

Mass Timber Construction: Perceptions of an Emerging Methodology Among San Francisco Bay Area Construction Professionals

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This research project aims to assess the status of mass timber construction in the San Francisco Bay Area, based on the perspective of local building design and construction professionals. Local architects, engineers and construction management professionals were surveyed for their experiences with mass timber construction projects in the Bay Area, as well as for their opinions of mass timber construction in general. The survey finds that a vast majority of local building design and construction professionals have no experience using mass timber on construction projects, but that a majority of them have a somewhat favorable opinion of its use for many different building types, mostly up to mid-rise height. Just over one third of survey participants felt that their employer would be an early adopter in mass timber construction if code changes allowed for its use in taller structures.

Key Words: mass timber, wood construction, San Francisco Bay Area, sustainability, green building

Introduction

Throughout North America, and in many other parts of the world, there is a steadily growing group of specifiers and construction professionals who are advocating for wood structures to be used for the types of buildings, which until recently would only ever be built in concrete and/or steel. The wood building products being touted as a viable alternative to steel and concrete are not standard dimensional lumber, as would be used for conventional light-framing, but rather solid wood panels, often up to six or eight inches thick, and solid wood posts and beams. These are the components of mass timber construction, and a project that uses these type of solid wood components, for some or all of its structural system, would be referred to as a mass timber project. Though there is no height requirement for a project to be considered a mass timber project, it is important to understand that most of the innovation in mass timber construction is focused on its potential for use in mid-rise and high-rise buildings. After a brief discussion of the current state of mass timber construction in general, this paper focuses on a survey of the San Francisco Bay Area's building design and construction professionals, in order to shed light on what construction industry professionals in this one local market think about this emerging construction methodology.

Literature Review

Type IV construction, also called heavy timber, has been around for decades in building codes, and many centuries in common practice. What differentiates modern mass timber construction from traditional heavy timber construction is that traditional heavy timber structural members are usually posts and beams made from single pieces of wood, which are each made from a single tree. Modern mass timber products are almost always engineered

wood products, composed of many smaller pieces of lumber, wood veneer, or wood strands. The first patent for cross-laminated timber (CLT) was issued in France in 1985 (Francis, 2018). In the early 2000's, interest in sustainable building and construction innovation helped spread the use of CLT throughout Europe. In the last 10-15 years, mass timber construction has spread into other global building markets including in Australia, Asia, and North America (Francis, 2018). North American adoption of mass timber began primarily in Canada, and more recently has spread into the United States, starting in the Upper Midwest and the Pacific Northwest. Today, there are modern mass timber projects speckled all over the United States. The concept of mass timber, and in particular, tall wood buildings, is growing in popularity worldwide. In 2003, there were 2000 cubic yards of CLT produced globally. It was predicted that in 2018, over 1,000,000 cubic yards of CLT would be produced (Greene, 2018).

One of the primary reasons for the expansion and push to leverage wood construction is because of the growing adoption of sustainable construction methods (Kibert, 2016). Steel and concrete are both very energy and carbon intensive to produce, while wood grows naturally with air, water, and sunlight, and as it does so, it sequesters carbon dioxide from the atmosphere. Wood is normally much less energy intensive to harvest, and wood products are significantly less energy intensive to produce (Mayo, 2015). In the United States, local supply chains for forestry products are currently operating sustainably, which is important if the mass timber construction movement causes demand for lumber to increase (Robertson, 2018). As of the most current data, the U.S. Forest Service reports that in U.S forest land, there are more trees planted annually than are harvested, and overall acreage of US forests have grown overall since the 1950's (Mayo, 2015).

A common idea among those designing taller wood structures is that hybridization is important; that is the combining of mass timber elements with other material elements such as steel or concrete. In fact, most modern mass timber buildings are inherently hybridized to some extent. The various joints and connectors that hold wood members together are usually metal and/or concrete, and they are critical for the design of a tall wood building. The vast majority of mass timber projects are built on a concrete podium to help ensure the wood structure stays dry, and in many mass timber building designs, floors are hybridized by adding a concrete topping layer for the combined benefits of stiffening, sound dampening, and fire protection (Skidmore, 2017).

Mass timber structures do not have the same susceptibility to fire that light-framed wood structures do. The larger dimensions of mass timber building components are very stable in a fire. Wood's structural properties are almost completely unaffected by heat, up to the point of combustion (Mayo, 2015). Once it is on fire, structural mass timber will char at a very predictable rate, and will often self-extinguish as the char layer chokes off the fire's fuel source (Mayo, 2015). One of the most extensive fire tests performed on mass timber structural assemblies to date was performed in July 2017 at the Bureau of Alcohol, Tobacco, Firearms and Explosives Fire Research Laboratory in Beltsville, Maryland (Zelinka, 2018). The results of these tests were consistent with many other recent fire tests of mass timber structures, which have mostly found that mass timber elements have inherent fire resistance due to the formation of a char layer, and fires in CLT structures will often self extinguish, even after four hours of burning, without failure of structural integrity (Fire Testing, 2017).

Mass timber structures have significantly less mass than an equivalent concrete or steel building. Structural engineers usually see this as a potential advantage for seismic design, as the forces of side to side shaking are reduced proportionally with reduction in building weight (Mayo, 2015). A recent series of seismic tests were conducted at UC San Diego on a 2-story CLT structure with a rocking wall system, which is designed to sway in an earthquake, but return to plumb afterwards (Pei, 2018). The structure moved with the many different simulated earthquakes, but returned to plumb afterwards on every occasion with very little structural damage. These tests are part of a series that will culminate with outdoor shake table seismic testing on a 10-story CLT structure in 2020. At the end of the seismic tests, they will also perform fire tests on that same structure (Pei, 2018).

A major shift towards the use of mass timber would be very difficult without changes to the building codes. The California Building Standards Code, like every other U.S. state building code, uses the International Building Code (IBC) as a model for its commercial building codes, with very minor changes specific to California (International, 2018). In order for construction codes to change in the Bay Area's building market, changes must be made to the IBC. In the lead up to the final approval process for the 2018 IBC, there was a push by some to increase the allowable buildings heights for wood construction. These propositions did not pass for the 2018 code cycle, however as a response to the increased interest in building taller wood buildings, the publishers of the IBC, the International

Code Council (ICC), announced the creation of the Tall Wood Ad Hoc Committee (TW-AHC). The purpose of the TW-AHC was to explore "the building science of tall wood buildings with the scope being to investigate the feasibility of and take action on developing code changes for tall wood buildings." The TW-AHC was to create a set of recommendations for the ICC to propose for inclusion in the 2021 IBC. After nearly three years of work, that committee proposed three new building classifications that would effectively enable mass timber structures to be permitted up to 18 stories. The current Type IV construction would be renamed Type IV-HT, and would remain unchanged. The new proposed classifications would be Type IV-A, Type IV-B, and Type IV-C (Locke, 2018). In late 2018, the ICC reported that those code changes were passed by their voting members. There are still more steps in the code cycle process but it seems assured that these new construction types will be included in the 2021 IBC.

Type IV-A would allow for heights up to 18 stories, or 270 feet, but would also require the greatest fire resistance ratings, as well as a non-combustible building egress core. Type IV-A would not allow any exposed mass timber elements, effectively allowing a project to take advantage of all the potential benefits of mass timber construction, except the aesthetic benefit. Type IV-B would allow for heights of up to 12 stories or 180 feet. This type would allow for some exposed mass timber elements, with restrictions placed on the amount of exposed wood surface area and how close exposed areas may be. Type IV-C would allow for building heights up to 9 stories or 85 feet, with very few requirements for non-combustible protection of interior mass timber (Locke, 2018). For each of the proposed construction types, the heights mentioned are only allowable in a fully sprinklered building. Currently, taller wood structures have to be permitted through an "alternative means and methods" path, which is a much more cumbersome process, in which project teams must prove to the permitting authority that their design is at least as good or effective as what the code requires. This process involves performing expensive practical tests, and/or a significant amount of research, and even then some jurisdictions are less amenable to the idea than others.

Methodology: Survey of Local Building Design and Construction Professionals

An anonymous online survey was designed to assess the perceptions about mass timber projects held by design and construction professionals. We chose an online survey format to gather this data because it was the most efficient type of survey for us to administer, and because it would be the most likely type to elicit responses from the surveyed population. Online surveys have been used successfully by many recent construction researchers looking for similar opinion data from construction professionals (Tafazzoli, 2018), as well as home builders and homeowners (Napier, Azhar & Farooqui, 2017). Before creating the research survey, we conducted a thorough review of literature pertaining to mass timber construction to see the ways in which it is currently being used globally, and also to understand the most commonly understood advantages and concerns, and most current research results. Using that information from the literature review, we formulated questions which could help us determine how AEC professionals in our region feel about this emerging type of construction. The survey was sent to employees of 93 of the area's architecture, engineering, and construction firms, the vast majority of which were organizations in the top 50 of their field in the San Francisco Bay Area based on revenue, as ranked by the San Francisco Business Times 2018. A few additional participants were referred to the authors and were not on the SF Business Times lists. All participants, at the time of being surveyed, were active in building design and/or construction activities for companies doing work in the Bay Area. In seeking out individuals to take the survey, LinkedIn was used as a search tool. Using the target organizations as search terms, the intent was to get as random of a sample of participants as possible, such that they would be representative of the Bay Area's community of architects, engineers, and builders, and that was kept in mind throughout the process of finding survey participants.

The survey was completed by 114 participants. Architects represent 57% of the surveyed population, engineers make up 30%, contractors/project managers were 11% of the surveyed population, and 2% classified themselves as working for building owners. Questions about experience working on mass timber projects were restricted to only those projects which were built within the Bay Area. In order to ensure that the respondents could clearly understand the scope of the survey, participants were provided with the following definition of a mass timber structure:

"Any building where the primary load-bearing structure is made of solid wood and/or solid engineered wood products, where the primary load-bearing members are typically glue-laminated columns (posts), beams and panels." The definition went on to state that "mass timber structures may be any number of floors, and they may include steel or concrete structural elements, including connectors or building core." It was specifically stated at the

end of the definition section at the beginning of the survey that light-frame wood construction, even multi-story projects, did not qualify as mass timber, so that there was no confusing this very popular building type with the much less common mass timber type.

The survey was comprised of three sections. Section 1 pertained to opinions of past experiences working with mass timber, section 2 sought opinions about mass timber construction in general, and section 3 was about predictions for the future of mass timber. The first question of the survey asked whether or not the participant had ever worked on a project with a mass timber structural system in the Bay Area. Those answering "yes" were directed to take every section of the survey in order. Those answering "no" were taken only to sections 2 and 3 of the survey. Among all survey participants, 86% had no experience working on a mass timber project in the Bay Area. Given how little mass timber construction is currently taking place in the Bay Area, it should be expected that the majority of local construction industry professionals would have no experience.

Survey Section 1: Mass Timber Experience

Survey section 1 was only provided to the 14% of participants who reported having experience working on at least one mass timber project in the Bay Area.

Among the survey participants with local mass timber experience, 63% had only worked on a single mass timber project. 25% had worked on two projects, and 12% had worked on 3 or more projects. Of the mass timber projects that survey participants reported working on, The vast majority are one, two or three stories. Survey participants reported that floors and columns were the most common elements to be built from mass timber with 69% of participants reporting that they worked on projects where those elements were made of mass timber. 56% reported working on a project with mass timber beams, and 50% reported working on a project with a mass timber roof.

69% of survey participants reported that the aesthetic value was a significant reason for using mass timber. The next most commonly reported reasons, at 44% each, were the lighter weight structure of mass timber, and the preference to use natural construction materials because of biophilia, which is the concept that natural materials make building occupants feel better. 38% of participants reported environmental concerns being a reason for using mass timber. Reduced construction schedule, ease of installation, and possibilities for prefabrication were each selected by 31% of survey participants, while energy efficiency was cited as a reason for selecting mass timber by 13% of participants. 6% were not sure why mass timber was selected.

The most frequently cited concerns about using mass timber, as perceived by survey participants, were the higher costs of mass timber compared to other building materials, and a lack of skilled labor capable of erecting mass timber. 31% of survey participants cited each of those concerns. The next most common concerns were scarcity of mass timber products, and lack of technical knowledge, which were each cited by 25% of respondents. These concerns are closely related to the first ones mentioned, and they are somewhat based in reality. There are legitimately no producers of CLT or most other mass timber products anywhere in California. The closest CLT manufacturer to the Bay Area is D.R. Johnson in Riddle, Oregon, which is more than 400 miles to the north.

The vast majority of those with local mass timber experience said that they felt it was a good choice for the projects on which they worked. This question was only used to determine if survey participants felt that these projects were successful generally, not based on any specific metric. As shown in Figure 1, 82% of respondents answered that way, while 12% were "not sure" if mass timber was a good choice, and 6% felt that mass timber was not a good choice for the particular project(s) they had worked on.

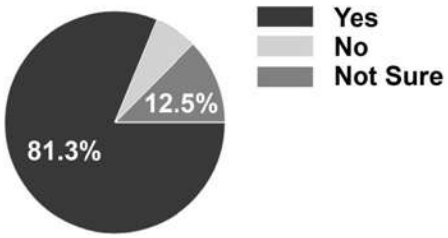

Figure 1: Results of survey question: " Based on your experience(s) was mass timber a good/successful choice for the projects on which you have worked?"

Based on their experiences working on past mass timber projects, a full 94% of survey participants said they would like to work on mass timber projects in the future, while only 6% said they would not.

Survey Section 2: Mass Timber Perceptions

This section was given to all 114 survey participants.

When asked how strongly they wanted to work on mass timber projects, on a scale from 1 to 7, 61.4% of survey respondents answered on the high end of the scale, with a 5,6 or 7, indicating that they feel favorably about the idea of working on mass timber construction projects. 11.4% answered on the bottom half of the scale, with a 3, 2, or 1, indicating unfavorable opinions about working on mass timber projects. 27.2% of respondents answered with a 4, meaning that they are neutral about the idea. As shown in figure 2, a majority of the local construction industry professionals that were surveyed feel positively about the idea of working on mass timber construction.

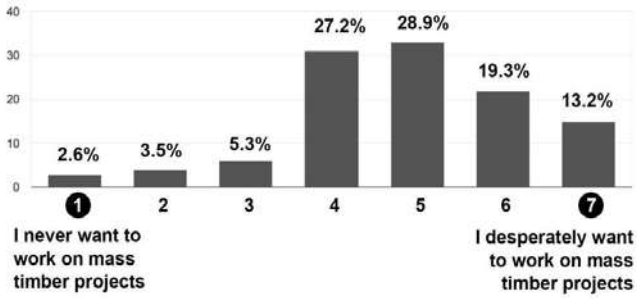

Figure 2: Results of survey question: "How strongly do you want to work on mass timber building projects?"

Among those surveyed, residential buildings were thought to be the most appropriate occupancy type for mass timber construction. A majority felt that low and mid-rise buildings were appropriate for mass timber construction but only 1 in 7 felt like mass timber was a good solution for high-rise projects. Given how few tall mass timber projects have actually been built worldwide, it makes sense that a vast majority of survey respondents do not feel that mass timber is a good choice for a high-rise.

The most commonly cited perceived advantage of mass timber construction is that “wood is aesthetically appealing when left exposed,” which was selected by 82.5% of respondents. 77.2% of respondents selected “wood is a renewable resource” as an appealing advantage of mass timber, and 64% selected “prefabrication decreases on-site construction time” as an advantage. 61.4% felt that “wood makes people feel good,” and 59.6% cited that lighter weight materials reduces foundation requirements. 50% of survey respondents selected the fact that wood sequesters carbon from the atmosphere.

The perceived barriers to the adoption of mass timber construction are shown in Figure 3. A barrier to adoption could be any concern which could leads to project teams not choosing to design and build with mass timber. Lack of familiarity with mass timber products, was the most frequently perceived barrier, selected by 75.4% of respondents. The next most frequently selected barrier to adoption was an insufficient demand for alternatives to steel and concrete which was selected by 45.6% of respondents. Difficulty of permit acquisition and cost risks were the next most frequently cited barriers to the adoption of mass timber construction.

Figure 3: Results of survey question: "What do you perceive to be the most likely barriers to the adoption of mass timber structural systems in the Bay Area construction market?"

When asked what entity they feel would be the most likely to steer a project towards using mass timber, 45.6% of respondents felt that an architect would, while 37.7% felt that an owner would be the most likely to make this choice. This result is shown in Figure 4.

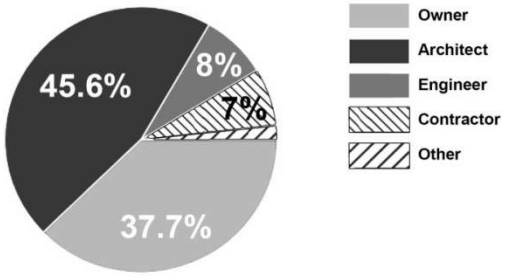

Figure 4: Results of survey question: "Which entity do you think is the most likely to steer a project towards mass timber?"

Survey Section 3: Predictions about Mass Timber's Future

When asked about the possibility for code changes allowing taller mass timber structures, nearly half of all respondents (47.7%) answered that they were "not sure" if these changes would occur. 28.9% of respondents said that they do expect these changes to occur for the 2021 IBC, and 20.2% said that they expected these changes to occur in the future, but not for the 2021 round of code changes. A very small minority of respondents (3.5%) reported that they did not ever expect changes to occur in the building codes that would allow for taller wood structures.

Survey participants were then asked to imagine if code changes did occur which allowed taller wood structures, how much of the construction that is currently done in steel and concrete would shift to mass timber. 47.4% of respondents said that between 5-10% of what is currently done in concrete and steel would be done in mass timber. 28.9% said that mass timber would take between 1-5% of the market away from concrete and steel. 17.5% of

respondents answered that mass timber would displace 10-25% of the market for concrete and steel, and 6.1% of respondents felt that mass timber could be used in 25-50% of the buildings that are currently built using concrete and steel.

When asked how they felt their current employer would react to changes in the potential code changes the most common response among survey participants (44.7%) was that their organizations "would neither seek, nor avoid, working with mass timber," essentially meaning that they do not perceive their organizations to have a strong opinion of mass timber construction at all. 36% of respondents felt that the organization that they worked for would be an "early adopter" of mass timber construction, while an additional 4.5% felt that their organization already pushes for using mass timber construction in many scenarios. 7.9% of respondents were not sure how their companies would react to these changes. Finally, 4.4% of respondents felt that their organization would avoid working with mass timber if these code changes occurred. These results are shown in Figure 5.

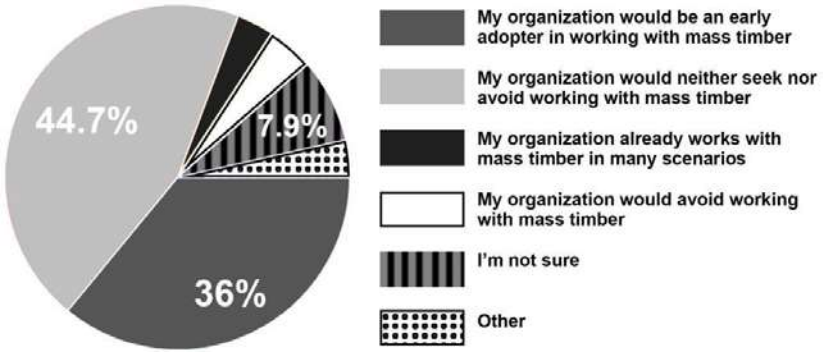

Figure 5: Results of survey question: "If code changes occur, what do you think would be the attitude of the organization for whom you currently work?"

Conclusions

Although mass timber construction is not a common building methodology in the San Francisco Bay Area, this research has found that a vast majority of those with experience working on a mass timber project felt positively about the experience and there is general interest among the Bay Area's AEC professionals to work with mass timber. The most commonly perceived advantages to mass timber construction are in line with the core messaging coming from mass timber proponents, including wood's aesthetic properties, environmental attributes, and speed of construction. Most of the perceived disadvantages of mass timber had to do with lack of knowledge, or uncertainty of risks, which are valid concerns for a nascent methodology. Although the survey findings show that individual AEC professionals in the Bay Area are interested in mass timber construction, they also show that construction is still a risk averse industry, indicated by a perceived lack of demand for alternatives to steel and concrete, and perceived limitations on mass timber's potential to capture market share. Confidence in any new building method is going to grow slowly as more successful projects are built, and more local AEC professionals have exposure working on them. Based on the preliminary voting results, the 2021 IBC will allow more tall wood structures. At the time of the survey, roughly a third of those individuals surveyed felt that if these code changes occured, their employer would be an "early adopter" of mass timber construction, while almost half felt that their organization would be neutral. The results of this survey indicate that the Bay Area's AEC professionals would be receptive towards more mass timber construction. As code changes allowing taller wood structures appear set to be implemented in 2021, more research similar to this study should be conducted periodically to determine how the perceptions of mass timber construction among local AEC professionals are evolving as more mass timber construction projects are designed and built, and more people are exposed to working on mass timber projects.

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