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FINDINGS FROM THE 2022 NORTH AMERICAN MASS TIMBER RESEARCH NEEDS ASSESSMENT WORKSHOP

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ABSTRACT: The 3rd North American Mass Timber Research Needs Assessment Workshop sponsored by the US Forest Service, Forest Products Laboratory was held September 20-22, 2022. The purpose of the workshop was to convene experts on mass timber and cross laminated timber to develop a prioritized list of research needs for the North American mass timber industry. Invited workshop participants included design professionals, academics, industry leaders, and government employees. The workshop built upon prior mass timber research needs workshops that were conducted in 2015 and 2018.

KEYWORDS: mass timber, cross laminated timber, building codes, structural design, fire design, life cycle analysis, economics

1 INTRODUCTION

Mass timber typically refers to engineered wood composites such as cross laminated timber, glulam, and structural composite lumber that have been laminated into large members with unique fire and structural properties. Of the composites that comprise mass timber, cross laminated timber (CLT) has received the most attention in recent research [1-3].

CLT is unique among mass timber composites in that it consists of large panels (up to 18 m long) that can be shipped to the job site with precut fenestrations and easily erected as wall or floor systems [4,5]. CLT was first recognized in the International Building Code (IBC) in 2015 [6]. Following this recognition within the IBC, interest in mass timber, especially CLT has rapidly increased within the United States and Canada. As of December 2022, the number of projects using modern MT and post-and-beam construction in multifamily, commercial, and institutional buildings had grown to 1,677 across all 50 states in the United States, an increase of approximately 40% in just 18 months [7].

In 2015, the US Forest Service, Forest Products Laboratory held a workshop to characterize what was needed to move the mass timber industry in North America forward [8]. A subsequent meeting was held in 2018 [9]. These research needs workshops helped to focus research activities and funding towards high impact research projects within the field of mass timber. Since the original workshop in 2015, research findings have justified code changes that have resulted in increases to the height and area requirements for mass timber buildings recognized within the 2021 and 204 version of the IBC [10].

2 2022 NORTH AMERICAN MASS TIMBER RESEARCH NEEDS WORKSHOP DEMOGRAPHICS

The workshop organizers solicited participation from members of industry, academia, government, and other research institutions. In total there were 132 workshop participants.

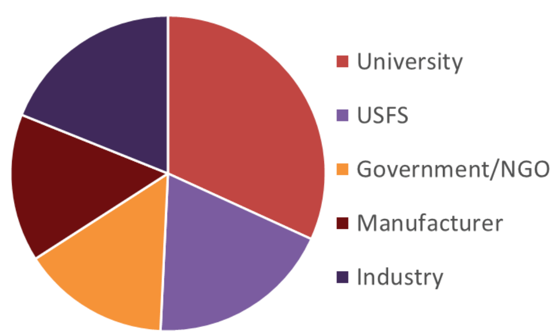

***Figure 1**: Professional composition of the 2022 North American Mass Timber Research Needs Workshop.*

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Figure 1 illustrates the composition of the workshop attendees. The largest group was University participants, with 42 members. The US Government had 32 attendees. The remaining 58 participants represented the industry, including non-governmental organizations that represent the wood industry. The geographical locations of the attendees are shown in (Figure 2), and is highly correlated with North American forest products manufacturing production in the Southeast US, Northeast US and Eastern Canada, and the West Coast of the US and Canada.

Figure 2: *Geographical location of the participants.*

Interestingly, nearly two-thirds of workshop participants had not participated in any of the previous mass timber research-needs workshops. Twenty percent of participants had participated in both previous workshops (Figure 3).

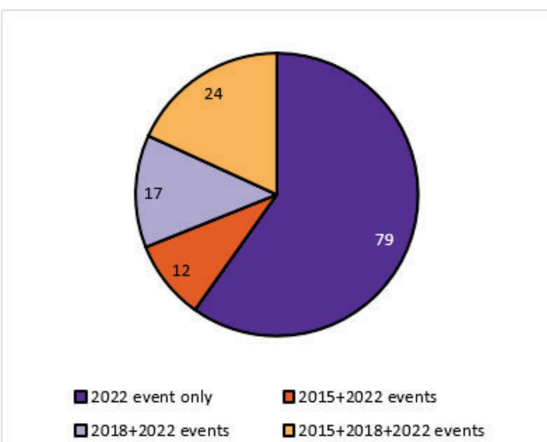

Figure 3: *Number of workshop attendees that had attended either the first or second Research Needs Workshops.*

3 PRIORITIZING RESEARCH NEEDS

Workshop participants were asked to give numerical scores to each research topic (Table 1) in both "effort" and "impact". The results were then plotted in real time on an impact-effort graph (Figure 4). The zero to one hundred scale of *effort* was calibrated by equating fifty percent effort with a 2-year $500,000 total investment of research time and money. This mark was chosen as it corresponds with a single Wood Innovation Grant. No other scaling was offered, so participants had to discuss and judge lower and higher impact efforts as a multiple of the time and budget assigned to the fifty percent effort. Scaling for *impact* was much less certain, because workshop participants were instructed to consider a variety of criteria. High impact could be judged by moving large volumes of wood, making commercial construction more sustainable, or developing a technology that fulfils a niche that competing materials cannot satisfy.

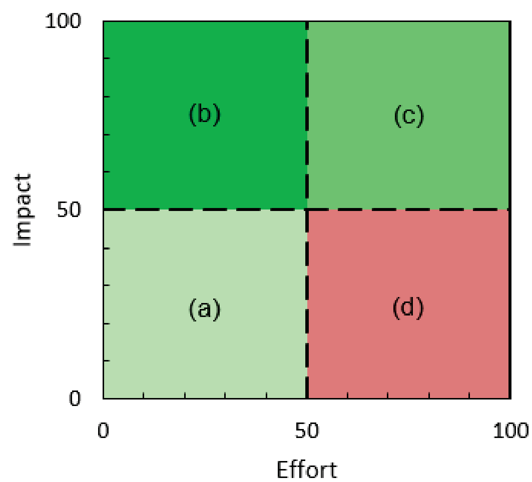

Figure 4: *Example of the impact effort matrix used to plot the results of the research needs symposium.*

Proponents of the impact-effort matrix recommend this type of group evaluation, because the results may be plotted and divided into four quadrants that may assist prioritization [11]. According to the vernacular terms, the bottom left (a), top left (b), top right (c), and lower right (d) quadrants respectively represent *incremental* gains, *easy wins*, *big bets*, and *money pits* [12]. Gilad critiques the standard effort-impact ranking system because people often underestimate effort and overestimate impact. To account for this bias, Gilad suggests using confidence values to redraw proportions of the chart quadrants, which typically renders the regions unequal in size. In addition, Gilad argues that negative impacts should be considered to identify potential *loss generators* in a fifth region of the plot.

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3.1 BREAKOUT SESSION TOPICS

The workshop contained seven breakout sessions for the prioritization of research needs. Workshop participants were divided into four rooms for the prioritization of research needs. Each room contained a moderator and a notetaker. An effort was made to shuffle the composition of the breakout rooms throughout the workshop while keeping the overall demographics similar to the workshop demographics (Figure 1).

Each of the seven breakout sessions covered a different topic (Table 1). Most breakout sessions were two hours long. However, the breakout sessions for "Architectural Research and Construction" and "Sustainability and Economic Analysis" were each only 1 hour long.

Table 1: *Breakout session topic areas*

Order	Subject
1	Fire performance
2	Durability and building physics
3	Architectural and construction research
4	Structural system design and performance
5	Materials and manufacturing processes,
6	Sustainability and economic analysis
7	Infrastructure and nonbuilding applications

The moderators began each session by collecting scores on ten topics that were identified as research needs by the meeting organizers. These topics were typically developed by identifying high priority topics from the previous workshop [9] that had not been addressed.

The 10 research topics suggested for prioritization in the *fire performance* breakout session are included below.

Table 2: *Topics prioritized in the fire performance breakout session*

Order	Subject
1	Non gypsum methods of encapsulation/fire protection
2	Penetrations in CLT for fire protection
3	Char rates for CLT (linear/non-linear models)- extending out to 3 hours
4	Safe amounts of exposed CLT
5	Hybrid connections (Steel + CLT)
6	Adhesives, lamella thicknesses, and delamination risk
7	Minimum separation distances for exposed mass timber surfaces (column to wall/floor or corner)
8	Fire spread in cavities and concealed spaces
9	Construction fires in mass timber buildings
10	Traveling fires in open floorplans

In addition to these research topics, moderators and notetakers were encouraged to collect "write-in" topics from the audience. These write-in topics were also scored within rooms.

3.2 DATA ANALYSIS

Following the workshop, the scores for research topics were then compared across rooms. Each room had a different method for determining a consensus score for the research topic. The polling method in one room asked participant to raise hands at the beginning of each polling period and lower them, when the level of effort that was called out seemed too high. Some hands were lowered early, while others remained up for the entirety of the topic scoring. The moderator, having the best perspective of the entire room had to judge the consensus score, based on values when most participants lowered hands. In other rooms, vocal participants proposed an initial score and revised it higher and lower via debate. Because individual and anonymized input was not recorded during the live polling sessions, the consensus score may be significantly influenced by moderator discretion and peer interactions within each room.

To account for these differences across rooms, it is important to examine both the mean value of the score along with the variation in the score across rooms. To illustrate this variation in the impact-effort matrices, a diagonal line was included for each data point. The length and slope of the error bars provides more insight. Short error bars indicate good consensus, in contrast to long error bars that indicate dissension among the consensus scoring of each room. Error bars with a shallow slope, nearly horizontal, indicate variations in assessing effort while there is general agreement on impact. Error bars with a steep, nearly vertical slope, indicate variations in assessing impact while there is general agreement on effort. Diagonal error bars of approximately one-to-one slope indicate differences in judging both impact and effort. The absence of an error bar typically indicates that a *write-in* topic was mentioned and scored only in one of the discussion rooms.

4 RESULTS

4.1 FIRE PERFORMANCE

The impact-effort graph for the fire performance breakout session is shown in Figure 5. The pre-determined topics for the group are illustrated as numbered topics shown in Table 2 and the write-in topics are listed in Table 3.

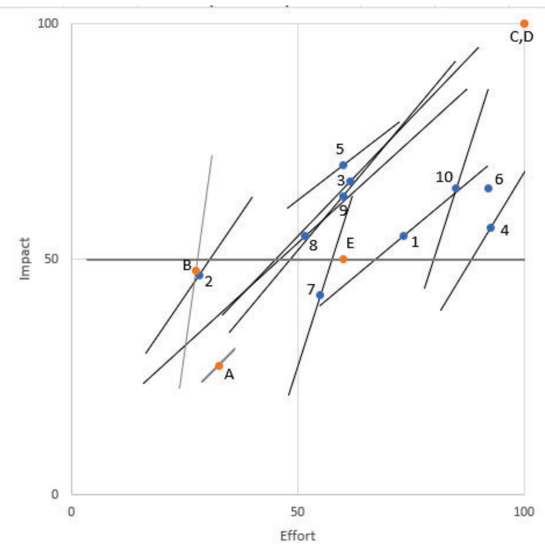

Figure 5:*Impact-Effort matrix for the fire performance breakout session. Numbered points refer to prepared research topics. Lettered points refer to a write-in topic. The topics associated with the numbers and letters are given in Table 2 and Table 3.*

Numerical values of the effort and impact along with the coefficients of variation are given in
Table 4. No topics in the fire research were ranked as "easy wins", that is, lying in the top left quadrant. However, Item B was nearly ranked as an easy win, falling just below the 50% impact. This item involved developing a database of fire tests that could be used for code approvals.

The fire research breakout session had only one item that could be characterized as fell in the lower right quadrant of the graph. This research topic involved determining the minimum safe separation distances for exposed wood members in mass timber structures. It should be noted that different rooms had a widely different view of the impact of this research item; the coefficient of variation was 50%. Most items fell in the upper-right quadrant (which Gilad [12] calls "*big bets*"). This speaks to the cost, and potential impacts of additional fire testing on mass timber.

Table 3: *List of write-in topics for the fire performance breakout session.*

	Subject
A	Post fire impacts: insurance loss models and post-fire repair.
B	Database development for approvals (prescriptive and performance-based design)
C	Fire retardant treated CLT
D	Exterior fire protection systems for mass timber buildings/infrastructure/structures
E	Development of guidelines or tools for performance-based design

Table 4: *Average effort and impact of the topics discussed in the fire performance breakout session along with their coefficients of variation (COV). A description of the items is given in Table* 2 *and Table 3. There was no COV for Item 6 as only one session provided results.*

	Average		COV	
	Effort	Impact	Effort	Impact
Item 1	73	55	25%	27%
Item 2	28	47	42%	36%
Item 3	62	67	46%	43%
Item 4	93	57	12%	31%
Item 5	60	70	20%	13%
Item 6	92	65	-	-
Item 7	55	43	13%	50%
Item 8	52	55	69%	57%
Item 9	60	63	42%	45%
Item 10	85	65	8%	33%
A	33	28	11%	13%
B	28	48	13%	52%
C	100	100	-	-
D	100	100	-	-
E	60	50	94%	0%

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4.2 STRUCTURAL SYSTEM DESIGN AND PERFORMANCE

The impact-effort graph for the structural system design and performance breakout session is shown in Figure 6. The prepared topics for the group are illustrated as numbered topics (1-10) and the numbers correspond with the topics in Table 2 and the write-in topics are listed in .6 and are represented by numbers 11-25.

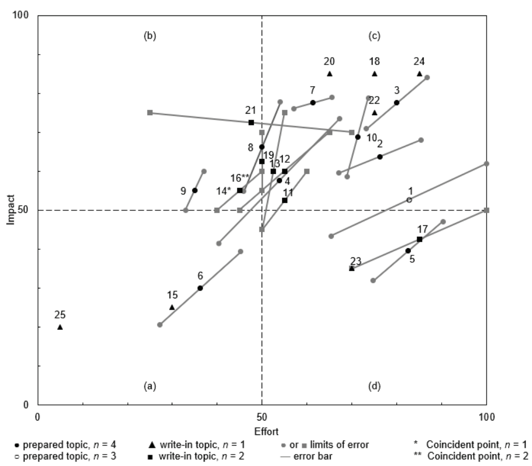

Figure 6: *Impact effort matrix for the structural system design and performance breakout session. Numbered points refer to prepared research topics. Lettered points refer to a write-in topic. The topics associated with the numbers are given in Table 5 and 6 .*

Table 5: *Topics prioritized in the structural system design and performance breakout session*

Order	Subject
1	Full-scale validation testing of structural assemblies (seismic, wind, blast, or progressive collapse simulations)
2	Braced frame development of various configurations (BRBs, specially detailed, concentric, range of ductility R = 3 to R = 6, etc.)
3	Shear wall development of various configurations (rocking post-tensioned or passive, conventional, hybrid, stiff R= 1.5 vs. ductile R= 6, etc.)
4	Diaphragm development of various configurations (simple span, cantilever, service, failure, load and displacement capacity, chord and fastener details)
5	Moment-frame development of beam-to-column connections (post-tensioned or passive systems)
6	Protective performance for multi-hazard resilience (wind-launched debris, blast and ballistics, disproportionate/progressive collapse)
7	Two-way slab development (post-tensioning, punching shear, load distribution, etc.)
8	Glued-in and cast-in connection development for improved force transfer in panelized and hybrid assemblies
9	Perp to grain bearing capacity and characterization of deformations under uniform and varying loads
10	Mass timber slab development for composite action, enhanced stiffness and vibrational characteristics

Table 6: Write-in topics for the structural systems design and performance session

	Subject
11	Standardization of mass timber rocking walls
12	Compare panelized SCL alternatives to CLT (e.g. GLT, NLT, DLT, LVL, MPP)
13	Mass timber moment connections
14	Screw reinforcement of mass timber
15	Edgewise bending of CLT beams
16	Penetrations and holes through mass timber panels and beams
17	Full-scale progressive collapse testing
18	Connection details for seismic displacement compatibility
19	Period estimation via vibrations monitoring for seismic and wind design
20	Intermediate shear wall - ordinary with ductile hold downs
21	Reinforcing at notches/openings of mass timber panels and beams
22	Timber-to-timber composites and built-up structural members
23	Full scale blast testing- windows, connector system
24	Seismic tests of 4-8 story buildings with fully wood systems
25	CLT tornado saferooms

The structural design section contained one item that fell into the lower right quadrant of the graph, Item 5, "Moment-frame development of beam-to-column connections (post tensioned or passive systems). The session also contained one "*easy wins*" in the top right quadrant, Item 9, "Perp to grain bearing capacity and characterization of deformations under uniform and varying loads." A summary of the scores along with the coefficients of variation are given in Tables 7 and 8.

Table 7: *Average effort and impact of the topics discussed in the structural system design and performance breakout session along with their coefficients of variation (COV). A description of the items is given in Table 5.*

Topic	**Average**		**COV**	
Number	Effort	Impact	Effort	Impact
1	83	53	36%	31%
2	76	64	24%	13%
3	80	78	17%	17%
4	54	58	50%	55%
5	83	40	19%	38%
6	36	30	50%	62%
7	61	78	14%	4%
8	50	66	16%	35%
9	35	55	12%	18%
10	71	69	7%	29%

Table 8: *Average effort and impact of the topics discussed in the structural system design and performance breakout session along with their coefficients of variation (COV). A description of the items is given in*

Topic	**Average**		**COV**	
Number	Effort	Impact	Effort	Impact
11	55	53	13%	20%
12	53	60	26%	24%
13	53	60	7%	35%
14	45	55	-	-
15	30	25	-	-
16	45	55	16%	13%
17	85	43	25%	25%
18	75	85	-	-
19	50	63	0%	17%
20	65	85	-	-
21	48	73	67%	5%
22	75	75	-	-
23	70	35	-	-
24	85	85	-	-
25	5	20	-	-

Note: COV = Coefficient of variation
No COV reported if $n = 1$
$n = 2$ unless noted otherwise

4.3 OTHER BREAKOUT SESSIONS

Given the space constraints of the proceedings paper, it is not possible to present all the data collected at the 2022 Mass Timber Research Needs Workshop. However, the full proceedings from the workshop will be available from the Forest Products Laboratory and WoodWorks.

5 FUTURE WORK

The research needs collected during the 2022 Mass Timber Research Needs Workshop will be used to guide mass timber research over the next few years. Coordinated efforts on mass timber research can continue to help the adoption of CLT and other engineered wood composites in building sectors of the United States and Canada.

6 ACKNOWLEDGEMENT

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