

Mass Timber Cost and Design Optimization Checklists

WoodWorks has developed the following checklists to assist in the design and cost optimization of mass timber projects.

The *design optimization* checklists are intended for building designers (architects and engineers), but many of the topics should also be discussed with the fabricators and builders. The *cost optimization* checklists will help guide coordination between designers and builders (general contractors, construction managers, estimators, fabricators, installers, etc.) as they are estimating and making cost-related decisions on a mass timber project.

Most resources listed in this paper can be found on the WoodWorks website. Please see the end notes for URLs.

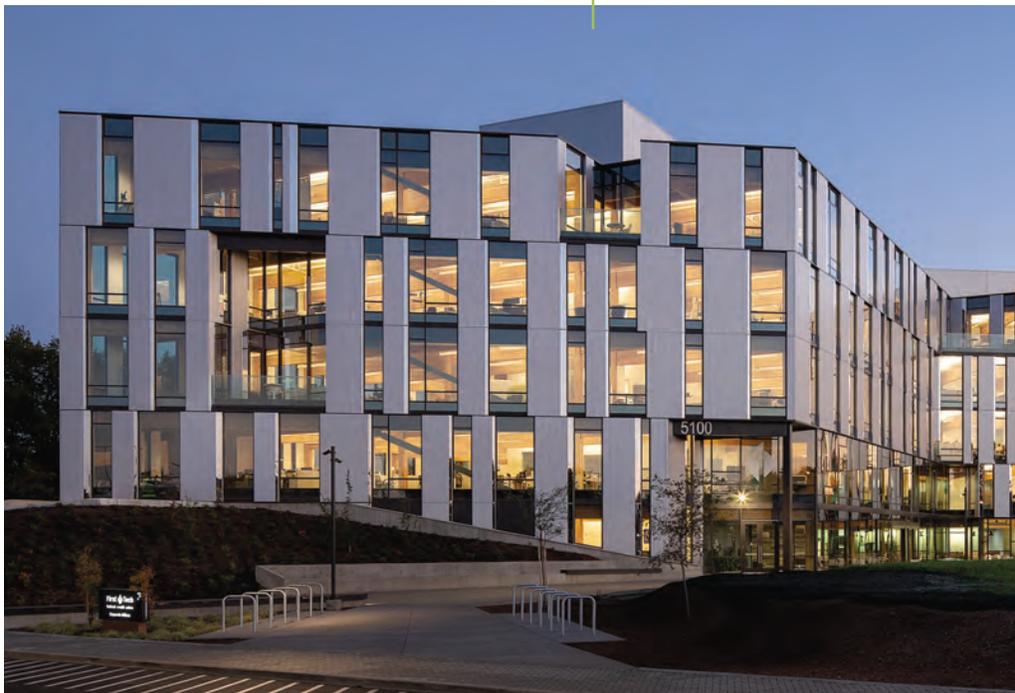
**First Tech Federal
Credit Union –**
Hillsboro, OR

ARCHITECT:
Hacker

ENGINEERS:
Kramer Gehlen & Associates,
Equilibrium Consulting

CONTRACTOR:
Swinerton

PHOTO: JEREMY BITTERMANN



PRE-DESIGN

Pre-construction coordination is important to optimize costs on a mass timber project.

Pre-Design Checklist

Design & Builder Team

- Discuss and establish the best contract model. The traditional design-bid-build approach without builder (and specialty subcontractor) input prior to the bid is neither a best-practice nor cost-effective. To reduce costs and maximize benefits, consider construction manager at risk, design-assist, integrated project delivery, or design-build models.
- Identify the project team. In addition to the architect, engineers and general contractor, it is important to engage key specialty subcontractors/design-assist subcontractors for mass timber material fabrication and installation, foundations, mechanical/electrical/plumbing (MEP), fire protection, and exterior façade early in the project.
- Coordinate design, pricing, site logistics/planning and schedule. Pre-construction coordination is important to optimize costs on a mass timber project.

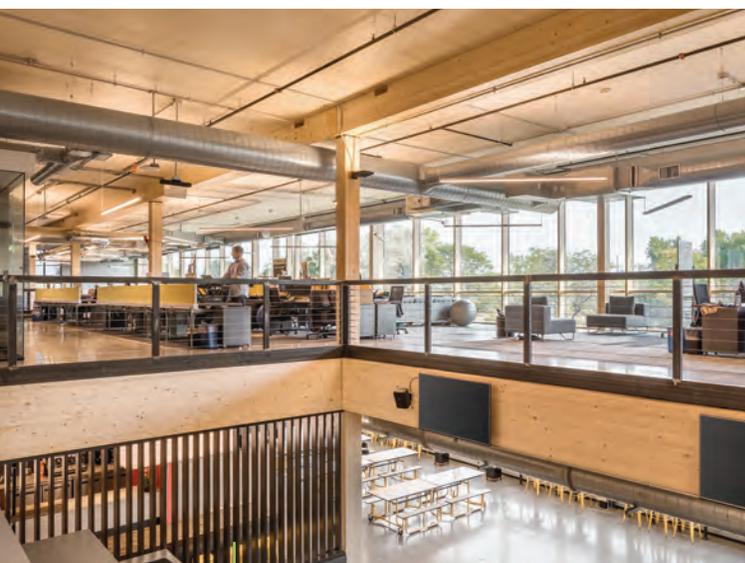
Cost Estimating Considerations

- Establish cost estimating milestones. As with any project, it is good practice to set budgets and perform cost estimates at the end of schematic design (SD), design development (DD), and construction documents (CD) phases.
- If the intent is to compare mass timber options against other structural material systems, include scope for additional design effort for the architect and engineering consultants.
- For publicly-funded projects that will be competitively bid, make the “go/no go” decision on mass timber by the end of SD. Proceed into DD after the material system has been chosen. Early bid the mass timber supplier at the end of DD or by 50% CD at the latest.

Contractual Considerations

- Undertake 3D modeling of the building systems, which is necessary to realize benefits of a pre-fabricated mass timber system. Models are often shared between designers and builders during the design phases. If this will be the case, consider workflow and software compatibility.

PHOTO: JC BUCK



Designed on a 20'x30' grid, The Loading Dock in Boulder, CO includes glulam beams and columns, CLT roof, wall and floor panels, and a CLT elevator shaft. Girders run east-west, allowing for fluid mechanical ducting north-south. OZ Architecture, KL&A, Quinlan Construction

- Coordinate with the building systems (MEP and fire protection) engineers and subcontractors. Detailed building systems coordination needs to be undertaken during the design phase to reap benefits such as schedule savings. Some choices that have traditionally been left to MEP and fire protection subcontractors on site should be made during design.
- Identify which of the building systems should be modeled and by whom. Identify required opening sizes in mass timber elements to be cut in the fabrication facility. Including MEP and fire protection systems can help realize savings during construction and minimize construction conflicts. Schedule structural steel component modeling so it does not delay mass timber modeling and prefabrication.
- Clearly define engineering scope of work for the mass timber system and its interface with other building elements. Sometimes a timber engineer will be responsible for providing stamped and signed engineering drawings for the mass timber system. If this is the case, clearly define which firms will provide design and detailing for the lateral system, connections and foundation anchorage.

Design Goals

- Establish design goals through discussions among the owner, designer and builder, and use them as a guide in decision making throughout design and cost analysis. Consider the relative value of the following benefits based on the project’s objectives and constraints. Decide if these benefits are project goals or value-adds.

Potential Benefits	Project Goal ✓	Value Add ✓
Fast construction/shorter schedules; pre-fabricated and precise		
Exposed wood <ul style="list-style-type: none"> • Aesthetic value; potential for faster leasing and lease premiums; portfolio distinction • Biophilia; healthy indoor environment 		
Lightweight structure, especially beneficial on sites with poor soils		
Labor shortage solutions <ul style="list-style-type: none"> • Small crews for timber frame erection • Utilize more entry-level laborers when MEP and fire protection systems are fully designed, coordinated and pre-planned 		
Just-in-time delivery and small staging/lay-down areas; ideal for dense urban areas		
Natural, renewable material; environmentally friendly with a lighter carbon footprint		
Support healthy forests and rural economies <ul style="list-style-type: none"> • Mass timber can be made from relatively small-diameter trees and those affected by insects or disease; creates a market incentive for forest thinning and other landscape restoration efforts that reduce the risk of high-severity wildfires 		

Contact WoodWorks for Free Project Assistance

WoodWorks is a non-profit organization with expertise in all aspects of wood building design, including (among others): innovative mass timber applications, tall wood code provisions, allowable heights and areas, structural design and detailing, fire resistance, acoustics, environmental performance, and alternate means of compliance. Staffed by architects and engineers, we provide free technical support to developers, architects, engineers, and builders related to commercial and multi-family projects across the U.S.

We can also connect you with experienced design professionals and builders for consideration as part of your mass timber project team.

To request assistance, contact the Regional Director nearest you (see www.woodworks.org/project-assistance), or email help@woodworks.org.

SCHEMATIC DESIGN (SD)

SD Design Optimization Checklist

Material Optimization/Panel Sizes/Grids

- Identify options for mass timber fabricators and suppliers.
- Maximize panel sizes to minimize machine cutting, material waste and costs. Unique geometries and varying slab edge conditions can increase costs; balance design with budget.
- Determine the thickness and grades of roof/floor panels based on preliminary loading. Minimize the thickness of floor/roof panels to control costs. Vibration often controls floor panel thickness rather than structural span capability.
- Approach mass timber design as a modular system. Start to think of your design on a module of 8 or 10 feet. For comparing material systems, the 8-foot module also works well for steel and concrete. The module can be refined early in the design development phase. For projects that include structured parking, consider modules that work well with the parking layout to minimize structural transfers.
- For panels sourced from overseas, shipping container size limits will govern maximum panel sizes. Actual panel size will be limited to a little less than 8 feet by 40 feet.

AHJs may be unfamiliar with mass timber systems. Early pre-application meetings can help to align expectations and mitigate concerns far in advance of permit application.

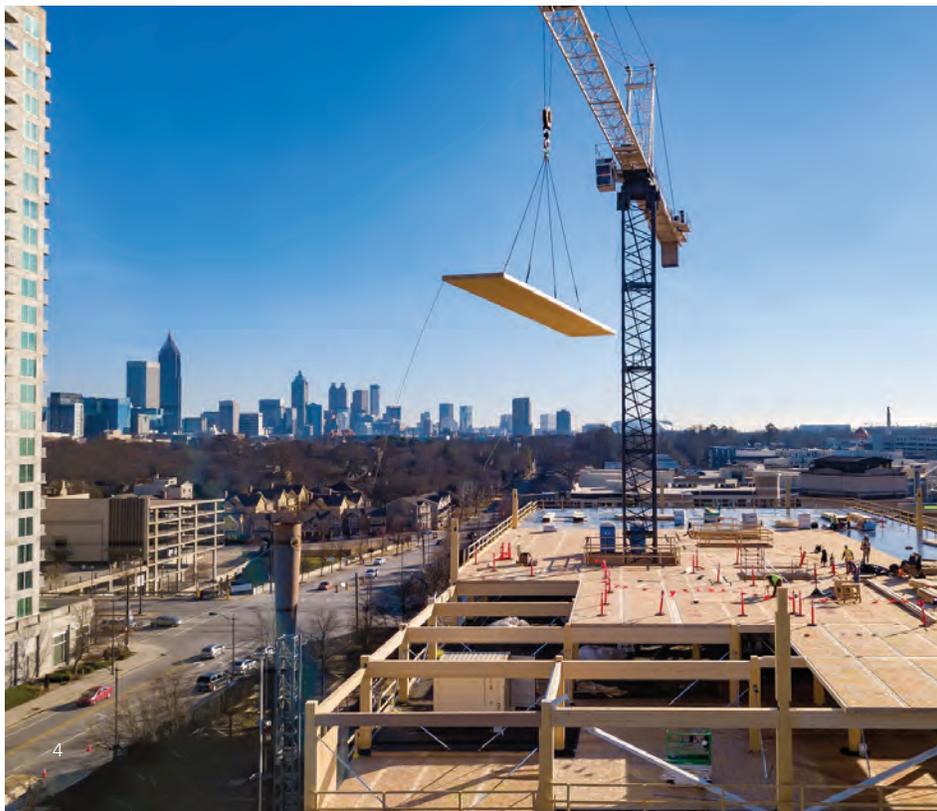
RESOURCES:

- ▶ *Ask an Expert: How can I create an efficient structural grid for a mass timber building?*¹

System Coordination

- Optimize structure, vibration, fire resistance and acoustics while minimizing the thickness of the floor/roof panels. These areas usually have the biggest influence on cost.
- Coordinate the structure, vibration, fire resistance and acoustic systems. Meet with the project's consultants/experts to discuss system options and how each impacts the others.
- Correlate acoustic and fire-resistance solutions. (They are interdependent.)

PHOTO: STRUCTURECRAFT



Structural Systems

- Determine where to use mass timber systems on the project. Consider: floor and roof systems, load-bearing walls, lateral force-resisting walls.
- Select the lateral system and consider how quickly it will be erected. Is the lateral system compatible with the fast speed of mass timber erection? Construction schedule savings can be significant with mass timber (and are a main driver for its use) and the choice of lateral system can greatly impact the construction schedule.

After completing the 7-story T3 Minneapolis, Hines switched from a concrete core to a steel brace frame for T3 Atlanta to keep up with the erection speed of the mass timber framing. HPA/DLR Group, Magnusson Klemencic Associates, StructureCraft, New South Construction

- Consider a mass timber core as an alternative to systems that have long cure times.
- Review the sequencing of erection. Do the lateral systems need to be installed prior to the mass timber?

RESOURCES:

- ▶ *An Approach to CLT Diaphragm Modeling for Seismic Design with Application to a U.S. High-Rise Project*²

Fire Resistance

- Optimize the construction type to minimize fire rating impacts.
- Consider fire protection approaches and what should be discussed with the Authority Having Jurisdiction (AHJ) during design. AHJs may be unfamiliar with mass timber systems. Early pre-application meetings can help to align expectations and mitigate concerns far in advance of permit application.

RESOURCES:

- ▶ *Fire Design of Mass Timber Members – Code Applications, Construction Types and Fire Ratings*³
- ▶ *Ask an Expert: When designing a mass timber building, what are the key design considerations related to fire ratings, panel thickness/member size and occupancy?*⁴

Acoustics

- Consider floor topping options and finishes.
- Determine how the wet vs. dry weight of toppings impacts schedule and mass of structure.
- Decide whether the mass timber floor/roof panels will be exposed on the ceiling side or concealed.
- Consider the minimum level of acoustical performance required by code and expected by the owner/occupant.

RESOURCES:

- ▶ *Acoustics and Mass Timber: Room-to-Room Noise Control*⁵
- ▶ *Inventory of Acoustically-Tested Mass Timber Assemblies*⁶

Finish Quality

- Start to consider the appearance of exposed mass timber elements and the species available from different fabricators. Selecting species provided by local fabricators will typically yield shipping/transportation cost savings.
- Specify desired finish grades (architectural, industrial, etc.) for budgeting purposes.
- Work with potential manufacturers to determine their appearance grade options and associated cost premiums in order to arrive at a solution that meets both aesthetic goals and budgetary constraints.

RESOURCES:

- ▶ *Ask an Expert: How should desired appearance grades and characteristics be specified for CLT, NLT and glulam?*⁷

PHOTO: ANDREW POGUE



Char calculations can be used to demonstrate fire-resistance ratings.³ This method accounts for mass timber's ability to form a char zone when subjected to fire, which insulates the remaining wood cross-section, allowing it to retain structural capacity. Carbon12, Path Architecture, Munzing Structural Engineering, Kaiser Group

SD Cost Optimization Checklist

Mass timber buildings are relatively new to the U.S. and, as such, not enough data is available to predict costs with the unit cost method. Cost estimating mass timber systems requires a holistic approach to compare costs and yield savings. This approach takes into account the considerations/questions in these checklists, such as the financial benefits of a shorter construction schedule. A direct comparison of the price of a mass timber structural frame to the price of a steel/concrete frame will not provide an accurate overall project cost comparison.

Schedule Savings = Cost Savings

- Mass timber buildings are erected more quickly than buildings made from other materials. Consider the financial benefits of shorter construction schedule and earlier lease/occupancy.

Example Timeframes for Mass Timber Projects					
Project	Stories	Area	Type	Time to Erect the Mass Timber Structure	Overall Construction Schedule
First Tech Credit Union (Swinerton ⁹)	5	150,000 sf	Office	12 weeks	14 months
Candlewood Suites at Redstone Arsenal (Lendlease ⁹)	4	62,700 sf	Military hotel	16 weeks	12 months
Seattle Mass Timber Tower (DLR Group hypothetical case study ¹⁰)	12	305,000 sf	Mixed-use office and hotel	24 weeks	18 months

Shorter construction schedules = less carrying costs + ability to lease/occupy sooner

Compressing the Typical Construction Schedule with Mass Timber^{8, 10, 11}

Look for these potential schedule savings in comparison to steel and concrete



- No cure times means follow-up trades can start working as soon as floor/roof panels are placed.

According to Lendlease, Candlewood Suites at Redstone Arsenal was built 37% faster overall and with 40% fewer construction workers than a similar cold-formed steel military hotel.

DLR Group projects that the Seattle Mass Timber Tower would be constructed 25% (5 months) faster than the baseline post-tensioned concrete building in its case study.

RESOURCES:

- ▶ *Candlewood Suites Hotel at Redstone Arsenal, AL*¹¹
- ▶ *Optimized Design, Efficient Construction: How One Company Successfully Constructed a Massive Timber Project*⁸
- ▶ *Tall with Timber: A Seattle Mass Timber Tower Case Study*¹⁰

SCHEMATIC DESIGN (SD) continued

Aesthetic Value

- The unique aesthetic of an exposed wood structure can offer market distinction with potential profits from leasing velocity, less tenant turnover and/or higher leasing rates.^{4,12,13}

Less Weight = Cost Savings

- Mass timber buildings weigh less than concrete buildings and some steel buildings. The lighter mass requires smaller foundations and can result in lower seismic forces.
- For sites with problematic soils, significant savings are possible because of the lighter foundations, which can result in less soil remediation costs, and an earlier start to the above-grade structure.

Fabrication

- For a better estimate of panel fabrication costs:
 - Include allowance for CNC fabrication of panels.
 - Include allowance for finish of mass timber, if known. If unknown, either provide a range or include the assumed appearance grade that is factored in the quote (architectural, industrial, etc.).

Shipping/Trucking

- The cost of shipping can vary widely. Will material be shipped on standard trucks or will panels require oversized trucks? Can oversized trailers access the site?
- For overseas manufacturers, consider the cost of:
 - Shipping containers and rail transit in addition to the typical manufacturing and trucking costs
 - Storage in a warehouse or the extra room and logistics to store on site (climate-controlled storage may be needed depending on project location)

Installation & Labor

- Include allowance for installation/labor. Mass timber frames are usually installed with one team lead and 6 to 10 team members.⁹
 - Labor shortages are common and predicted to increase. Relatively small crews are needed to install prefabricated mass timber systems.
 - Lendlease trained unemployed veterans for the Redstone Arsenal project.⁹
 - Swinerton was able to use entry-level electricians for the First Tech Federal Credit Union.⁸
- Start thinking about who will install the mass timber, GC or subcontractor.
- Consider whether on-site training of crew by the manufacturer or an install specialist will be necessary.
- Capture savings from pre-fabrication. Installation costs of MEP elements can often be reduced.

PHOTO: JEREMY BITTERMANN



According to Swinerton, using CLT and glulam instead of steel for the First Tech Federal Credit Union's new campus resulted in a 4 percent cost savings and four fewer months of construction. (See cover photo.)

DESIGN DEVELOPMENT (DD)

DD Design Optimization Checklist

Revisit the SD Checklists

- The SD checklists are still relevant. Continue to revisit them and develop those items.

Material Optimization/Panel Sizes/Grids

- Check with manufacturers for available panel sizes/spans. Machinery press sizes or the optimization of raw material sizes can influence panel sizes. Most manufacturers can produce panels in lengths ranging from 40 to 64 feet and widths of 8 to 12 feet.
- For large panel/member sizes, consider transportation and shipping.
- For competitively bid projects, size grids for a variety of manufacturer options.
- Are there slight adjustments to the grids that can be made to help control costs?

Hybrid Considerations

- Consider the following early in design development:
- What is the 'Plan B' approach in wood if the first system does not work?
- All-wood mass timber buildings tend to be cost competitive; however, some projects may benefit from hybrid systems. Hybrid systems to consider include mass timber panels on steel beams, concrete slabs on glulam beams, mass timber panels and beams on precast concrete girders/columns, and timber-concrete composite systems for longer spans or where vibration control is critical.

System Coordination

- As mentioned in SD, try to optimize the structure, fire resistance and acoustics/vibration control. These usually have the biggest influence on cost.
- Consider prefabricated exterior and interior wall elements that preserve the schedule savings achieved by the structure.

Fire Resistance

- For exposed panels, fire resistance provided by charring of wood can be calculated. Some manufacturers also have tested assemblies.
- Determine if fire caulking or other applications are required between panels and members.

Resources

- ▶ *Fire Design of Mass Timber Members – Code Applications, Construction Types and Fire Ratings*³
- ▶ *Inventory of Fire Resistance-Tested Mass Timber Assemblies & Penetrations*¹⁴
- ▶ *Ask an Expert: How do you demonstrate the fire resistance of exposed wood members using char methods in lieu of gypsum?*¹⁵

With early engagement/design-assist, it is possible to prefabricate many openings and interface points that are much less costly and less prone to risk (damage, error, debris, etc.) than when completed in the field.

MEP Systems

- Compare a completely prefabricated approach for incorporating MEP and fire protection systems to field accommodation techniques and decide on the best approach for your project.
- With early engagement/design-assist, it is possible to prefabricate many openings and interface points that are much less costly and less prone to risk (damage, error, debris, etc.) than when completed in the field. Seek MEP contractors skilled in prefabrication of their respective areas (piping, units, duct, etc.).
- Consider solutions to accommodate openings without cutting holes in panels (i.e., at ends of panels or routing above/below). Also consider MEP layout in structural grid placement.

Resources:

- ▶ *Ask an Expert: How is MEP accommodated in exposed mass timber buildings—e.g., CLT and NLT wall and floor/roof panels?*¹⁶

Finish Quality

- Obtain material samples and consider finish grade and coatings. Specify several “range and finish” samples, perhaps 6 feet by 6 feet to convey an accurate sense of the outcome.
- For cost savings, are there areas where industrial grade appearance can be specified?
- Consider surface coatings that can be added for protection during construction, durability, staining, etc. Discuss coatings with fabricators and the GC. Consider whether the options are applied in the shop or field.

Specifications

- Determine the thickness of panels, number of laminations, grade/species, finish, etc.
- Use the manufacturer’s standard product options to help control costs.
- Consider protection of steel connectors during construction (paint/primer). Prevent rust stains on exposed wood by priming connectors.
- Protect panels during construction with sheathing and by taping seams; cover all end grains/joints; specify shop-applied sealants.
- Specify a moisture mitigation plan during construction which outlines how the timber is to be protected.
- Costs of stainless/galvanized connections vs. a shop-primed finish can be significant. Consider the cost of these special materials/coatings vs. protection in storage and once in place to mitigate staining.
- Consult with fabricators for standard specifications.

PHOTO: STRUCTURECRAFT



At T3 Minneapolis, the MEP system is located below an upturn beam and branches out to various bays. Michael Green Architecture, DLR Group, Magnusson Klemencic Associates, StructureCraft, Kraus-Anderson Construction

Protect wood during shipping and construction to prevent moisture damage as well as damage to exposed elements.

Key Details

- Consider panel-to-panel joint connection options. Determine which is the most appropriate for the project overall, including installation speed, lateral forces, and overall panel length to minimize waste.
- For beam-to-column joints:
 - Consider whether connections will be concealed or exposed. Where members such as beams, columns and floor/roof panels require a fire-resistance rating, connections between members must have sufficient protection to provide the same fire-resistance rating.
 - Evaluate shrinkage and consider continuous columns or steel post stubs.
 - Consider prefabricated vs. custom fabricated hangers and the need to CNC timber to accommodate hangers and hardware.
- For column-to-foundation details:
 - Consider prefabricated/preinstalled anchors for quick installation.
 - Allow for field adjustment to accommodate tolerances of different materials.
 - Detail for moisture and insect protection.
- Detail for durability and keep moisture from building up, especially at end grains and joints.
- Tolerances of mass timber are much tighter than other materials. Consider tolerances and discuss details with the builder and fabricators of all trades.
- Determine how the tolerances will be accommodated at the foundation/base level of the project. This area has the greatest potential for differences.
- Hold a preconstruction coordination meeting with the GC, foundation subcontractor, and mass timber manufacturer/designer to address tolerances and base connections. This is a mandatory best practice with steel (AISC) and structural precast concrete (PCI) and should be the same for mass timber.

RESOURCES:

- ▶ [*Accommodating Shrinkage in Multi-Story Wood-Frame Structures*¹⁷](#)



PHOTO: LENDLEASE

DESIGN DEVELOPMENT (DD) continued

DD Cost Optimization Checklist

Revisit the SD Checklists

- The SD checklists are still relevant. Remember to continue developing these items. As with SD, a holistic approach is required to compare costs and yield savings during DD.

Less Weight = Cost Savings

- Smaller cranes can be used for lifting wood panels since they are lighter than other materials. With a smaller crane, pick cycles are increased, improving daily output and reducing total duration.
- With the speed of mass timber construction, crane time on site can be reduced, also yielding savings.
- For shorter buildings, portable equipment can possibly be used (fork lifts and lulls).

Schedule Savings = Cost Savings

- Subcontractors can work faster on a wide open floor with no shores interrupting work flow.
- Mass timber buildings have realized schedule savings even in severe winter conditions.⁸

Cost & Value

- As costs are further defined, consider these additional benefits of mass timber systems:
 - Less waste and fewer deliveries to the site than other material systems
 - Quicker fastening than with other material systems (bolt and screw connections are typical, and welding can usually be avoided)
 - Quieter sites and less disruption, which can have a positive impact on how neighbors perceive the project and can be favorable from jurisdictional approval standpoint (because of fewer complaints)
 - Where mass timber is designed to be exposed, no need for additional fireproofing materials or finishes such as gypsum wallboard or trim

Fabrication

- Consider the impact of CNC work for architectural reveals, MEP and fire protection penetrations, connections, etc. Work with the fabricator to define a deadline for coordination of penetrations.
- Coordinate the lifting points and erection connections.
- Determine which connectors are installed in the shop vs. field. Maximize shop-installed and minimize field-installed for cost savings.

Installation & Labor

- Determine whether the GC or subcontractor will install the framing. Organize training if needed.
- Ensure that safety policies and procedures are in place to protect against construction fires.

Finish Quality

- Determine which finishes are applied in the shop vs. field. If finishes are shop-applied, include allowance for field touch-up of exposed panels that might be damaged during shipping, storage or construction. The owner and GC should discuss how to cover any overages on a contractual level.

Protection

- Protect wood during shipping and construction (e.g., end grains covered/wrapped, tarps, etc.) to prevent damage. Exposed structural elements must be handled with care to minimize damage and discoloration. Just-in-time delivery helps prevent damage to panels stored on site.
- Protect steel connectors (e.g., shop-applied paint/primer, cover, etc.).

RESOURCES:

- ▶ *Press Release: WoodWorks Installer Training program*¹⁸
- ▶ *Construction Fire Safety Coalition*¹⁹

Sources

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