Umass Amherst Design Building
Leading the Way with Mass Timber Solutions

Tom S. Chung, AIA LEED BD+C
Principal, Leers Weinzapfel Associates

Disclaimer: This presentation was developed by a third party and is not funded by WoodWorks or the Softwood Lumber Board.
Course Description

Currently under construction, the Design Building at the University of Massachusetts Amherst is the first of its kind in the U.S. At four stories and 87,000 sf, this mass timber project, designed by Leers Weinzapfel Associates, features a glue-laminated (glulam) timber column-and-beam frame, mass timber lateral force-resisting systems, composite cross-laminated timber (CLT) floor systems, and unconventional cantilevered forms. It also includes an open floor plan, exposed mass timber framing throughout, and a composite glulam zipper truss spanning a central commons, with a green roof courtyard above.

This presentation by the project’s principal architect will review the process and collaboration required to see this groundbreaking structure to fruition in a steel-dominated construction industry. Topics will include design, detailing, procurement of materials, code approvals and construction, with an emphasis on issues and solutions.
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Learning Objectives

• Explore the design team’s approach to material and construction selection for a mass timber building in lieu of traditional steel systems.

• Discuss the use of composite CLT floor systems and associated design considerations.

• Review the code approval and local permitting steps taken to achieve compliance for a first-of-its-kind mass timber building.

• Highlight innovative structural solutions implemented by the design team in the central commons and courtyard in order to meet massing and occupancy needs.
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AGENDA/OPTLINE

Introduction
• Background & Context
• Design Concept

Process
• Mass Timber Structure Design
• Steel Systems vs Wood Systems
• Assuring the Client: Budget, Procurement & Code

Design Details and Construction
• Central Commons and Courtyard Design
Program Organization

- Learning courtyard
- Skylights & green roofs
- Studios
- Offices
- Classrooms
- Mechanical
- 2-story commons
- Shops
- Workyard

2 Story Commons
With learning courtyard above
Stacked Studios/Stacked Offices
Program Organization
Regional Context
Fenestration Concept
View from Campus Core

View from Haigis Mall, across North Pleasant Street
View from Historic Stockbridge Way
Design Process
Post and Beam Structural Framework
Carbon Summary

Volume of wood products used (m³):
2081 m³ (73482 ft³) of lumber and sheathing

U.S. and Canadians forests grow this much wood in:
6 minutes

Carbon stored in the wood:
1463 metric tons of CO₂

Avoided greenhouse gas emissions:
1218 metric tons of CO₂

Total potential carbon benefit:
2681 metric tons of CO₂

Equivalent to:
512 cars off the road for a year

Energy to operate a home for 228 years

Timber Structure Revit Model
CHANGE IS POSSIBLE EVERYWHERE

Steel Post & Beam $\rightarrow$ GL Post & Beam

Steel/Concrete Floors $\rightarrow$ CLT/Concrete Floors

Steel Deck Roof $\rightarrow$ CLT Roof

Concrete Shafts $\rightarrow$ CLT Shafts

Steel Braces $\rightarrow$ Glulam Braces
Steel

Post and Beam Structural Framework
Post and Beam Structural Framework

Glulam
Glulam Beam to Column Connection
Glulam Beam to Column Connection
Steel and Concrete

Floor System
CLT and Concrete
CLT and Concrete Composite Floor
CLT and Concrete Composite Floor
CLT and Concrete Composite Floor
CLT Panels
Lateral Cross Bracing

Steel Bracing

Glulam Bracing
Lateral Cross Bracing
Lateral Cross Bracing
Project Team

- **Client:** University of Massachusetts Building Authority
- **User:** University of Massachusetts, Amherst Architecture & Design, LARP, Building Construction & Technology
- **Architectural / Structural Design Team:**
  - Architect: Leers Weinzapfel Associates
  - Structural Design Engineer: Equilibrium Consulting
  - SER: SGH
- **AHJ:**
  - MA State Building Inspector
  - MA Board of Appeals
- **Construction Team:**
  - Construction Manager
  - Timber Fabricator and Installer
Process: Assuring the Client

EQUILIBRIUM

Structural Engineers
Equilibrium Consulting Inc.
202–388 West 8th Ave
Vancouver, BC V5Y 3K2
Canada
+1 604 730 1422
info@equilibrium.ca
equipanada.com

Floor
The proposed floor is a state-of-the-art example of recently developed high-tech wood technologies. The composite action between concrete and CLT is achieved by an innovative perforated glued-in steel system. HBV, see Appendix. The floor is strong and stiff with excellent vibration resistance while minimizing the overall depth and providing an exposed architectural surface below with no finishes required.

The floor beams are also connected to the concrete layer and act as a T-section that minimizes the overall depth with low deflections and excellent vibration performance. The glulam posts have a central cut out to receive the beams. This detail ensures direct parallel to grain bearing between the stacked columns and limits the shrinkage to a single depth of a floor beam.

To minimize the structural height at the long spans over the first floor, and the cantilevers at grade A, steel beams have been proposed for the preliminary pricing, see Appendix. The potential use of glulam beams or trusses at these locations will be examined at the Design Development stage of the project.

Lateral Load Resisting System
CLT/plywood and CLT/concrete diaphragms, together with glulam beams, working as drag struts transfer the lateral seismic and wind forces to the CLT shear walls. These walls, that are mostly located around the stair and elevator cores, transfer the forces to the foundations. The alternative solution uses diagonal glulam braces. These two systems will be investigated in more detail during the Design Development stage of the project.

Cost
The cost of the timber structure is currently being prepared by two independent fabricators. This price will be compared with the price of the steel structure. It should be noted that there are two possible steel options that can be used for comparison to the wood option for this project: 1) an industrial steel option and 2) an exposed architectural steel option. The industrial steel option is currently being considered, which is economical but has an industrial finish and has to be covered. It is argued that for a fair cost comparison with the architectural quality wood option, the architectural steel option should be priced. In the case that the industrial steel option is chosen, its price should also include the finishes required to cover it.

Project Team and Stakeholders

Energy Performance
Energy performance of a wood structure is by far superior to other material options. Steel columns are the most typical heat bridges and are a major contributor to localized long term mold damage and low energy performance. The most efficient large scale wood buildings use the glulam post and beam system as proposed in this report. Current examples include Norwich Academy in the UK, Earth Sciences Building in Vancouver, BC and Wood Innovation and Design Centre in Prince George, BC.

Based on conversations with the owner group for the IDB project, energy performance is an important topic that will be taught in the building. Thus, the building should reflect best practices in this regard and use wood which is thermally insulating.

Structural Advantages of the Wood System
1. Open plan of the building can be easily achieved with the proposed system. It also provides the lightest load which limits seismic forces and size of foundations.
2. All timber elements are rated Heavy Timber and provide the required fire resistance.
3. Prefabrication of all timber elements together with the ease of electrical and mechanical installation in a timber structure ensures the shortest possible construction time.
4. Use of Wood/Concrete composite allows large spans with a minimum structural depth.
5. Wood structures are typically the easiest to accommodate any future changes in plan for new building layouts.
6. Use of carefully detailed prefabricated Mass Wood Elements enables the erection of all timber members in all weather conditions.
8. Superior energy performance of wood members that eliminates heat bridges.
The Benefits of Sustainable, Structural Wood
7006 Integrated Design Building, April 11, 2014

The UMass IDE design team is actively considering the use of engineered wood as the primary structural material for the building. Engineered wood products—generally referring to glue-laminated beams (Glulam) or cross laminated timber (CLT)—are gaining popularity for their rapid renewability, physical and aesthetic attributes, and cradle-to-grave sustainability properties. While concrete and steel have long been the primary structural materials for large-scale buildings, engineered wood products are proving equal in reliability, strength, and effectiveness. Wood products can now match or exceed the thermal, resilient, and structural properties of concrete or steel and are increasingly cost-competitive especially when measured on a life cycle basis for performance, embodied energy, and comfort.

A comprehensive evaluation of wood as a viable sustainable construction material can be approached through a life cycle analysis. This takes into account all aspects of a material's usable life, including extraction, transportation, modification, construction, revision, and disposal. Other than mill work to adjust its dimensions, wood essentially needs no additional processing after its harvesting. Wood construction methods generally use glue-laminated beams (Glulam) or cross laminated timber (CLT), that require minimal further alterations.

Concrete is the combination of multiple materials from just a few extraction sources. The cement in concrete is largely limestone, which needs to be mined and heated at extreme temperatures to produce cement in the powder form required for mixing. Concrete also contains aggregate and water, combined either on-site or pre-mixed and delivered. The combination of these ingredients requires increased transportation for each material, cost, and embodied energy (discussed later). When a concrete building or site is to be demolished, the concrete needs to be crushed for reuse. However, the cement is not extractable, new concrete requires freshly manufactured cement. When a wood structure is to be removed or torn down, it can be used as is, or re-milled to necessary specifications.

Steel begins as iron ore, extracted from a mine, then smelted into steel. Smelting involves the removal of impurities like silica, phosphorus, and sulfur, along with the addition of alloys to create steels of different physical properties. This post-processing requires vast amounts of energy and labor. Steel is a very strong building material, but has its weaknesses. Moisture can cause rust, and if left untouched can cause failure. At a corrosion rate of 260 μm/yr, this does not accumulate too much over the lifetime of a large steel beam. However, thinner steel, such as that used in rebar, can cause cracks in concrete, or bending under strain. Through a 90% recyclability rate, it is one of the most reused materials. This does not nearly meet the demand, resulting in more mining and processing.

The initial extraction of any product will affect the environment. Concrete requires quarries for limestone. Steel needs iron ore mines, each irreversibly, and adversely, changing the natural landscape. Timber requires deforestation, which destroys natural habitats, as well as changing the landscape. However, these effects can be limited given responsible forest management. Quarries and iron ore mines are effectively irreparable, and indefensible, given the time span prior to their harvesting for the products to accumulate.

The Forest Stewardship Council (FSC) provides guidelines and rules for responsible forest management. Through the FSC, wood can be tracked from forest to site via Chain of Custody (CoC) documentation, ensuring that those wood products were grown and extracted from a properly managed sustainable forest. Following FSC strategies, timber extraction and regrowth can close to match the carbon sequestration of an untouched forest. The graph displays the amount of carbon stored in a statistically average FSC regulated forest. Each trough of the red, orange, and blue lines represent timber extraction events, followed by regrowth and proportional carbon sequestration. The green line represents a forest with no harvesting. Through the overall carbon sequestered is less for those forests that are managed, not included.
Key Issues

• Danger of “Over Estimating Contingency” by Construction Managers or Cost Estimators due to the “Unknown”

• Importance of multiple Bidders

• Coordination of Fabricator and Installer Team

• Proper scoping of work for Bids. Especially if based on Progress Drawings

• Consideration of Contractor Reputation and History. It’s a small world!
### Process: Assuring the Client

#### Preliminary Estimates

**Budget**

**Date:** May 8, 2014

**Attention:** Estimating

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**Grand Total:** $[Total Price]

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**Main Building Glulams**

[Diagram of building structure]
### Timber vs Steel Budget Comparison

**Process: Assuring the Client**

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<th>DESCRIPTION</th>
<th>QTY</th>
<th>UNIT</th>
<th>COST</th>
<th>ESTD COST</th>
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</table>
| Lamar
| Wood framing option, installed (average quote)                  | 1   | Is   | 3,500,000.00 | 3,500,000  |
| Add basement "no" structure (10,790 sf)                        | 65  | Tns  | 3,750.00  | 243,750   |
| Metal decking @ basement                                      | 10,790 | sf | 4.00  | 43,160    |
| Fill at decking at basement                                   | 10,790 | sf | 5.00  | 53,950    |
| 4" Concrete topping to all upper floor slabs                  | 52,388 | sf | 4.00  | 209,552   |
| Additional steel beams, columns and bracing (per Le Massieu)   | 85  | Tns  | 4,250.00 | 361,250   |
| Additional sprinkler heads                                    | 1   | Is   | 100,000.00 | 100,000   |
| "" insulation @ upper slabs                                    | 52,388 | sf | 1.50  | 79,552    |
| Additional trim to CLT                                         | 15,040 | sf | 3.50  | 52,640    |
| Allowance for protection of finished wood structure during construction | 52,388 | sf | 0.75  | 39,291    |
| **Subtotal Wood structure cost**                               |     |      |        |           |
| Steel option                                                   |     |      |        |           |
| Steel, decking and fill                                       | 9,520 | sf | 20.00 | 190,400   |
| Add CMU shallwalls at stairs & elevators                      | 15,040 | sf | 3.50  | 52,640    |
| CMU acoustical barrier ceiling                                 | 2,200 | sf | 12.00 | 26,400    |
| Wood grille ceiling at 2 story, Central Space                  | 5,000  | sf | 20.00 | 100,000   |
| Wood grille ceiling at Cafeteria/Exhibit/Library               | 2,000  | sf | 20.00 | 57,600    |
| Plant exposed ceiling/deciding                                 | 48,276 | sf | 3.00  | 144,834   |
| **Subtotal Wood structure cost**                               |     |      |        |           |
| **DELTA BETWEEN OPTIONS**                                      |     |      |        | 27.25%    |
| Add Markups                                                    |     |      |        |           |
| TOTAL ADD FOR WOOD STRUCTURE INCLUDING MARKUPS                 |     |      |        |           |

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| Metal decking @ basement                                      | 10,790 | sf | 4.00  | 43,160    |
| Fill at decking at basement                                   | 10,790 | sf | 5.00  | 53,950    |
| 4" Concrete topping to all upper floor slabs                  | 52,388 | sf | 4.00  | 209,552   |
| Additional steel beams, columns and bracing (per Le Massieu)   | 85  | Tns  | 4,250.00 | 361,250   |
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| Add Markups                                                    |     |      |        |           |
| TOTAL ADD FOR WOOD STRUCTURE INCLUDING MARKUPS                 |     |      |        |           |
### Process: Assuring the Client

**Fabricator/Installer Bid Quotes**

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**Note:** Further details and specifications are available in attached documents and bid packages provided for the project.
Process: Code Review & Variance

Alternative Structural Systems

CLT roof/floor panels and shear walls

CLT floor panels and glulam beams with composite concrete
Proposed Alternate Structural Systems

Cross Laminated Timber (CLT) roof and floor decks and shear walls

- 20+ years in Europe, recent projects in Canada similar to IDB
- ANSI/APA PRG -320: current material fabrication requirements and stress grades
- Connections between CLT panels similar to traditional wood frame construction
- Employing high strength, ductile HSK connections as shear wall anchors

CLT floor decks and glued laminated timber beams with composite concrete deck

- 20+ years in Europe, extensive research and testing in Germany with HBV connector system
- CLT units provide required strength, concrete decks only counted on for stiffness
TESTING
Central Commons and Courtyard Design

Structural Challenges:

• Long span with heavy loading above
• Minimize structural depth
• Wet garden on a wood structure
Preliminary Courtyard Plan
Central Space Structural Concepts
Zipper Truss Final Concept

- Option 3
- USE SIZES 20% SMALLER THAN BEFORE
- Rev. 2
Central Connector Studies
Central Connector Studies
Central Connector Studies
Grasshopper Parametric Definition
Rhino Model Detail
Zipper Truss Installation
Section Through Commons and Learning Courtyard
Central Commons
THANK YOU!

Designing the Design Building at UMass Amherst
QUESTIONS?

This concludes The American Institute of Architects Continuing Education Systems Course

Tom S. Chung, AIA LEED BD+C Principal, Leers Weinzapfel Associates tsc Chung@lwa-architects.com