Modular Wood Framing Goes Vertical

By: Troy Bean, P.E., S.E.
DCI Engineers
January 2013

Learning Objectives

At the end of this program, participants will be able to:

1. Identify where and when modular construction makes sense as a wood-framed delivery system.
2. Learn about the economical design parameters for both fabrication and transportation of modular units.
3. Discuss what engineers are doing to account for design loads, gravity and lateral load paths, as well as different options for foundations, floors, wall, and ceiling systems.
4. Examine different examples of delivery and project completeness available with factory-built modular units.
Wood Framed Modular

Modular Framing is NOT:

- Modified shipping containers
- Single or double wide mobile homes
- Kit buildings or homes
- Modified other vehicles or assemblies

What is Modular?

Wood framed delivery system utilizing efficiencies and quality control while minimizing on-site construction and material waste.

- Factory built, transported to the site, and set into final positions to form a completed building
- No fixed or permanent axles
- Designed to current IBC requirements
- Completed to various degrees. Typically all MEP systems are factory installed and inspected. Interior and exteriors are finish as much as desired or practical.

Site Considerations

To be efficient and practical the following should be considered before deciding to consider modular for your project:

- Suitable modular manufacturer should be within 500 miles
- Initial trip study to ensure clear transportation and delivery routes
- Extra staging area for units or at least near site to minimize delivery efforts or valuable crane time during setting phase
- Crane access or limitations, i.e. trees, power lines, staging, or reach issues

Location issues

Modular Construction has a competitive advantage when:

- Local workforce is limited such as in remote locations
- Construction noise or time impact to neighborhood is an issue
- Delivery to market (speed of construction) impacts project success
- Project requires prevailing wages for on-site construction efforts
Economical Design

Design considerations for cost efficiency:

- Optimize factory capabilities and construction techniques
- Lay out building to consider efficient unit sizes and types
- Maximize repetition and uniformity of units
- Construction material flexibility to take advantage of bulk pricing, sourcing, and waste management
- Attention to unit shipping sizes to avoid multiple trips or additional permits and pilot or chase cars

Typical architectural limits:

- Design within 16’ W x 12’-8” H x 68’ L
- Lay out units to stack on perimeter units below
- Including such design elements as overhangs, step backs or open units are less efficient and increase costs and field construction efforts
- Modular construction provides a deeper ceiling to floor assembly that must be accounted for in stairs and overall building height
- Including portions that are not easily manufactured or shipped that will be site-built also create inefficiency

Modular System Types

Barbell Unit Configuration:

- Suited for double loaded corridor building layout
- Allows for unit type variety based on unit width and depth
- Units must align across hallway
- Ceiling in corridor can be removed on-site for chase ways and MEP
- Maximizes possible unit length
- Can be used for economy structures like hotels, but can be opened up between adjacent units to form 2-3 unit spaces

Saw Box Unit Configuration:

- Smaller individual units that have the same width manufactured and shipped in a single unit
- Limits unit type variety based on unit width
- Requires approximately 4’ spacing between units for fabrication and finishes
- Must optimize or pair units to maximizes possible unit length
- Can be saw cut at staging area to solve near site transportation issues
- Can be used to solve limited crane maneuverability issues
Modular System Types

Crosscut Unit Configuration:
- By rotating the modular units across individual units rather than in direct line, the maximum lengths can be resolved in units where saw box techniques would not apply (i.e. 40’ deep units x 2 = 84’ >68’)
- Allows for unit type variety based on unit width
- Does not provide vibration breaks across units
- Requires a much higher level of on-site work to patch units together inside all the units
- Unit layouts should include wet side/dry side to maximize efficiency

Engineering Design

Design Criteria:
- All IBC load requirements for the specific use, occupancy, and site specific loading due to wind or earthquake
- Understanding of manufacturing process as the unit is assembled and moved through the plant
- Determining transportation methods. Typically units are supported by rails at 8’ OC that reverse the loading on floor framing to a cantilever condition.
- Construction live loads (worker safety and access during construction)
- Crane picking and placing or other placement methods

Modular units – Walls:
Typical framing consists of conventional stud framing using top and bottom plates. Since each modular unit consists of a six sided box, these walls serve multiple functions:
- Tenant demising walls (double wall with 1”-2” gap)
- Exterior insulated walls
- Plumbing walls in lieu of plumbing chases or shafts
- Shear wall elements with rated plywood or OSB sheathing
- Bearing walls
Engineering Design

Modular units – Ceilings:
Typical framing utilizes ceiling joists spanning across the modular unit in the short direction and are supported by continuous or spliced rim joists. Joists need to be designed for construction live loads as well as ceiling loading. These members are sometimes penetrated by small MEP and fire sprinkler. If larger ducting is necessary, either drop soffits or much deeper joists. The ceiling framing can also be used as an exposed architectural feature that provides additional volume. Sound and vibration from above are minimized due to the space between units provided during the set sequence.

Modular units – Lateral:
Modular units experience their greatest loading during the manufacturing, shipping, and craning process and need to perform like ridged boxes until set into their final position in the building. Individual lateral elements are designed into the modular unit to maintain the stiffness and utilize the continuous rims in both the floor and ceiling assembly to transfer the internal loads. Overall building lateral systems include the shear walls and horizontal floor and ceiling diaphragms. Modules tied together using field installed plates, straps, sheathing and nominal lumber form the completed building. Goal during the interconnection process is to keep all connections to the exterior of the units to minimize patching or repair to the interior of the finished unit.

Manufacturing

Plant manufacturing goals:

- Install all windows and doors including weatherproofing.
- Complete the interior unit as much as possible.
- Install all fixtures, appliances, and finishes.
- Complete all inspections possible including MEP.
- Protect modular unit for shipping and during construction until dried in.
- Limit the need for floor or wall access panels for field connections that would require field finishing or patching.

On-Site Work

Set Sequence:

- Where included, install roof trusses on top of sleepers and complete lateral transfer of roof diaphragm to modular units.
- Set upper unit and connect unit to sleeper plates. Install any straps specified. Repeat.
- Set adjacent unit and field install top sleeper plates that serve as drags, chords, and diaphragm continuity. Repeat.
- Set initial unit and provide lateral connections between unit and wood nailer.
- Ready foundation or support framing with wood nailer that has easily removable sections to allow for recovery of straps.
Site Finishing
After modular units are set (typically 6-8 per day):
Temporary walls, ceilings and floors can be opened up for installation of stairs, elevators and in connecting adjacent units or providing larger open spaces. In cross cut units or adjacent units that open to each other, patching and finishing is necessary to cover the mate line gaps on the floor, ceiling and walls.
Connections between the individual units to the primary MEP systems can be installed. These connections are typically in the corridor utilizing ceiling space or in open shafts or plumbing walls that allow for the connections to be made both horizontal and vertical. Interior finishing and patching can be installed after inspections are completed.
Exterior siding can be completed to provide a finished building.

Trailhead Condos at Suncadia
Cle Elum, Washington
• Post-tensioned concrete parking level below grade
• Three levels of modular construction
• Double loaded corridor (barbell units)
• 2-3 adjacent units formed individual living units with open rooms utilizing flush clear span ceiling beams
• Interior finishes only MEP and rough drywall
• All exterior siding applied in field
• Site-built roof truss package (high snow load area)

Harbour Landing
Regina, Saskatchewan
• Pile-supported foundation with steel support beams and wood nailers
• Four levels of modular over a crawl space
• Double loaded corridor (barbell units)
• Inside corner utilized cross cut units
• Finished interiors except the corridors
• 80% of exterior siding factory installed
• Site-built roof truss package

Joint Base Lewis-McCord
Lacey, Washington
• Slab on grade foundation
• Site-built first level
• Two levels of modular units in townhome layout
• Interior finishes complete
• Roof truss built into package
• Factory installed roofing
• Appliance packages shipped with units down to ceiling fans
• Site applied exterior siding
Questions?

This concludes The American Institute of Architects Continuing Education Systems Course

Troy Bean, P.E., S.E.
DCI Engineers
tbean@dci-engineers.com