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DESIGN OF WOODEN STRUCTURES TO ENSURE STABILITY AND SAFETY DURING A FIRE EVENTS

With growing public interest in sustainable building and with the addition of "mass timber" Construction Types IV-A, IV-B, and IV-C to the 2021 International Building Code (IBC), design professionals are increasingly required to design mass timber building elements to fire-resistance ratings prescribed by the IBC. While many members of the public, and even building design professionals at times, associate wood construction with inherent fire risks, it is feasible and can even be cost-effective to design wood structures for resilience and safety during fire events.

Specialty engineers and architects routinely handle fire protection design. This standard of design is effective and sensical for non-combustible structural materials as many commercially available products can be used to directly obtain a time-based fire-resistance rating. On the other hand, combustible materials, such as wood, used in building structures are not typically covered with sprayed fire-resistant materials and are often intentionally exposed for aesthetic purposes. The charring of a structural wood member, as well as the associated reduction of the member's cross-section and material properties, necessitates the involvement of a structural engineer.

To properly protect wood structural connections, one must first understand char depth, effective char depth, and char contraction. Wood members exposed to fire develop a char layer that extends into the member cross-section over an exposure time. This char layer can, in turn, act as an insulator for the member, slowing char growth over time. Due to the insulative properties of the char layer, a linear growth rate tends to underestimate char depth under short time frames and overestimate char depth under longer time frames.

Cross-laminated timber (CLT) manufactured with certain adhesives exhibits different char growth behavior due to the tendency for char to fall off as the char depth approaches the glue line. This fall-off behavior leads to a speed up and a slowdown of charring encom. New fire test protocols have been developed and are included in Standard for Performance-Rated Cross-Laminated Timber, to ensure adhesives used in CLT will not result in this behavior.

For determining the fire-resistance rating of a structural member, this conservatively increased loss of structural section is all that is required. However, it becomes necessary to consider the effects of char contraction when unbonded members abut, such as at structural connections or where wood trim is used as an insulative protective layer.

As wood members exposed to fire begin to char, the charred wood shrinks such that the volume occupied by the charred member is less than the original volume of the wood before fire exposure. In fact, the actual thickness of char is approximately 70% of the calculated char depth. This gradual member shrinkage is termed char contraction. Char contraction plays a critical role in determining the fire protection of connections. For two abutting but unbonded members, the joint between the two members grows as char contraction occurs at the abutting corners. The gap that forms at the joint reveals the initially protected faces and allows ignition to occur increasingly at the location where the unbonded members meet. At these abutting edges, recommends using a depth of ignition into the formed gap of twice the calculated approximate char depth (Fig. 1).

Understanding char depths and char contraction make it possible to determine protection times for wood member connections. The presents multiple ways to add time to the fire-resistance rating of wood structural members and to protect connections by adding sacrificial wood, type X gypsum board, or non-combustible materials such as mineral wool or fiberglass insulation. These materials can be used in combination, and their impacts on the fire-resistance times can be considered directly additive.

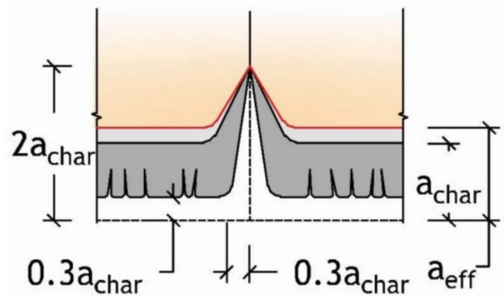

Fig. 1. Char Contraction at Unbonded Abutting Wood Members

Consider the detail in Figure 2, where two similar fire protection designs are used to protect a CLT floor-to-wall connection. This detail shows the char pattern for a 90-minute exposure on each protection scheme (dark gray represents char). The design on the left incorrectly neglects the effects of char contraction; thus, the steel angle becomes exposed to increased temperatures prior to 90 minutes. The design on the figure's right correctly protects against the effects of char contraction between the CLT wall and the 2×12 protection by adding a nominal 2×2 trim piece and successfully providing a 90-minute fire-resistance rating.

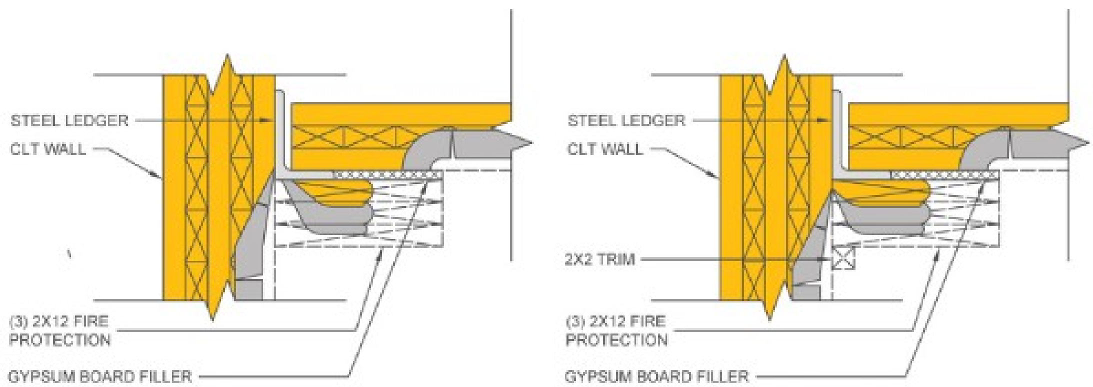

Fig. 2. Effects of Char Contraction on Differently Protected Steel Ledgers

Type X Gypsum Board can also provide fire protection for wood structural members and connections. To establish a fire protection time with gypsum board, a designer should use regulatory values. These values can be directly added when multiple layers of gypsum board are used to protect a structural member or connection. Type X gypsum board can be used for the protection of structural members and connections or, as it has been traditionally used, for the protection of structural assemblies such as a series of floor joists or wall studs.

For the base layer of thermal protection of the gypsum board, which is the layer adjacent to the steel being protected, the time of thermal separation shall equal the time of protection multiplied by 0.50.

As the carbon-neutral and sustainable design market continues to grow, there is an increasing need for structural engineers who can design wood structures for the fire-resistance ratings required by the IBC. Company's are excellent resources for engineers designing mass timber elements and their connections where fire-resistance-rated members and assemblies are required.

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ANALYSIS OF POSSIBLE WATER CONTAMINATION RISK, POTENTIAL THREATS TO USERS' HEALTH

Water consumption and supply play an integral role in our modern daily lives. Water pollution can pose a serious threat to human health and the environment. A detailed analysis of potential water contamination risks is crucial for ensuring the safety and quality of water for consumers.

Identification of Pollution Sources: a thorough examination of pollution sources, such as industrial wastewater, agricultural discharges, municipal waste, and other factors that could negatively impact water quality.

Evaluation of Chemical and Bacteriological Indicators: determining the concentrations of chemical substances and studying bacteriological indicators in water to identify potential hazards to user health.

Analysis of Contamination Pathways: studying possible pathways through which contamination may enter the water supply system and identifying vulnerability points in this process.

Development of Monitoring Systems and Preventive Measures: implementing effective monitoring systems for timely detection of changes in water quality and devising strategies to prevent contamination.

Establishment of Quality Parameters: setting parameters that serve as indicators of water quality and determine its safety for consumers. This may include chemical, physical, and bacteriological indicators.

Adoption of Modern Monitoring Technologies: identifying and implementing modern monitoring technologies, such as sensors, IoT solutions, and automated data collection systems, to obtain real-time and accurate information about water quality.

Creation of a Centralized Monitoring System: developing a centralized system that ensures reliable data collection and analysis from various monitoring sources. This may include sensor networks, laboratory measurements, and data from consumers.

Development of Algorithms and Software for Anomaly Detection: creating algorithms and software for detecting anomalies and unusual changes in water quality, enabling prompt responses to potential threats.

Implementation of Alarm Systems and Rapid Response: developing an alarm system that automatically notifies relevant authorities in case of critical anomalies and ensuring swift responses to water contamination.

Analysis of Monitoring Results for Prevention Strategies: analyzing monitoring results to develop strategies for preventing water contamination. This may involve optimizing purification processes, regular maintenance of infrastructure, and effective risk management.

Involvement of the Public and Consumers: engaging the public and consumers in the monitoring system through informational campaigns, providing access to results, and promoting awareness of the importance of preserving water quality.