Connecting the Pieces: Fundamentals of Modular Building Design

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1.0 Learning Units
Ralph Tavares, PE
Pedro Tavares, Assoc. AIA

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Course Description

Modular wood structures built off-site using innovative new techniques allow designers to streamline project completion and cost-effectively assemble buildings in a more efficient, quality controlled environment. While these benefits have the potential to improve construction delivery, designers may be hesitant to consider this option because they aren’t sure how to adapt traditional design approaches and processes. This presentation will introduce design fundamentals for modular construction, including best practices for layout, detailing examples, as well as key cost information.
Learning Objectives

• Review the cost and value of modular construction techniques
• Demonstrate through project examples the wide range of applications for modular design
• Understand how the design process of modular differs from traditional design including: when and how to engage a modular manufacturer, how work flow and consultant scope change, and differences in permitting and inspections.
• Discuss best practices for project design including economical parameters for layout and detailing
Acknowledgements/Credits

Modular Building Institute
http://modular.org

University of Utah Integrated Technology & Architecture Collaborative
http://itac.utah.edu

University of Alberta Hole School of Construction Engineering
https://www.ualberta.ca/engineering/research/groups/construction-engineering

Woodworks Wood Products Council
http://woodworks.org

American Institute of Architects
http://aia.org
Ralph & Silvana Tavares
Modular construction is construction of 3D volumes to IBC/IRC building codes with a high level of finish off-site, typically in a warehouse, yet at times in nothing more than a yard, that is shipped to a site in sections and then assembled into place utilizing a lifting mechanism. Once on-site, utility and structural connections as well as patching or finishing is completed between modules.

Modular construction is estimated to make up 3-5% of total US construction industry.

- 3D-Volumetric modules
- IRC/IBC Building Code
- High level of finish performed off-site
- Shipped in sections
- Assembled into place via a lifting mechanism
- Utility, Structural and finishes typically finished on-site
- 3-5% of total US construction industry
Other types of Off-Site Construction

• ANSI code A119.5:
  • Park model trailers
  • Limited in total square footage
  • Allow loft spaces
  • Permanently attached to a chassis with axles
  • Has VIN # from DMV

• HUD Federal code:
  • Mobile/Manufactured housing
  • Federal-level code
  • Generally regulated to mobile home parks or jurisdictions w/o regulations

IBC/IRC “Flat pack” or “Panelized” building systems
Wall, floor and roof frames built in 2D sections and loaded onto carriers
Tilt-up erection on-site
Sometimes include rough-ins for MEP

• Wet core modules
  • Bathroom or kitchen pods
  • Widespread use in Europe and other areas
  • Gaining traction in US
  • Difficulty in US adoption due to ADA threshold challenges
Benefits of Modular Construction

• Resource efficient
• Controlled conditions
• Improved quality
• Precision
• Inherently “Green” processes
Traditional US Construction

Challenges

- Workers typically exposed to high levels of:
  - Noise
  - Dust/airborne particles
  - Adverse weather conditions
- Site compaction & soil erosion from construction equipment
- Material storage challenges
- Adverse weather conditions
- Unskilled labor force
Traditional Modular Construction in the US

**Challenges**

- Approval process / code challenges
- Design & engineering unfamiliarity
- Transportation limitations
- Inspectors & code official unfamiliarity
- Seismic area height challenges
- “Mobile home” stigma
Modular Construction in the US

**Benefits**

- Controlled conditions
- Consistent quality control
- Supervision of labor
- Material & tool storage
- Fewer On-site material deliveries
Modular Construction in the US

**Benefits**

Reductions in:
- Material waste
- On-site air & water pollution
- On-site dust & noise
Modular Construction in the US

**Benefits**
- Fewer conflicts in work scheduling
- Reduction of On-site material storage
- Fewer losses/misplacement of material & tools
- Increased worker safety
- Retention of workforce talent
Benefits of Modular: Costs

- **Cost-Savings**
- Elusive Target
- Breakpoints in production
  - Economies of Scale possible with highly repetitive product
  - Many factories capable of building 4+ complete modules per day
- Realized cost savings:
  - General conditions
  - Construction financing
  - Time to occupancy/market
Benefits of Modular: Costs

- **Cost Considerations**
  - Manufacturer preferences
    - Hardware
    - Suppliers
    - Brands
  - Supply chain & purchasing power
    - Manufacturers buy in bulk
    - Spec materials from typical vendors
    - Lack of familiarity with custom materials
- State-level permitting
  - 35 states have modular programs
  - Time & cost of state permits often significantly less than local jurisdictions with heavy regulatory environments
- Prevailing Wage
  - Typically not required for off-site components
- Union Labor
  - Often avoided for off-site components
Benefits of Modular: Costs

Key Findings: Quantitative Analysis

<table>
<thead>
<tr>
<th>Cost</th>
<th>16% Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schedule</td>
<td>43% Savings</td>
</tr>
<tr>
<td>Quality</td>
<td>5.4 Average Change Orders</td>
</tr>
<tr>
<td>Safety</td>
<td>0.25 Average Safety Incidents</td>
</tr>
</tbody>
</table>
**Benefits of Modular: Costs**

**Key Findings: Return on Investment**

<table>
<thead>
<tr>
<th>Schedule Reduction</th>
<th>Average Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>25%</td>
<td>$5.81/SF</td>
</tr>
<tr>
<td>50%</td>
<td>$10.93/SF</td>
</tr>
</tbody>
</table>
Benefits of Modular: Time

Compressed project schedules

- Components manufactured off-site while: Foundation built
- Utilities ran
- Site work completed

Compressed project schedules

- State-level approvals and inspections via 3\textsuperscript{rd} party approval agencies
- No local inspections for off-site product
Advances in Modular Technology: Europe
Advances in Modular Technology: Japan
Advances in Modular Technology: Japan
Herron Project, Nashville
Three on Abbott, San Diego
Shipping Constraints

• Width:
  • Up to 16’-0” most places
  • Breakpoints at 12’ & 14’
  • TX up to 18’-0”

• Length:
  • Typically around 72’-0”
  • Dependent on factory layout

• Height:
  • 17’-0” including trailer in many jurisdictions
  • 16’-0” Elsewhere. Location specific
Shipping Constraints

- Mods of the same width can be loaded on the same trailer up to maximum shipping length
- Manufacturers typically set up to serve 500’ mile radius
- We often estimate $10/mile/shipment for standard shipments
Raised Foundation
Mod to Mod Connections @ Mate Lines
Belly Bands

**15 EXTERIOR BELLY BAND SPLICE**

1 1/2" = 1'-0"

AIA Conference on Architecture 2018
June 21-23, New York City
Modular UL listed assemblies

- UL Listed Assemblies available for modular components:
  - Fire rated
  - STC/IIC rated
  - Floor/Ceiling
  - Mateline/Mateline
  - Floor/Crawlspace
- General excellence in STC/IIC qualities due to redundancy in framing and air gaps
Off-site Finishing Capabilities
Financing

- Many banks nervous
- Factories typically require 100% payment before product leaves yard and may require as much as 50% to get started
  - Large amount of interest reserve used early in project
  - Construction *should* wrap up shortly after arrival of mods
  - Typical draws before mods arrive for site work/utilities and foundation
Finding Modular Consultants

• Modular Building Institute Member Finder (Commercial Projects)
  http://modular.org/Finder/Default.aspx
• Modular Home Builders Association Member Finder (Residential)
  https://modularhousing.com/Finder/Default.aspx
• Be wary of paid ads on google and other searches
  • Paid SEO ≠ quality consultants
Additional Resources

1. Advancing the Competitiveness and Efficiency of the US Construction Industry, NIST/NRC, National Institute of Standards and Technology and National Resource Council, 2010

2. Improving Construction Efficiency & Productivity with Modular Construction, Modular Building Institute


4. Woodworks “Putting the Pieces Together”
Questions?

• This concludes The American Institute of Architects Continuing Education Systems Course