Mass Timber Structural Engineering Curriculum: Assessment of Current Teaching and Resource Needs

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Abstract

Mass timber is an emerging construction technology growing in popularity in the United States and throughout the world. This is because of the various benefits of mass timber, such as structural stability, fire performance, ease of construction, low carbon footprint, and biophilic aesthetic. One identified obstacle in the gradual adoption of mass timber construction is the limited availability of qualified engineers. Structural engineers are needed to design safe and resilient buildings using advanced construction materials and techniques. Currently, most structural engineering professionals learn mass timber design while working post-graduation rather than from coursework. This is due, in part, to a lack of timber and mass timber education offered at the undergraduate level. Historically, universities have offered timber-focused design courses. However, currently these are much less commonly taught than concrete and steel design. To train the next generation of civil engineers to be designers of mass timber projects, more structural engineering courses are needed that focus on the design of mass timber structures.

The purpose of this research is twofold. First is to identify gaps in teaching related to timber, creating an outline of the current state of timber-focused curriculum within civil engineering. Second is to assess where there are needs and opportunities to improve available resources to support programs interested in integrating mass timber structural design into their curriculum. To achieve the first objective, this research identifies and documents existing timber engineering courses available to undergraduate and graduate students and instructors in the United States. The two largest higher educational institutions by enrollment in each state were assessed to inventory courses related to engineering design that mentioned “timber” or “wood” in their course description, resulting in 63 total identified courses across the institutions surveyed. These were evaluated to determine the availability and composition of timber-related design and engineering courses, as well as to identify the programs offering instruction in the discipline. To achieve the second objective, instructors of the identified courses were contacted, resulting in 11 Zoom-based interviews. These structured interviews focused on understanding details of the courses currently taught, the resources used by the instructor to teach these courses, gaps in the available resources, and suggestions on what new educational resources are needed to help increase the availability of mass timber-related courses taught nationwide.

Results showed that 59% of the higher educational institutions investigated offered an undergraduate- or graduate-level course(s) in timber design, although the frequency of teaching is often not clear. The analysis of available undergraduate-level coursework suggests that structural engineering programs do not prioritize the instruction of timber-related courses, resulting in limited timber design education. These results provide clarity on the need for additional curriculum to ensure graduating structural engineers are prepared to work with mass timber elements. Additionally, the available course inventory and interview results suggest that

increased prioritization of timber courses and resources is needed to support a growth in instruction of mass timber within the structural engineering discipline.

Introduction

Among modern construction projects of mid- to high-rise structures in the United States, concrete and steel structural elements dominate. Although these materials are widely used, the environmental impact of the use of concrete and steel is important to consider, particularly given increasing climate change concerns [1]. In terms of production, for every ton of steel or cement produced, it is estimated that 1.85 tons and 1 ton of carbon dioxide are emitted, respectively [2]. An alternative structural material increasingly being used in such construction projects across the United States is mass timber, i.e., massive, engineered wood products. The potential climate benefits due to the sequestration of carbon in the wood fibers has resulted in the emergence of mass timber as a more sustainable alternative. Recent research suggests that mass timber structures have an average embodied greenhouse gas emissions that is 43% lower than structures made from reinforced concrete [3]. In addition, due to its prefabricated nature, mass timber structures can also be installed on site more quickly than steel and concrete structures, thus decreasing on-site construction time [2]. Superior structural stability during earthquakes and fire resistance have further contributed to the implementation of mass timber in the U.S. [2]. However, compared to steel and concrete, there has historically been less exposure to timber and mass timber design methods in structural engineering education in the U.S.

In a nationwide survey of 100 randomly selected construction companies, 94% indicated that they were aware of mass timber but only 45% reported having experience working with or designing structures utilizing mass timber [4]. A similar lack of experience was demonstrated in U.S. architecture firms, where 57.5% reported being unfamiliar with or having never heard of mass timber [4]. This is expected as mass timber was only recently introduced in the U.S. (mid-2000s) [2]. As mass timber projects continue to increase in popularity across the country, gaps in existing curriculum begin to emerge, particularly in undergraduate and graduate civil engineering programs. As such, structural engineering students entering the industry are likely unaware of the methodology, techniques, and the available and rapidly evolving resources used for the design of timber and mass timber structures [5]. Currently, structural engineering professionals working on mass timber projects have developed the necessary competencies through their work post-graduation rather than through coursework [5]. Expanding structural engineering curriculum to support more broad availability of timber and mass timber focused design courses can help to reduce the need for timber-focused structural engineering training in industry. It should also increase structural engineering firms' awareness of and capacity to support the increasing use of mass timber structures throughout the United States.

In an initial effort to support the expansion of mass timber curriculum in the U.S., it is first important to understand the extent to which mass timber design, and more broadly, timber design is taught at U.S.-based higher educational institutions. A review of recent literature suggests that there has not been an investigation to understand the extent to which this is taught. In addition, there is no known literature available to suggest what kinds of knowledge and resource gaps in structural engineering education exist in the mass timber design space that may be preventing the increase in teaching of such coursework; similarly, it is not known what resources would be most helpful to support further teaching of mass timber design. Therefore, in this research, an inventory of higher educational institutions currently offering instruction in timber design was

conducted to better understand the availability and composition of these engineering. Interviews were also conducted with structural engineering instructors to obtain detailed information on current instructional methods, as well as teaching challenges, opportunities, and further needs. The results of this research establish an understanding of the current state of structural engineering mass timber design teaching, as well as identification of opportunities to further support mass timber design. The remainder of this research is organized as follows: the methods section discusses how the course data was collected and how interviews were conducted; the results and discussion include the findings from the course review and interviews, and the conclusions summarize findings, as well as discuss limitations and future work.

Methods

A multi-step process was completed to better profile the current state of timber- and mass timber-related instruction in structural engineering curriculum within the United States. First, an inventory of current timber design and engineering courses was compiled. Second, interviews were conducted with faculty identified during the course search. These methods are further outlined in the sections below.

Course Inventory

Of the top 50 institutions by total bachelor's degrees awarded in Civil Engineering in 2022, 48 were public [6]. Following this statistic, when conducting the course inventory, the two largest public institutions of higher education (based on Fall 2022 enrollment data) were considered in each state (n=100). The research team recognizes that there are other institutions beyond these 100 teaching civil engineering and that using this set of institutions does not encompass all coursework offered to students in the U.S. However, following this method enables a reasonable scope while still supporting evaluation of a broad cross-section of civil engineering programs. For the educational institutions identified, the online course catalogs were reviewed for undergraduate- and graduate-level engineering courses related to timber or wood. Course titles and descriptions were screened for keywords, including "wood," "timber," "design," and "engineering." General civil engineering materials courses were excluded from the inventory as this assessment focused on courses including content on the design of timber structures. All identified course codes and titles were compiled, as well as any available syllabi and instructor contact information.

Instructor Interviews

Following the course inventory, available contact information was used to reach out to all identified instructors listed to be teaching the timber or mass timber focused coursework within civil engineering. Structured interviews were then conducted to better understand the content of the courses being taught, the resources used, and what gaps prohibit effective instruction of timber and mass timber courses, and where there are opportunities for further improvements and resource development. To maintain consistency, all interview participants were required to be current instructors or to have previously served as an instructor for a relevant course at a higher educational institution. During the interview, each participant was asked to state their title and describe their experiences with timber and mass timber, including their teaching and educational backgrounds, any industry experience, and their involvement in any relevant research projects.

The participants were then asked a series of questions regarding their current course of instruction. Participants were asked to describe how they came to teach the course, commenting on if the course was self-developed or inherited from another instructor. Participants also were asked to describe the course's focus and to estimate the percentage dedicated to concepts of mass timber. They were then asked to outline which concepts related to mass timber, including cross-laminated timber (CLT) and glue-laminated timber (glulam), are covered in the course and the extent to which these concepts are discussed. Lastly, participants were asked to describe the types of references used to guide the development of their instructional materials related to timber and mass timber.

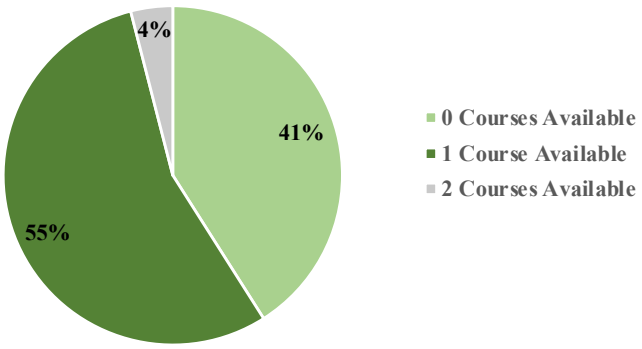
The remaining questions focused on challenges in teaching timber and mass timber coursework, and opportunities for improvement and additional resource development. Specifically, participants were asked to describe what gaps they have experienced in currently available resources that they feel impact how well they are able to teach concepts related to mass timber. The participants were asked to elaborate on this idea, including a commentary on what types of materials they would find most helpful when developing content (e.g., lecture notes, assessment materials, case studies, or student design project outlines.

For analysis of the interview data, open-ended responses were summarized then coded by common themes in response to each of the questions. These codes were then used for analysis.

Results and Discussion

Course Inventory

Of the 100 institutions surveyed, 59 were identified to offer at least one course in timber design (Figure 1). Of the 59 institutions currently offering courses in timber design, 55 only offer one course, while the other 4 offer multiple courses at both the introductory and advanced levels, resulting in 63 total courses. The fundamental courses are primarily offered to undergraduate students while the advanced courses are offered to those completing graduate coursework. Several of the courses inventoried also covered a combination of timber and masonry design content. Figure 2 shows the distribution of only timber (n=53) and timber/masonry hybrid courses (n=10) offered across the survey universities.



Note: "Available" means that the course is listed as being offered. Frequency of offering is not considered in this inventory.

Figure 1. Percent of surveyed U.S. public higher educational institutions (two largest per state, n=100) offering engineering courses related to timber design.

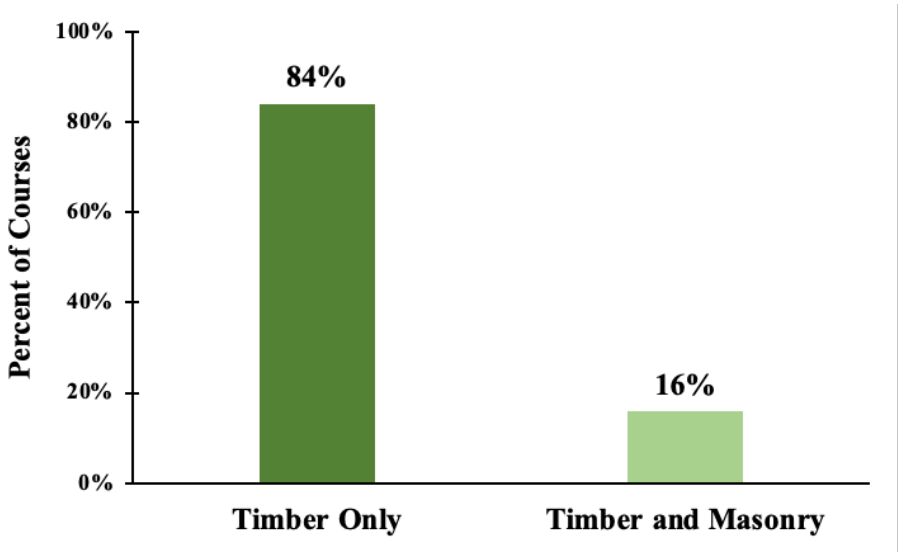
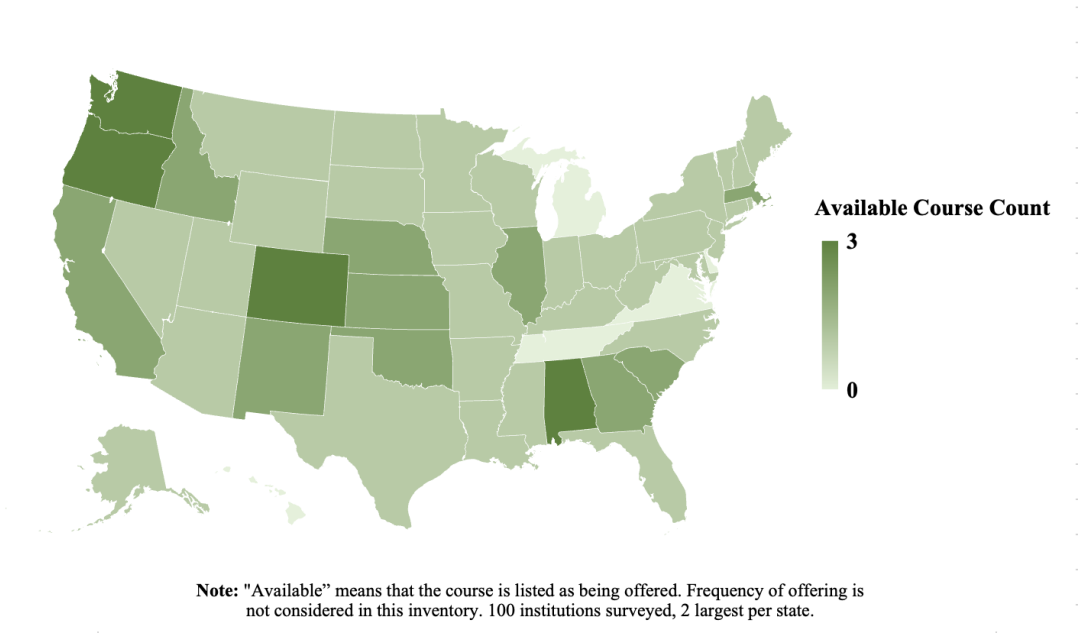


Figure 2. Percent of courses (n=63) covering only timber and/or a combination of timber and masonry design at the surveyed U.S. public higher educational institutions. ***Note: 100 institutions surveyed, 2 largest per state*****.**

Figure 3 shows the distribution of the available courses across the United States. The highest concentration of available courses at higher educational institutions appears to be in the Pacific Northwest (PNW), the U.S. region including Washington, Oregon, and Idaho. This is likely due to the Pacific Northwest being heavily forested, resulting in a large portion of industrial sector using wood products, such as mass timber manufacturers and designers, thus encouraging increased education of these subject areas [7]. Similarly, it is anticipated that there would be more timber courses at higher educational institutions south of the Mason-Dixon line (i.e., the boundary between Maryland and Pennsylvania) and east of the Great Plains (the grassland region east of the Rocky Mountains), regions populated with southern yellow pine forests commonly used in mass timber products in the U.S. [8]. However, unlike the PNW, only three states were noted to have more than one timber engineering-focused course in this region (Alabama, Georgia, and South Carolina). Interestingly, Colorado and Alabama each had 3 documented timber-focused courses. This is possibly due to the surveyed institutions in these states offering more diverse engineering curriculum, however further investigation is needed to best understand if there is a reason for this.



Note: "Available" means that the course is listed as being offered. Frequency of offering is not considered in this inventory. 100 institutions surveyed, 2 largest per state.

Figure 3. Concentration of currently available courses in timber design across surveyed U.S. public higher educational institutions.

Instructor Interviews

The backgrounds of the interview participants are shown in Table 1. In total 11 interviews were conducted, with 10 of the participants being current instructors within the United States. Participant K taught in Canada; however, Participant K was still included in this in the study. This was determined since it allowed for a larger sample size, and since Participant K indicated that many of their students came to their institution in Canada from the United States due to the uniqueness of their program and courses. Most participants were Assistant or Associate Professors, and all but one had experience in teaching timber or mass timber courses. Participant E did not have prior experience instructing in timber or mass timber concepts. However, they were in the process of developing a timber course. It was determined to include them in the results and analysis since their feedback on challenges and opportunities in teaching and developing course content in this area would be uniquely helpful.

Table 1. Experience and background information of interviewed structural engineering instructor participants.

Participant	Title	General Timber Experience	Mass Timber Experience	Region	Fall 2023 Enrollment†
A	Professor of the Practice	Design, Industry, Teaching	Teaching	Southeast	19,500
B	Lecturer	Design, Graduate School, Teaching	Research, Teaching	Northeast	11,300
C	Associate Professor	Industry, Teaching	Industry, Teaching	Southeast	9,000
D	Assistant Professor	Industry, Teaching	Teaching	Midwest	56,400
E	Assistant Professor	-	-	Midwest	60,000
F	Associate Professor	Research, Teaching	Research, Teaching	Southwest	69,600
G	Adjunct Professor	Industry, Teaching	Industry, Teaching	Southeast	32,100
H	Associate Professor	Graduate School, Teaching	Research, Teaching	Southeast	33,000
I	Assistant Professor	Design, Graduate School, Research, Teaching	Teaching	Southwest	32,700
J	Associate Professor	Teaching	Industry, Teaching	West	36,800
K	Project Lead, Instructor	Industry, Teaching	Industry, Teaching	Canada	50,000

Note: Participant E was developing but had not yet taught a timber course.
† Enrollment numbers taken from institution websites.

Most participants reported having more experience with general timber concepts compared to mass timber concepts. This is not surprising given that mass timber is a much newer concept to the United States than is timber design. Figure 4 shows the most common avenues through which the participants gained their experience in timber and mass timber concepts.

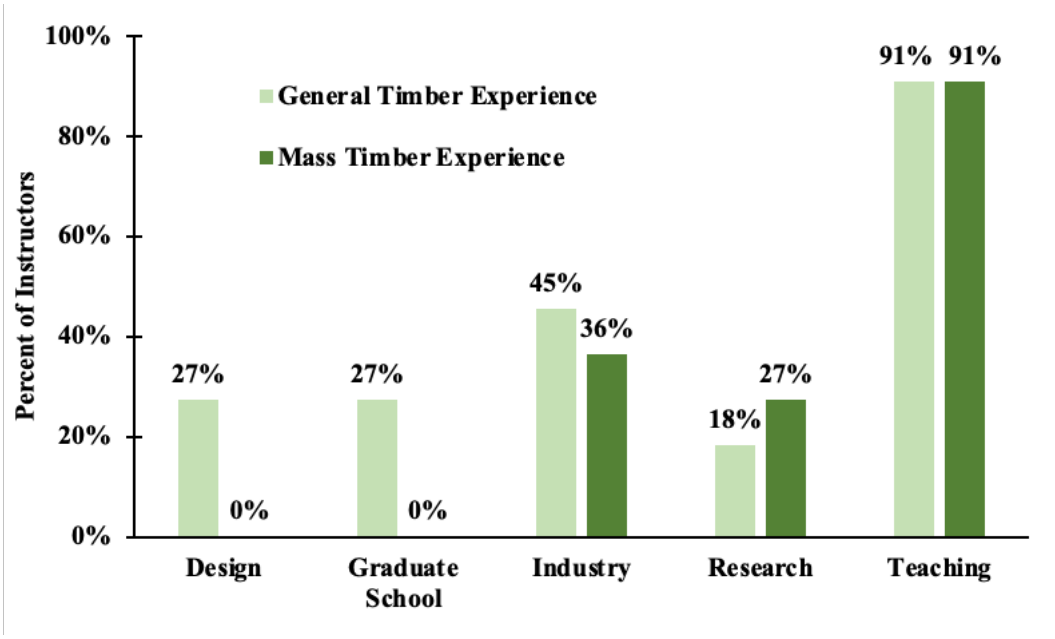


Figure 4. Interviewed structural engineering instructors' experience working with timber and/or mass timber (n=11).

As expected, 10 of the participants had prior teaching experience with timber and mass timber. Of the 10 that had taught timber or mass timber courses, in addition to their role as an instructor, 5 of the participants (50%) had industry experience with general timber concepts and 4 had industry experience with mass timber (40%). Three of the interview participants (30%) reported working with general timber design concepts during their graduate studies, however, none of the participants reported having any formal coursework in mass timber. This is likely due to a lack of available courses resulting in engineers gaining their first timber and mass timber experience

while working in the industry post-graduation. It is also worthy to note that while 45% and 36% of participants reported having industry experience with timber or mass timber, respectively, the remaining 55% and 64%, respectively, did not and were teaching based on teaching experience or research experience alone. This suggests that for this set of instructors in particular, they may not have access to industry feedback, resources, or case studies that the others may have, and that they likely can benefit from more industry support to enhance teaching, particular in such a rapidly evolving field.

Table 2 shows the interview responses related to the structure and content of the courses taught by the participants. Specifically, the table includes the "Course Focus" which outlines the key concepts covered in the course, how they came to teach this course (inherited or self-developed), the approximate percentage of the course that includes concepts of mass timber, and which mass timber concepts are covered. Six of the interview participants (60%) teach a timber design-focused course, three (30%) instruct a timber and masonry design course, and two instruct a course related to construction practices involving timber (20%). Additionally, four of the participants (40%) directly inherited their course from another instructor and another six participants (60%) created their course without existing content or guidance. As previously noted, Participant E was in the process of developing their timber and masonry design course at the time of the interview, and thus unable to comment on the percent content and topic coverage.

Table 2. Timber design course focus areas and mass timber coverage of the timber courses currently taught by the interviewed structural engineering instructors (n=11).

Participant	Course Focus	How did you come to teach this course?	What percent of the course includes concepts of mass timber? (Self-reported)	What mass timber concepts (CLT, glulam, etc.) are covered in the course?
A	Timber and Masonry Design	Self-developed	2%	Glulam, CLT
B	Timber and Masonry Design	Inherited	33%	Glulam, CLT
C	Timber Construction	Self-developed	40%	Glulam, CLT
D	Timber Design	Inherited	20%	Glulam
E	Timber and Masonry Design	In Development	-	-
F	Timber Design	Self-developed	2%	Broad Overview
G	Timber Design	Self-developed	33%	Glulam, CLT
H	Timber Design	Inherited	10%	Glulam, CLT
I	Timber Design	Inherited	30%	Glulam, CLT
J	Timber Design	Self-developed	40%	Glulam, CLT
K	Timber Construction - Trades	Self-developed	100%	Construction of Mass Timber Structures

Although each of the courses considers timber design concepts, Table 2 demonstrates the extreme variation in mass timber coverage within these courses. The range of mass timber coverage is 2-100%, however, the timber design courses have greater variability in percent coverage (2-100%) compared to the combined timber/masonry design courses (2-33%). This variability suggests there are inconsistencies in coverage of timber and mass timber education.

In terms of types of mass timber concepts covered, most instructors interviewed indicated that there was coverage of concepts for both Glulam and CLT design (70%). However, it is important to note that there was significant variability within responses to this question in terms of content specifics. For example, eight participants mentioned covering glue-laminated timber (glulam), but only three participants provided specific details on coverage of glulam connections and applications. A similar conclusion can be made regarding CLT. Due to the variability in details provided by instructors, the Table was simplified to only state what type(s) of mass timber are covered rather than details on specific concepts.

Regarding resources used by the interviewed instructors, Table 3 identifies what resources are currently utilized in coursework, and what resources are referenced as supplemental materials. Figure 5 demonstrates the categorization of the responses in a visual format. Among the possible categories of references, responses were divided into *Design Standards, Academic Resources, Industry Resources, and WoodWorks Resources.* Considering these categories, *Design Standards* were among the most commonly used to guide course development and instruction. Approximately 55% of respondents (n=6) stated they use the National Design Specification (NDS) for Wood Construction [9] and an additional 27% of respondents (n=3) mentioned use of both the main NDS and the NDS Supplement [10] during instruction. Another commonly utilized category was *Academic Resources*. 64% of participants (n=7) reported using textbooks in their course and another 27% reported using online videos as aides during instruction (n=3). Industry materials, including vendor product specifications (27%, n=3), and resources provided by WoodWorks (36%, n=4) were also noted as supportive resources.

Table 3. Percent of interviewed structural engineering instructors (n=11) utilizing various resources for timber-related course development and instruction.

Category	Resource	Currently Utilized Response Rate	Supplemental Response Rate
Design Standards	AWC *National Design Specification (NDS)*		
	Main only	55%	9%
	Main and Supplement	27%	-
	CLT Handbook/Design Guide	27%	9%
	ANCI/AWC *Special Design Provisions for Wood and Seismic (SDPWS)*	27%	-
	Engineered Wood Association *Load-Span Tables for APA Wood Structural Panels*	9%	-
	Forestry Products Laboratory (FPL) *Wood Handbook*	9%	-
Academic Resources	Textbooks		27%
	Design of Wood Structures - ASD/LRFD, 8th ed.[11]	55%	-
	Structural Wood Design - ASD/LRFD, 2nd ed.[12]	9%	-
	Online videos	27%	-
	Teaching Seminar for Timber	-	9%
	Instructional Tools and Materials		
	Example Syllabus	-	9%
	Lecture Materials	-	27%
	Problem/Solution Sets	-	18%
	Assessment Materials	-	18%
	Design Projects	-	36%
Industry Resources	Vendor Products Specifications		
	Unspecified	18%	18%
	Simpson Strong-Ties Wood Construction Connectors catalog	9%	-
	Publications	18%	-
	Case Studies	9%	18%
	Site Visits and Tours	-	9%
WoodWorks Resources	Seminar Videos	9%	-
	Website	9%	-
	Local Representative	18%	-

Note: "Currently Utilized" refers to resources that participants currently use in course instruction. "Supplemental" refers to resources that participants believe are currently unavailable but would be beneficial for future course instruction.

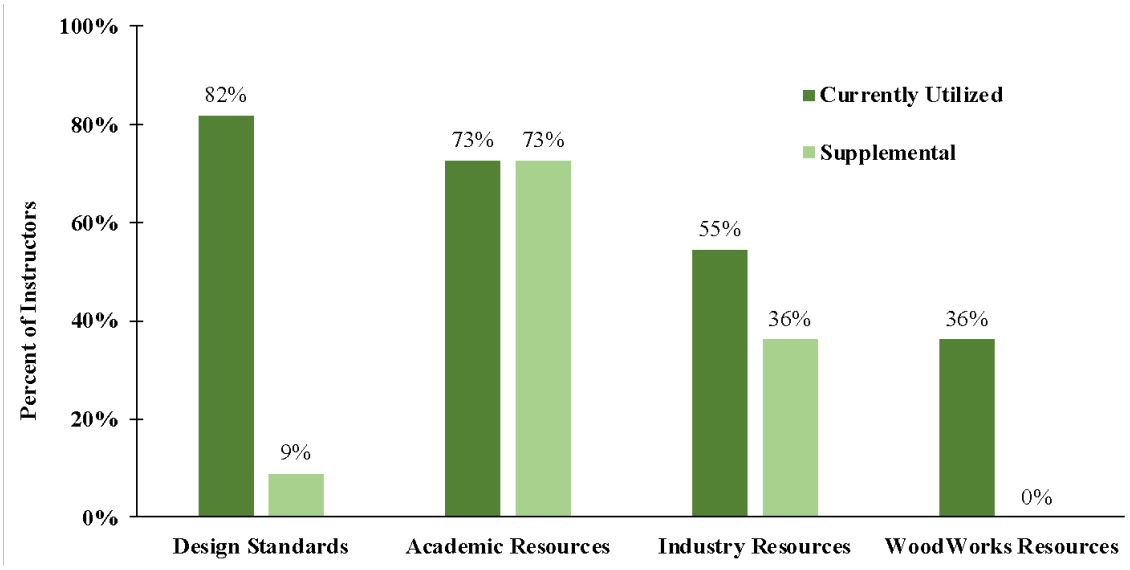


Figure 5. Percent of interviewed structural engineering instructors (n=11) indicating current use of or supplemental reference to timber-related resources, sorted by type of resource.

Participants were then asked to describe their experience finding materials to support the instruction of their course and to suggest any supplemental resources that could potentially resolve any challenges that have prevented them from adequately teaching mass timber concepts. The open-ended feedback from participants indicated that there is a significant gap in resources dedicated to the instruction of timber within the structural engineering discipline. The participants stated that the development of instructional tools and materials would ease the gaps in available resources. Suggested materials included student design projects (36%, n=4), lecture materials and notes (27%, n=3), practice problem/solution sets (18%, n=2), and example assessment questions and materials (18%, n=2). Participant K who was in the process of developing their course suggested an example syllabus outlining student learning objectives, reference materials, and an example schedule would be beneficial. Practical examples from industry perspectives were also listed as a potentially helpful resource, with 18% of respondents identifying case studies (n=2) and another respondent suggesting site visits and tours. This feedback clearly identifies gaps in instructional resources and can be used to guide the direction of future mass timber curriculum development.

Conclusions

Historically in the United States, civil (structural) engineers have been trained to and worked in industry designing buildings and infrastructure predominately in steel and concrete. In recent years, awareness of mass timber as an alternative structural building material has been increasing; construction of mass timber buildings also continues to increase. However, to train the next generation of structural engineering industry professionals, courses needed to be taught to undergraduate and graduate students that cover concepts in timber and mass timber design. This research focuses on understanding the current state of teaching of timber and mass timber design at U.S. based higher educational institutions. This includes understanding of how prevalent such courses are, and an assessment of gaps in teaching and resource needs in timber

structural engineering curriculum. This is accomplished by inventorying the current availability of courses in the design of timber structures across the two largest public institutions in each state, then conducting interviews with instructors of these courses.

Results suggest that 59% of the largest public institutions in each state offer instruction in the design of timber structures with a total of 63 introductory and advanced-level courses being available to students. Of these courses, 10 are combined timber and masonry design courses, however the remaining 53 strictly focus on instruction of timber content. Results from instructor interviews suggest that most courses cover some concepts in mass timber (glulam and CLT) but for a fairly limited percentage of the course there is wide use of design standards which are considered helpful references.

In terms of needed resources, interview results also indicate there is a need for more teaching-specific resources, as there is not repositories of teaching aids and references for mass timber concepts like there are for steel and concrete design. A total of five types of academic resources that would be helpful to instructors teaching mass timber were suggested during the interviews. These included lecture and assessment materials, practice problems, and design project prompts. Results also suggest that while some instructors have industry experience, others do not and would benefit from collaboration with industry on the development and updating of such resources, particular in such an evolving field.

In summary, the results of this analysis can be used to guide curriculum development that can support the implementation of further coursework in timber and mass timber design throughout the United States. There are some limitations in this study. Limiting the course inventory to the top two institutions in each state with the largest enrollment excludes private and smaller institutions from review. The small sample size of universities and interview participants can result in decreased generalizability of the findings and sampling bias. To increase the validity of the study, future work can broaden the scope of the course inventory and increase the sample sizes of interviews.

Acknowledgements

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