



Rethink Modular:

Assessing the Durability and Life Cycle of Modular Construction

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Pictured left: Europe’s tallest modular building—a \$34 million UK project. Designed by O’Connell East Architects of Manchester, the 24 story student dormitory is made up of 805 modules and designed to be built in 27 weeks.



“The life cycle expectancy of modular construction is the same as conventional, and in a world where sustainability is gaining momentum each day, there are also several basic principles intrinsic to the modular construction process that make it more eco-friendly than conventional construction. - American Institute of Architects “External Issues & Trends Affecting Architects, Architectural Firms, and the AIA” - American Institute of Architects, February 2008.

“The module-to-module combination of the units appears to have provided an inherently rigid system that performed much better than conventional residential framing.” - Mitigation Assessment Team Report: Hurricane Andrew in Florida – FEMA 1992

Overview

A senior analyst with the Physical Infrastructure Team of the U.S. Government Accountability Office contacted the Modular Building Institute on Monday July 6, 2009 to seek the modular industry's input into a review that the G.A.O was conducting at the request of the House Armed Services Committee. The review focused on the Army's decision to allow the use of all construction types (including type V, wood frame construction) for military construction projects. The following whitepaper was prepared as a result of this inquiry.

About MBI & the Commercial Modular Construction Industry

Founded in 1983, the Modular Building Institute (MBI) is an international non-profit trade association serving approximately 300 companies engaged in the commercial modular construction industry. Our regular members are manufacturers, general contractors and dealers of commercial modular structures, while our associate members are companies supplying building components, services, and financing. It is MBI's mission to grow the industry and its capabilities by encouraging innovation, quality, and professionalism through communication, education, and recognition.

Definitions:

Modular Construction – “An off-site project delivery method used to construct code-compliant buildings in a quality-controlled setting in less time and with less materials waste.” Note: This definition is not limited to Type V construction. While Type V construction is much more prevalent within the modular industry, several companies have successfully designed and built all types of facilities for a multitude of purposes utilizing modular construction processes.

Type I – Typically, concrete frame buildings made of noncombustible materials. All of the building elements (structural frame, bearing walls, floors and roofs) are fire resistance rated.

Type II -These buildings are constructed of noncombustible materials. Typically, masonry bearing walls structures with steel studs for walls and steel bar joists for floor and roof structures. IIA has fire rated building elements (structural frame, bearing walls, floors and roofs). IIB is the most common construction type for commercial buildings because the building elements are not required to be fire resistance rated but still must be non-combustible.

Type III - Construction in which the exterior walls are of noncombustible materials and the interior building elements are of any material permitted by the code (combustible or non-combustible). This is typical of buildings with masonry bearing walls and wood roofs or floors.

Type IV (Heavy Timber, HT) - Type of construction in which the exterior walls are of noncombustible materials and the interior building elements are of solid or laminated wood without concealed spaces.

Type V - Typically wood frame construction. Type of construction in which the structural elements, exterior walls and interior walls are of any materials permitted by this code.



432,000 sq ft Company Operations Facility at Ft Bliss



*Millmont Elementary School, Reading, PA
60,000 sq ft built off site*

Type II vs. Type V Construction

The structural approach used in buildings designed to meet the requirements of Construction Type II and Type V take basically the same type of elements, just use different types of materials. Each of these construction types can be of materials that are classified as “light framed” which normally depend on roof and intermediate floor sheathing to distribute the lateral forces from wind and seismic to walls (normally exterior walls) that have sheathing which provide rigidity to brace the building.

In the code the classification of the two construction types are based on the fuel contribution available in case of a fire. Thus, the code places limits on the permitted heights and building size depending on the material's potential to be a fuel source in case of a fire. For example, a building of a business occupancy group, a Construction Type V building has a base allowable area of 9,000 square feet when Construction Type II permits 23,000 square feet. In addition, again for the business occupancy, a Construction Type II building can be constructed to four stories where the building of Type V is limited to only two.



500,000 sq. ft UEPH Facility at Ft Bliss exterior (above) and interior (right)



- Good roof diaphragm strength and stiffness, (not as good as steel deck over steel framing).
- Requires less engineering and detailing for most normal applications since it is a “traditional” material.
- Creates less of a thermal bridge from the exterior to the interior, especially when compared to a metal member with much higher thermal conductive properties.
- Wood traditionally is lower cost vs. steel.

Negatives of Wood Construction (Construction Type V):

- Quality inconsistencies due to grain, knots and wane; for quality construction additional inspection and occasional culling is required. Especially a concern where high quality wall finishes are demanded.
- Is a cellulose material, will create mold if moisture is applied with the right conditions.
- Not insect resistant.
- Grain orientation makes mechanical connections in some directions more difficult requiring special connection devices.
- Wood grain floor decking with thin floor finishes has the potential of “telegraphing” the grain of the surface of the plywood and the seams between the plywood sheets. Traditionally the solution is to apply self leveling gypsum or cement based underlayment to provide a more consistent surface for application of the floor finish. Based on the material type and thickness applied the final sizing of the structural support system will be impacted due to the additional dead load of the material.

Positives of Light Gage Steel Construction (Construction Type II):

- Straight and consistent.
- Light weight and strong.
- Simple to construct using mechanical connections.
- Excellent roof diaphragm strength.
- Allows for thin skinned steel shear walls that have considerable strength.
- Mold and insect resistant.

Negatives of Light Gage Steel Construction (Construction Type II):

- Requires more engineering and detailing.
- The “C” shape of the members normally available on the market is not a symmetrical shape as the normal wood member requiring in some conditions additional blocking or bridging.
- Strength is very dependant on the integrity of the shape of the section. If the established geometry is compromised the member potentially loses strength rapidly.
- Not as resilient as wood.
- Bearing elements must align with the vertical support members below. Plates are weak when compared with a double wood member.
- Web stiffening must be properly detailed and utilized where loads are supported by a members’ web. Under load, without a properly installed web stiffener, a greater potential exists for localized failure.
- In multi story construction the floor of the intermediate floor usually is concrete placed in a steel deck. Due to the weight of the concrete either there will have to be more supports located in the space below or elements of substantial strength will have to be designed to support the weight of the concrete and to limit deflections.

Other than regulating building size to limit the potential fuel source the building code is not intended to imply that a Construction

Type I is better than Construction Type II, II from III, III to V, etc; from the codes perspective all construction types are deemed viable as long as the provisions of the codes for safety and structural integrity are met.

Wood vs. Light Steel Framing

The perspective of the following is the use of the materials as structural elements to resist loads as defined in the building code. If properly engineered per the provisions of the code and the established material strengths either material type will perform adequately for the intended life of the building, whether that time be for five years or fifty years assuming that the building is properly maintained.

Positives of Wood Construction (Construction Type V):

- Simple to construct utilizing basic construction methods.
- Light weight and strong.
- Based on the wide range of growth properties of wood the material strength has a very conservative factor of safety included in its published strength values.
- Very resilient to short term duration loads. This allows increases in material strengths that are not allowed for other materials.
- Studs/joists rectangular full cross section of wood fibers provides a very geometrically stable material that does not pose a problem for concentric loads applied through the member, i.e. under most normal load applications web buckling is not a concern.

- Steel joists and studs create a thermal bridge that in many climates will require the addition of board type insulation installed on the building's exterior.
- Steel traditionally is higher cost than wood.

Key Elements to Structural Longevity

- High quality exterior finishes for the walls and roof.
- Use of properly designed secondary water plains.
- Interior finishes that are easily cleaned, repaired and refinished.
- Proper foundation design and construction. The foundation design must be based on a properly conducted soils investigation for the type of building intended and the range of loads anticipated.
- Proper development of the building pad including testing to verify the design parameters are met.
- The building is maintained throughout its life.

Wood (Construction Type V) and light gage steel frame (Construction Type II) are long respected methods of construction that have been used in many buildings throughout the United States. Both methods are fully code compliant and due to the competitive cost each provides a great value as a long-term building solution.

The industry is generally in agreement with the 2009 U.S. Army's Posture Statement for MilCon Transformation:

"The MILCON Transformation is the project delivery process the Army is using to provide quality, adaptable, and sustainable facilities in less time and at lower cost. ... The potential pool of contractors capable of providing the needed facilities increases with the inclusion of Type I (noncombustible) thru Type V (composite) construction and the expanded use of manufactured building (permanent) solutions."

Studies comparing the life-cycle costs of facilities built with traditional construction methods verses non-traditional construction

Given that a key component of life cycle cost analysis is determined by cost and quality of materials and workmanship in the building, the differences of life cycle costs between non-traditional construction methods and traditional methods are negligible as both are using the same materials, just assembled utilizing a different process or method. The industry would contend that the quality controlled environment in which the building modules are constructed, as well as the precision required to build off site and assemble on site, lends itself to a higher level of quality and workmanship, and less material exposure to inclement weather.

Further, since sustainability concepts are incorporated into the design and construction of all facilities in accordance with the "Memorandum of Understanding for High Performance & Sustainable UFC 1-200-01 27 November 2007, modular construction methods add value to the life cycle analysis. Modular construction methods are well suited for the USGBC's LEED Rating System, a requirement of many federal agencies.

http://modular.org/marketing/documents/Modular_09V3LEED.pdf

A report from the American Institute of Architects (AIA) called "External Issues & Trends Affecting Architects, Architectural Firms, and the AIA" from February 2008 was prepared because "The AIA wants to keep abreast of elements that are known to impact or that may in the future have an impact on the architecture profession and the American Institute of Architects." Modular construction is a topic included in the report on page 59 of the attached link. The report concludes:

"The life cycle expectancy of modular construction is the same as conventional, and in a world where sustainability is gaining momentum each day, there are also several basic principles intrinsic to the modular construction process that make it more eco-friendly than conventional construction. They spend significantly less on-site time, a result of a shortened construction cycle, (the outcome of the simultaneous activities of on-site development and off-site building construction), notably minimizes the overall impact on a site. And finally, modular construction methods and materials allow a building to be more readily "deconstructed" and moved to another location should the need arise, so complete building reuse or recycling is an integral part of the design technology."

<http://www.aia.org/aiaucmp/groups/aia/documents/pdf/aiab046303.pdf>

Many of the life cycle reports and research focus on the environmental life cycle of a building rather than its economic life cycle. One such example can be found on the EPA's website at: <http://www.lifecyclebuilding.org/files/Lifecycle%20Construction%20Resource%20Guide.pdf>

And while non traditional methods such as modular construction are comparable to traditional methods in terms of economic life cycle, modular construction provides significant advantages in terms of environmental life cycle analysis. This advantage is a result of a combination of less materials waste on the initial site coupled with the fact that modular structures are designed for deconstruction at the end of their useful life much more so that traditional buildings, thus reducing the amount of materials waste in landfills upon demolition.

Designed for maximum durability with minimum maintenance need, and cost effective.

After Hurricane Andrew hit in 1992, FEMA's Mitigation Assessment Team conducted a study of various building types and how well they weathered the storm. In their summary the Mitigation Assessment team concluded that "in general, it was observed that masonry buildings and wood-framed modular buildings performed relatively well."

The report went on to state that "overall, relatively minimal structural damage was noted in modular housing developments. The module-to-module combination of the units appears to have provided an inherently rigid system that performed much better than conventional residential framing. <http://www.fema.gov/library/viewRecord.do?id=2765> This is documented research from a government agency attesting to the fact that modular construction is a more durable and rigid building system than conventional site built in terms of Type V construction.

Another example of modular construction's durability can be seen in San Antonio. The Hilton Palacio del Rio Hotel is a 21-story concrete modular hotel built in 1968, still in use today - <http://www.modular.org/htmlPage.aspx?HtmlPageId=400> . This is believed to be the tallest modularly-constructed facility in the United States.

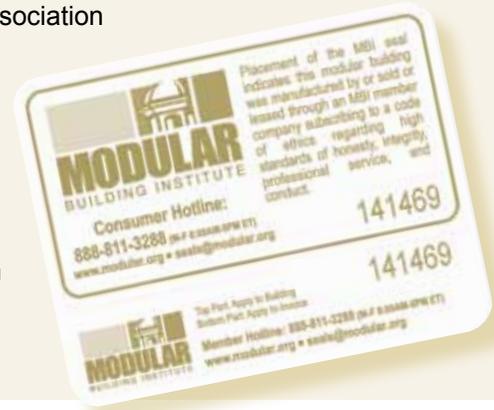
Summary

It is our industry position that, regardless of the type of construction selected, non traditional construction methods, specifically modular construction, offer compelling advantages in terms of quality, cost, durability, and environmental impact.

Any agency, architect or end user should have no reservations about the durability, longevity or life cycle cost and environmental impact of the modular construction process, if properly designed, constructed and maintained.

MBI code of business ethics and conduct

Members of the association subscribe to our code of business ethics and conduct. The MBI Seal is a visible sign of that commitment. Ask for the MBI seal on your next project.



Combined Brigade/Battalion Headquarters building for the Combat Aviation Brigade at Fort Bliss, El Paso, Texas. Currently under construction and scheduled for completion in fall 2009.