towards the fabrication of school furniture and in disadvantaged regions. Publication of information related to light framing construction will be restricted to scientific and trade journal articles since code requirements will dictate ultimate use of any constructions developed.

What was accomplished under these goals?

For last four years we focused on development and testing of durable construction systems (building frames and furniture) using lower quality, yet available material. We concluded that by incorporating strength design methodology, durable, useful and aesthetically appealing products could be developed.
During last year, research was conducted in the areas of round mortise and tenon joints applicable for furniture construction and light timber frames. Additional results were also produces in the area of knock-down furniture joinery with fasteners applicable for contemporary case goods construction. Following research outcomes were obtained:
Light-Timber Frames for Transitional Disaster-Relief Housing - Two approaches were presented, namely, a) round (or) square mortise and tenon joint frame construction and b) through-bolt with pipe-nut joint frame construction. Both constructions can be used in post-disaster relief efforts to build canvas covered frame shelters that subsequently can be up-graded into permanent structures for long-term housing. Frames can be as simple or complex as desired. Initial frames may contain only a floor and a framework sufficient to support a canvas covering. Later, studs, rafters, and other members can be added to provide the framework for conventional siding, roofing, etc. No substantive initial foundation is needed because both types of frames are well-suited for simple corner foundation support.
Withdrawal and Compression Tests of Pinned-End-to-End Round Mortise and Tenon Joints Forest Products Journal

-Tests were conducted to determine the withdrawal and compression capacity of end-to-end round mortise and tenon joints constructed of nominal 88.9 by 88.9-mm Hem-Fir studs with tenons cross pinned with either 1 or 2 pins. For specimens with 1 tenon cross pin, withdrawal capacities increased from 9,083 to 14,457 N as tenon diameters increased from 31.8-to 50.8 mm. Comparable values for joints constructed with two (smaller) cross pins ranged from 14,991 to 21,867 N. Capacities of comparable joints with a single 12.7 mm tenon cross pin loaded in compression decreased from 219,951 to 165,696 N as tenon diameters increased from 31.8 to 50.8 mm.

Bending Moment Capacities of L-Shaped Mortise and Tenon Joints under Compression and Tension Loadings - Tests were carried out to determine the bending moment capacities of L-shaped mortise and tenon furniture joints under both compression and tension loadings. Effects of wood species, adhesive type, tenon size (width and length) on static bending moment capacity of joints under the same loading conditions were investigated. An empirically derived expression was developed that estimated the average ultimate bending moment capacity of joints under compression and tension loads of the specimens tested as a function of wood species, adhesive type, and tenon size.

Mechanical Properties of Knock-down Joints in Honeycomb Panels - This study focuses on the usage of demountable furniture joints in combination with 38-mm thick honeycomb panels. These fittings were incorporated into L-shaped corner joints and then tested to determine their bending moment capacity. Overall, seven combinations of dismountable fittings were tested. These groups of connectors represents solution without glue, partly glued connectors and fully glued connectors.

What opportunities for training and professional development has the project provided?

Training (workshops) and information on furniture strength design is offered to furniture manufacturers on the local scale (to Indiana and Michigan furniture producers) and on the global scale to leading researchers in the area of furniture strength design.

How have the results been disseminated to communities of interest?

Results have been disseminated through presentations and publications through consultations with individual furniture producers (in Indiana and Michigan) and internationally through collaboration with Mugla University, Turkey. Also we have worked with NGO groups interested in furniture construction for developing countries.

What do you plan to do during the next reporting period to accomplish the goals?

Project is completed but information dissemination will continue. New project will advance already developed knowledge into product sustainability and end-of life options studies.

Participants

Actual FTE's for this Reporting Period

Role	Non-Students or faculty	Students with Staffing Roles			Computed Total by Role
		Undergraduate	Graduate	Post-Doctorate	
Scientist	0.8	0	0	0	0.8
Professional	0.8	0	0.5	0	1.3
Technical	0	0	0	0	0
Administrative	0	0	0	0	0
Other	0	0	0	0	0
Computed Total	1.6	0	0.5	0	2.1

Student Count by Classification of Instructional Programs (CIP) Code

Undergraduate	Graduate	Post-Doctorate	CIP Code
	1		03.05 Forestry.

Target Audience

peer scientists; industrial leaders; forest products manufacturers; NGO's groups; governmental agencies;

Accession No. 201152 **Project No. IND011524MS**

Products

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2014	NO

Citation

Haviarova, E. and C.A. Eckelman. Light-Timber Frames for Transitional Disaster-Relief Housing. FNR Extension Publication 493-W, Purdue University, Lafayette, IN.

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Submitted	2014	YES

Citation

Haviarova, E. and C. A. Eckelman. 201? Withdrawal and Compression Tests of Pinned-End-to-End Round Mortise and Tenon Joints Forest Products Journal (in review)

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Submitted	2014	YES

Citation

Kasal, A. and C. Eckelman, E. Haviarova, Y. Z. Erdil, ?brahim Yalcin 201? Bending Moment Capacities of L-Shaped Mortise and Tenon Joints under Compression and Tension Loadings. Wood and Fiber Science (in review).

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2013	NO

Citation

Koreny, A., M. Simek, C. A. Eckelman, E. Haviarova. 2013. Mechanical Properties of Knock-down Joints in Honeycomb Panels, BioResources, Vol. 8(4), 4873-4882. http://ojs.cnr.ncsu.edu/index.php/BioRes/index

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2014	NO

Citation

Haviarova, E. and J. Bois, H.P. Quesada. 2013. Development of Optimal Forest Products Supported by LCA, Paper presented at International Scientific Conference of Hardwood Processing, Florence Italy, proceedings.

Other Products

{Nothing to report}

Changes/Problems

LCA analysis and End of Life options will have to deal with challenges of missing and limited inventory data on national scale.