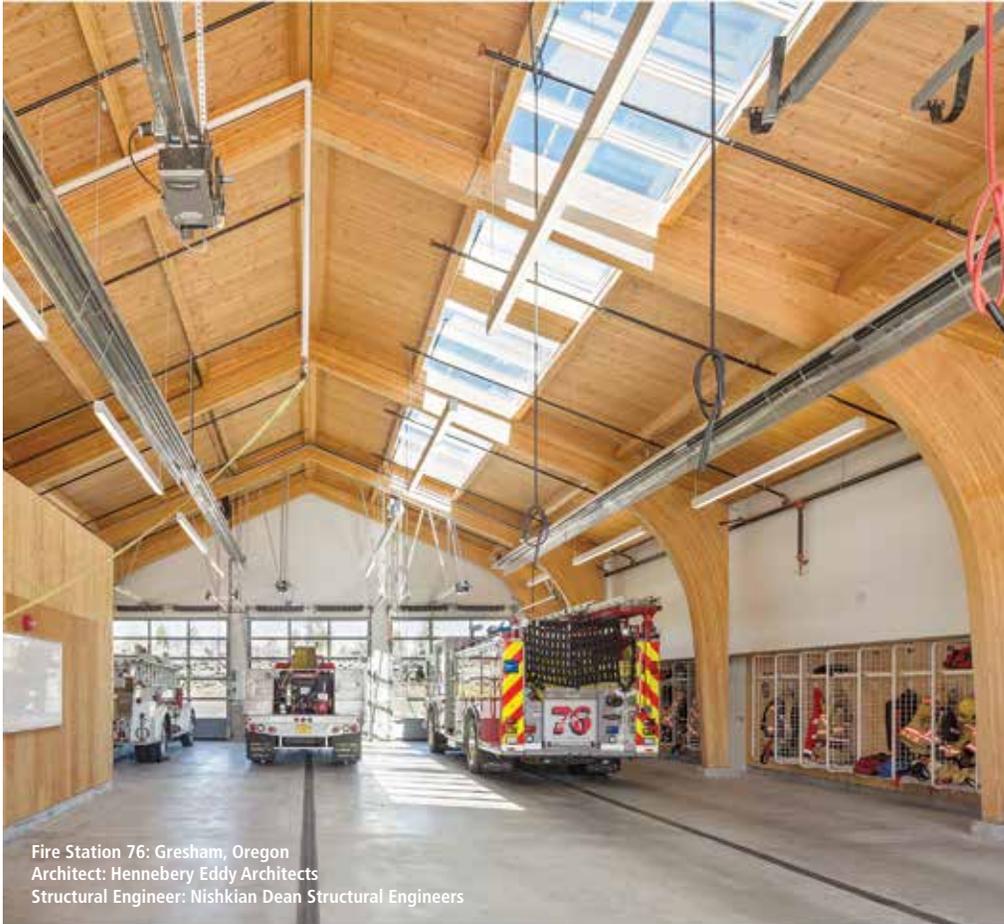


BUILDING RESILIENCE: EXPANDING THE CONCEPT OF SUSTAINABILITY

CAN TRADITIONAL AND NEW WOOD BUILDING SYSTEMS MEET EVOLVING DESIGN OBJECTIVES?

Presented by:

**THINK
WOOD®**



Fire Station 76: Gresham, Oregon
Architect: Hennebery Eddy Architects
Structural Engineer: Nishkian Dean Structural Engineers

Part of the structural system, the arches in this apparatus bay are designed to resist vertical and lateral loads required for essential facilities under the Oregon Structural Specialty Code. This project won a 2016 WoodWorks Wood Design Award. Photo credit: Josh Partee Photography

Building resilience is one of those concepts you read about and think, 'Of course.' It's an obvious next step in the evolution of sustainable design, conceived to meet a critical need, just as green building itself can trace its beginning to the oil crisis of the 1970s and the need to reduce energy consumption. Today's need is to anticipate and prepare for adverse situations—such as earthquakes and hurricanes, the effects of climate change, even deliberate attacks—because there is nothing sustainable about having to rebuild structures before the end

of their anticipated service lives and all of the resources that entails.

As the American Institute of Architects (AIA) recently pointed out, "A resilient building in a non-resilient community is not resilient." In the context of building materials, a complementary statement is that no building material in and of itself is the answer to resilience. Although materials such as wood have inherent characteristics that positively affect their performance, there are many greater factors that go into the design of a truly resilient structure.

LEARNING OBJECTIVES

Upon completion of this course the student will be able to:

1. Discuss why the concept of resilience can be viewed as another step in the evolution of sustainable building design.
2. Identify the strengths of traditional wood framing and mass timber systems in the context of building resilience, including performance during and after earthquakes, hurricanes, and other disasters, as well as the relevance of carbon footprint and embodied energy.
3. Explain how the International Building Code (IBC) and referenced standards such as the National Design Specification® (NDS®) for Wood Construction support building resilience.
4. Describe examples of research related to the development of new building materials and systems that could help communities meet more stringent resilience criteria.

CONTINUING EDUCATION

AIA CREDIT: 1 LU/HSW
GBCI CREDIT: 1 CE HOURS

AIA COURSE NUMBER: AR062017-5



Use the learning objectives above to focus your study as you read this article. To earn credit and obtain a certificate of completion, visit <http://go.hw.net/AR062017-5> and complete the quiz for free as you read this article. If you are new to Hanley Wood University, create a free learner account; returning users log in as usual.

With that in mind, this course will consider traditional wood framing and mass timber systems in the context of resilience, including performance during and after earthquakes, hurricanes, and other disasters, as well as the relevance of wood's light carbon footprint and low embodied energy. It will describe how building codes and standards such as the National Design Specification® (NDS®) for Wood Construction support resilience now, and consider how wood structure can be utilized to meet evolving resilience objectives.!

INTEGRATED DESIGN BUILDING, UNIVERSITY OF MASSACHUSETTS



Photo credit: Alexander Schreyer, University of Massachusetts

Location: Amherst, Massachusetts

Architect: Leers Weinzapfel Associates

Structural Engineer: Equilibrium Consulting Inc.

Despite its location on the East Coast, the University of Massachusetts Integrated Design Building was governed by seismic as opposed to wind loads—and the aspect of the project that best illustrates resilience is its innovative seismic design. Comprised of an exposed heavy timber structural system and cross laminated timber (CLT) decking and shear walls, the four-story, 87,000-square-foot structure accommodates the rules of capacity design—where certain elements of a structural system are intended to yield, and others are intended to remain elastic. In this case, structural engineer Robert Malczyk, principal at Equilibrium Consulting, explains that all of the elements of the lateral system are oversized except the bottom of the hold down brackets, which are sized to yield at the level of the design earthquake.

In a seismic event, the brackets are intended to dissipate energy, without causing further structural damage, with the idea that they can be replaced afterward for faster building recovery. The wood structure is relevant because of its weight. “The seismic force is proportionate to the weight of the building,” says Malczyk. “If this building were designed in concrete, which was considered, the weight would be six times more than the mass timber design, which means the seismic forces could also be up to six times greater. All of the elements, including foundations, hold downs, and everything else, would have needed to be much stronger. This is part of the reason wood buildings are so popular in high seismic regions.”

DEFINING RESILIENCE

In 2014, the National Institute of Building Sciences (NIBS), AIA, ASHRAE, American Society of Civil Engineers (ASCE), and other organizations representing some 750,000 professionals issued a joint statement on resilience with a definition drawing from the National Academies.² Describing resilience as “the ability to prepare and plan for, absorb,

recover from, and more successfully adapt to adverse events,” the statement read: “The promotion of resilience will improve the economic competitiveness of the United States. Disasters are expensive to respond to, but much of the destruction can be prevented with cost-effective mitigation features and advanced planning. Our practices must continue to change, and we commit ourselves to the creation of new practices to break the cycle of destruction and rebuilding. Together, our organizations are committed to build a more resilient future.”

Recognizing the importance of “contemporary planning, building materials, and design, construction, and operational techniques,” the group outlined its commitment through steps that include:

- Research related to materials, design techniques, construction procedures, and other methods to improve the standard of practice
- Education through continuous learning
- Advocating for effective land use policies, modern building codes, and smarter investment in the construction and maintenance of buildings and infrastructure
- Response, alongside professional emergency managers, when disasters do occur
- Planning for the future, proactively envisioning and pursuing a more sustainable built environment

Within this context of improvement, it is useful to consider how current design practices align with resilience objectives.

BUILDING CODES AND STANDARDS: A BASE LEVEL FOR RESILIENCE

The International Building Code (IBC) includes countless provisions and guidelines for designing structures to better withstand disasters. It is updated on a three-year cycle and, throughout its history, has continued to evolve to improve building performance. Although building codes accept that some non-structural and structural damage will occur in a major event, they seek to preserve life safety, prevent structural collapse, and ensure the superior performance of critical and essential facilities, such as hospitals and fire stations, relative to other structures.

For wood building design, the code is supported by referenced standards such as the National Design Specification (NDS) for Wood Construction, Special Design Provisions

RISK-BASED CODE REQUIREMENTS

From a resilience perspective, an important aspect of the IBC is that it is scaled to reflect risk—which, in this context, describes the combination of event probability and consequence of building failure. Buildings are classified into risk categories based on use, from Risk Category I for those representing a low hazard to human life in the event of failure (such as storage buildings) to Risk Category IV for structures with greater consequences associated with their failure (such as hospitals). The higher the category, the greater the evaluated risk.

They are further defined based on the likelihood of a specific type of event occurring. Buildings constructed in regions known for hazards such as hurricanes, earthquakes, or floods, for example, are subject to design requirements that make them better able to withstand these events.

For wind and seismic design, statistical modeling based on prior event history is used to anticipate the magnitude of future events, even if they have not yet occurred at that scale.

for Wind and Seismic (SDPWS), and Wood Frame Construction Manual (WFCM). These standards provide the tools for the design of wood buildings to meet structural loadings associated with naturally occurring threats, such as wind and seismic events.

Earthquakes

Seismic design forces are specified in the IBC to allow for proportioning of strength and stiffness of the seismic force-resisting system. Structures with ductile detailing and redundancy, and without structural irregularities, are favored for seismic force resistance. These beneficial characteristics are specifically recognized in seismic design requirements. The IBC establishes the minimum lateral seismic design forces for which buildings must be designed primarily by reference to ASCE 7-10: Minimum Design Loads for Buildings and Other Structures.³ For wood buildings, design guidance is provided in the NDS, SDPWS, and WFCM.

Traditional wood-frame buildings that are properly designed and constructed to comply with code requirements have been shown to perform well during seismic events. This is often attributed to the following characteristics:

Light weight. Wood-frame buildings tend to be lightweight, reducing seismic forces, which are proportional to weight.

Ductile connections. Multiple nailed connections in framing members, used in shear walls and diaphragms of wood-frame construction, exhibit ductile behavior (the ability to yield and displace without sudden brittle failure).

Redundant load paths. Wood-frame buildings tend to be comprised of repetitive framing attached with numerous fasteners and connectors, which provide multiple and often redundant load paths for resistance to seismic forces. Further, when wood structural panels such as plywood or oriented strand board (OSB) are properly attached to wood floor, roof, and wall framing, they form diaphragms and shear walls that are exceptional at resisting these forces.

Compliance with applicable codes and standards. Codes and standards governing the design and construction of wood-frame buildings have evolved based on experience from prior earthquakes and related research. Codes also prescribe minimum fastening requirements for the interconnection of repetitive wood framing members; this is unique to wood-frame construction and beneficial to a building's seismic performance.

There are numerous examples of post-disaster reports—and city disaster plans—noting the ability of wood-frame buildings to perform well in earthquakes. In California, for example, where wood-frame schools are common, an assessment of the damage to school buildings in the 1994 Northridge earthquake was summarized as follows: “Considering the sheer number of schools affected by the earthquake, it is reasonable to conclude that, for the most part, these facilities do very well. Most of the very widespread damage that caused school closure was either non-structural, or structural but repairable and not life threatening. This type of good performance is generally expected because much of the school construction is of low-rise, wood-frame design, which is very resistant to damage regardless of the date of construction.”⁴⁴

ADVANCEMENT THROUGH INNOVATION: SEISMIC DESIGN

As described under Defining Resilience, ongoing research is key to meeting evolving design objectives. This includes post-disaster investigations that lead to recommendations for improved construction techniques. It also includes the development of improved design procedures. In one study, for example, a full-scale wood-frame apartment building was subjected to a series of earthquakes on the world's largest shake table in Miki, Japan.⁵ The test evaluated a performance-based seismic design procedure developed to gain a better understanding of how mid-rise wood-frame buildings respond to major earthquakes. The building was subjected to three earthquakes ranging in seismic intensities corresponding to a 72-year event through a 2,500-year event for

Los Angeles, California. According to the report, it “performed excellently with little damage even during the 2,500-year earthquake.”

Research is also key to the development of new building materials and systems that could help communities meet more stringent resilience criteria, such as the mass timber products being used in taller wood buildings.

The impetus for timber high-rises, which already exist in other countries, is largely based on wood's renewability, low embodied energy, and lighter carbon footprint compared to other materials. The fact that wood buildings continue to store carbon while regenerating forests absorb and sequester more carbon is viewed by many as a compelling reason to expand the use of wood.

To determine the safety of taller wood buildings, a great deal of research has focused on seismic systems. For example, in a study using the same shake table in Japan, researchers tested a seven-story CLT building.⁶ After being subjected to 14 consecutive seismic events, the building suffered only isolated and minimal structural damage. The study is described in the U.S. CLT Handbook, which states, “There is a considerable advantage to having a building with the ability to quickly return to operation after a disaster and in the process minimizing the life cycle impacts associated with its repair. Based on full-scale seismic testing, it appears that CLT structures may offer more disaster resilience than those built with other heavy construction materials.”

Another test evaluated “rocking” mass timber shear walls for use in high seismic regions.⁷ Seismic activity was simulated by cyclic loading that pushed and pulled the top of a 16-by-4-foot CLT panel with an embedded vertical pre-tensioned rod into a rocking motion. The wall was able to reach 18 inches of displacement while maintaining its ability to self-center back to a vertical position. The result: the series of tests demonstrated the ability of this innovative building system to resist earthquake forces.

Hurricanes

Structural wind-loading requirements are specified in Chapter 16 of the IBC and obtained primarily through reference to ASCE 7-10. The minimum requirements are intended to ensure that every building and structure has sufficient strength to resist these loads without any of its structural elements being stressed beyond material strengths prescribed by the code. The code emphasizes that the loads prescribed in Chapter 16 are minimum loads and, in the vast majority of conditions, the use of these loads in



Subjected to three earthquakes on the world's largest shake table in Miki, Japan, this full-scale wood-frame apartment building performed excellently with little damage. Photo credit: John W. van de Lindt, Colorado State University

the design process will result in a safe building. However, it also recognizes that a designer may, and sometimes must, use higher loads than those prescribed. The commentary to ASCE 7-10 outlines conditions that may result in higher loads.

One of wood's characteristics is that it can carry substantially greater maximum loads for short durations than for longer periods of time, as is the case during high wind and seismic events.⁸ As with seismic performance, the fact that wood buildings often have repetitive framing attached with numerous fasteners and connectors also helps to resist forces associated with high winds, as do diaphragms and shear walls made from wood structural panels properly attached to wood wall and roof framing.

According to a report by the Federal Emergency Management Agency (FEMA) on building performance during the 2004 hurricane season, new wood-frame houses built in accordance with the 2001 Florida Building Code performed well structurally, including those located in areas that experienced winds of up to 150 miles per hour (3-second gust). For these buildings, load path was accounted for throughout the structure, including the connection of the roof deck to supporting trusses and rafters. Because of this, loss of roof decking on newer homes was rare.⁹

Tornadoes

Because of the low probability that a building will incur a direct hit from a tornado, the extreme winds of tornadoes are not included



In this rocking test of a CLT shear wall, the panel maintained its lateral load-bearing strength under cycling loading to simulate seismic conditions and returned to a vertical position at completion of the test. Photo credit: ARUP

in building code requirements for the wind design of buildings other than tornado shelters. However, it is generally agreed that a building properly designed and constructed for higher wind speeds has a good chance of withstanding winds of weaker tornadoes. Statistically, weaker tornadoes—rated by the National Weather Service as between EF-0 and EF-2 on the Fujita Tornado Damage Scale—comprise 95 percent of all tornadoes.

Stronger tornadoes (rated EF-3 to EF-5) require more rigorous design but are much less common. Designing for higher wind speeds can make a significant difference in terms of withstanding loads from even these tornadoes when the structure is located along the outer reaches of the area influenced by the vortex of such storms.

After a devastating tornado season that cost hundreds of lives and thousands of homes in 2011, the FEMA Mitigation Assessment Team investigation found that newer homes generally performed well under design-level wind loading, but a lack of above-code design left buildings vulnerable to damage.¹⁰ Appendix G of the report, which makes reference to the WFCM and includes similar approaches, lays out prescriptive techniques that can improve

ROCKY MOUNTAIN INSTITUTE (RMI) INNOVATION CENTER



Photo credit: ©Tim Griffith, courtesy ZGF Architects

Location: Basalt, Colorado

Architect: ZGF Architects

Structural Engineer: KPFF Consulting Engineers

Designed with a combination of mass timber, structural insulated panels, and dimension lumber, RMI's new Innovation Center meets a number of resilience objectives.

The project is net zero energy, designed and tested to meet Passive House protocols. Its energy model was run against the new Leadership in Energy and Environmental Design (LEED) pilot credit for Passive Survivability and Functionality During Emergencies for Option 1 (Thermal Resilience), requiring it to maintain livable temperatures during a power outage that lasts seven days during peak summer and winter conditions of a typical year. Thanks to a highly insulated envelope, the project met this criteria for the entire year, including peak periods, without any power. Daylighting strategies also allow the building to operate without electrical lighting for 91 percent of the annual daytime office hours.

The use of CLT structure on the first floor also allowed for dedicated service chases and increased floor-to-floor dimension, with extra space for future systems modification, addition, or expansion. This 'future proofing' will allow the building to be at the forefront of technology well into its 100-year design target.

Other features include a lightning protection system to protect the building systems and infrastructure, and siting above the 500-year flood plain event (instead of the more common 100-year event level).

building performance during weaker tornadoes. It notes that "Strengthening buildings by maintaining load path continuity and reinforcing connections has proven successful for mitigating hurricane and wind damage, and provides a good model for mitigating tornado wind damage." Techniques are also provided for developing a complete load path starting from an engineered design for wind resistance—i.e., sheathing to roof framing, roof framing to wall framing, and wall framing to foundation connections.

Highlighting wood's recognized performance as a structural material, FEMA P-320: Taking Shelter from the Storm: Building a Safe Room for Your Home or Small Business, includes information and design drawings for building wood-frame safe rooms.

ADVANCEMENT THROUGH INNOVATION: WIND DESIGN

As with seismic performance, post-disaster investigations are essential to improving the performance of buildings during high-wind events, leading to recommendations from bodies such as FEMA and the improvement of building codes.

Testing of building materials, systems, and techniques is another key part of the equation. For example, the 'Wall of Wind' (WOW) at Florida International University is capable of simulating a Category 5 hurricane and has contributed greatly to the understanding of hurricane impacts and their mitigation. A collaboration with the International Hurricane Research Center, it is viewed by the insurance

CENTRE FOR INTERACTIVE RESEARCH ON SUSTAINABILITY (CIRS), UNIVERSITY OF BRITISH COLUMBIA



Photo credit: Martin Tessler, courtesy Perkins+Will

Location: Vancouver, British Columbia, Canada

Architect: Perkins+Will

Structural Engineer: Fast+Epp

The Centre for Interactive Research on Sustainability at the University of British Columbia includes a number of features intended to enhance resilience. For example, a narrow footprint (30 feet) for the offices allowed full daylighting of office/lab zones, while operable windows provide natural ventilation. These two strategies mean the building can continue to be occupied during a temporary power outage or other unforeseen event. While wood was not directly responsible for the daylight and ventilation, an innovative wood moment frame was designed to permit large openings in the exterior wall to support these principles.

Goals for the project also included a light carbon footprint (in this case, net zero operational carbon and structural carbon sequestration), which is cited by some as an important resilience objective. During design, Perkins+Will compared the carbon footprint of steel, concrete, and glued-laminated timber (glulam) for the building structure, and found that wood offered a clear advantage.

industry as revolutionary to wind engineering in the same way crash testing was to the automotive industry. Similarly, the Insurance Institute for Business & Home Safety research facility includes a wind tunnel able to test full-scale one- and two-story buildings under realistic disaster scenarios in a controlled, repeatable fashion.

Fire Protection and Life Safety

Building codes require all buildings to perform to the same level of safety, regardless of materials, and wood buildings can be designed to meet rigorous standards for performance in a fire situation.

Effective fire protection involves a combination

of active and passive features. Active fire safety features include fire detection or suppression systems that provide occupant notification, alarm transmittance, and the ability to suppress fire growth (sprinklers) until the fire service arrives. In the context of resilience, where the focus is often fires that burn in the aftermath of an earthquake or other disaster, passive fire protection is especially important. Passive fire protection is what contains a fire in the area of origin or slows the spread of fire through the use of fire-resistant building elements, such as fire-resistant floors and walls, and open space.

In general, there are two passive measures that decrease a building's fire hazard: isolating the

building from other structures and constructing the building with fire-resistive materials. IBC Chapter 5 defines the allowable height and size of wood buildings based on the type of construction, occupancy, presence of a fire sprinkler system, degree of open perimeter, and resistance of the assemblies.

Advancement Through Testing: Fire Safety

With growing interest in tall wood buildings, the fire performance of mass timber is often identified as a research need. However, a great deal of information is known. The structural fire resistance of mass timber elements has long been standardized in the NDS, which includes a char calculation procedure to provide calculated fire resistance. The NDS was also expanded in 2015 to address the design of CLT buildings for structural and fire performance. Similarly, the IBC was revised in 2015 to expand the use of CLT into the heavy timber construction classification (Type IV).

Changes to the IBC were based in part on a successful fire-resistance test on a load-bearing CLT wall. The test, conducted by AWC in accordance with ASTM E-119-11a: Standard Test Methods for Fire Tests of Building Construction and Materials, evaluated CLT's fire-resistance properties. The five-ply CLT wall (approximately 6 7/8 inches thick) was covered on each side with a single layer of 5/8-inch Type X gypsum wallboard and then loaded to 87,000 pounds, the maximum load attainable by the testing service equipment. The 10-by-10-foot test specimen lasted 3 hours, 5 minutes, and 57 seconds (03:05:57)—well beyond the 2-hour goal.

Further study and full-scale tests continue to support expansion of mass timber's applicability. Other areas of research include new assembly configurations, performance under nonstandard fires, and the development of prediction tools. For more information, the latest research can be found at www.ThinkWood.com/research.

Floods

Whatever the building material, there are two important aspects of flood-resistant design: elevating the building above the design flood elevation, and designing for the increased loads associated with a building that's higher off the ground.

Reinforcing the performance of wood in appropriate applications, FEMA P-550: Recommended Residential Construction for Coastal Areas, includes a number of open foundation timber pile solutions for elevating

structures to withstand floods. FEMA TB2: Flood Damage-Resistant Materials Requirements highlights wood products “capable of withstanding direct and prolonged contact with floodwaters without sustaining significant damage,” with “prolonged contact” defined as at least 72 hours, and “significant damage” meaning any damage requiring more than cosmetic repair. For timber pile foundations, preservative treated wood is required.

RESILIENCE, LONGEVITY, AND GREEN BUILDING

While resilient design and green building objectives do sometimes conflict—e.g., redundant systems that provide greater structural performance may increase environmental impact—they share many objectives.

For example, some experts have proposed that resilience objectives include the use of low carbon-input materials with low embodied energy, such as wood—which makes sense, since even the best designed community is likely to experience structural loss in a major disaster and need to rebuild.¹¹ Durability has also long been a tenet of green building and is likewise promoted in the context of resilience. However, despite many examples of wood buildings that have stood for centuries, wood has a perception issue when it comes to longevity.

A report from research organization Dovetail Partners put it this way: “Despite a pervasive perception that the useful life of wood structures is lower than buildings of other materials, there is no meaningful relationship between the type of structural material and average service life.” The report added that “Current indices of the useful lives of various products allocate lower useful lives to wood than other materials without any basis for any of the chosen values.”

Supporting this conclusion, a study of buildings demolished in Minnesota found that most were demolished because of changing land values, changing tastes and needs, and lack of maintenance of non-structural components.¹² In fact, wood buildings in the study were typically the oldest; the majority were older than 75 years. In contrast, more than half the concrete buildings fell into the 26-to- 50-year category, and 80 percent of the steel buildings demolished were less than 50 years old. Overall, the fact that wood buildings had the longest lifespans shows that wood structural systems are fully capable of meeting a building’s longevity expectations.

Although adaptability from a resilience



Made from CLT, the four-story Candlewood Suites Hotel at Redstone Arsenal, Alabama, had to meet Anti-Terrorism and Force Protection standards required for every structure built on a U.S. military base. Extensive engineering analysis was used to determine compliance with blast-resistance criteria. Photo credit: Lend Lease

perspective most often means climate change adaptation, the fact that a wood structure is easily adapted with basic construction tools could contribute to faster recovery in the aftermath of disaster. The Resilient Design Institute also includes the use of locally available, renewable or reclaimed resources among its design principles, which favors wood use.

Performance-Based Design and Life Cycle Assessment

Although the concept of ‘designing for resilience’ continues to evolve, a number of principles have been put forth by architects and engineers, as well as city planners and others involved in the design of buildings.

In a 2014 presentation at Greenbuild, for example, structural engineer Erik Kneer, SE, LEED AP BD+C, discussed the benefits of incorporating performance-based design (PBD) and the science of hazard loss estimation with a project’s environmental life cycle assessment (LCA).¹³

“The stated intent of the building code is to prevent against major structural failure and loss of life, but not to limit damage or maintain function. Therefore, a code-based building is essentially a disposable building,” he said. “If we design a code-based LEED Platinum building and put it on top of an earthquake fault, and we haven’t considered and evaluated its life cycle performance from those earthquake risks, I don’t think we can call the building sustainable. We need to protect the environmental and economic investment in our buildings.”

Described in “A Framework for the Integration of Performance-Based Design and Life Cycle Assessment to Design Sustainable Structures,” the marriage of PBD and LCA seeks to achieve a more comprehensive version of sustainability that includes a balance between social, economic, and environmental factors— often referred to as the “triple bottom line.”

PBD, where decisions are based on desired performance outcomes, is an alternative to the prescriptive approach of satisfying requirements

prescribed in a building code for the structure to be deemed safe. Although the IBC contains many performance aspects (e.g., high risk category buildings are expected to perform better than lower risks category buildings), the concept of PBD generally refers to performance above code minimums or the use of alternative methods of design than those described in the building code. Whether a project is targeting code minimums or higher performance objectives, the approach for a wood building design involves the use of standards, such as the NDS and SDPWS.

Life cycle assessment is a method for measuring the environmental impacts of materials, assemblies, or buildings over their entire life cycles, from extraction or harvest of raw materials through manufacturing, transportation, installation, use, maintenance, and disposal or recycling. It allows building designers to compare alternate designs based on their environmental impacts and make informed choices about the materials they use.

As with PBD, LCA is an alternative to the traditional prescriptive-based approach to material selection, but in the context of environmental instead of structural performance. An example would be specifying a material based on its actual environmental impacts instead of assuming that a product with recycled content is automatically better for the environment without considering its manufacturing process.

Put briefly, a mix of the two involves working to identify a design solution that meets engineering, societal, environmental, and economic performance objectives. For many applications, that solution may well be a wood structure. In terms of engineering performance, this course includes several examples of buildings that perform beyond code minimums. LCA studies have also consistently shown that wood outperforms other building materials in environmental impact categories that include embodied energy, air and water pollution, and carbon footprint.¹⁴ Societal performance, which could be anything from corporate citizenship to business ethics, could be achieved in part through the use of a renewable resource from sustainably managed forests, and wood’s cost effectiveness could be the factor that allows a project with high engineering and environmental performance goals to pencil out.

GOVERNMENT AND PRIVATE INITIATIVES

The concept of resilience has gained sufficient momentum that it is now encouraged to

varying degrees through federal, state, and local government policy, and through numerous private initiatives.

Prior to the recent Earthquake Resilience Summit, for example, the federal government issued an executive order establishing a Federal Earthquake Risk Standard, which calls for new, leased, and regulated federal buildings to meet seismic safety provisions outlined in the IBC and International Residential Code (IRC).

“There is no more important contributor to reducing communities’ risks from earthquakes than the adoption and application of modern building codes and standards,” said ICC Chief Executive Officer Dominic Sims, CBO. “To survive and remain resilient, and to assure the rapid recovery of local economies, communities must employ the most up-to-date code provisions. This executive order ensures that federal facilities and their occupants will be safe when the next earthquake strikes.”

The ICC works collaboratively with NIBS and ASCE to translate National Earthquake Hazards Reduction Program provisions into the IBC. The Council’s three-year code development cycle incorporates the most up-to-date science and technology for seismic safety for broad use by designers, contractors, manufacturers, and code officials. The executive order calls for federal agencies to comply with the provisions of updated versions of the IBC and IRC within two years of their release.

The ICC is also a founding member of the US Resiliency Council (USRC), along with organizations such as the National Council of Structural Engineers Associations (NCSEA), engineering and architecture firms, industry representatives, and individuals. Created to

SUPPORTING WOOD BUILDING DESIGN

For individuals involved in the design, construction, review, and approval of buildings, WoodWorks and the American Wood Council offer a variety of resources at no cost.



Project support: WoodWorks provides free project assistance, as well as education and resources related to the code-compliant design, engineering, and construction of nonresidential and multi-family wood buildings. www.woodworks.org



Codes and standards support: Expert staff at the American Wood Council develop state-of-the-art engineering data, technology, and standards for wood products to assure their safe and efficient design. They also provide information and education on wood design, building codes, and green building. www.awc.org

establish rating systems for the performance of buildings during natural hazard events, the USRC recently launched an Earthquake Building Rating System, which measures expected building safety, damage, and recovery time for buildings subject to earthquake forces.

Resilience is also being encouraged through green building certification systems.

The U.S. Green Building Council recently added three pilot credits to the LEED program related to assessment and planning for resilience, designing for enhanced resilience, and passive survivability and functionality during emergencies.

“Resilience is becoming a major focus for governments and communities,” said Vicki Worden, executive director of the Green Building Initiative, which oversees the Green Globes rating system. “Green building has always included a focus on resilience. It’s just

taking more explicit shape. Concern about changing climates is leading to promotion of integrated design processes. This encourages community input, site selection that considers regional climatic impacts, materials selection through use of life cycle assessment and building service life analyses, life cycle cost analyses, and moisture control analyses.” GBI also recently updated its Mission & Principles to include resilience.

CONCLUSION

As resilience becomes a more entrenched objective for structures and communities, it is useful to consider the advantages of building materials and systems. As this course illustrates, traditional wood framing, mass timber, and other wood systems have many strengths that make them worthy of consideration from a resilience perspective. ■

ENDNOTES

- 2015 National Design Specification (NDS) for Wood Construction, American Wood Council, www.awc.org
- National Academy of Sciences, National Academy of Engineering, Institute of Medicine, and National Research Council
- Minimum Design Loads for Buildings and Other Structures (ASCE 7-10), American Society of Civil Engineers/ Structural Engineering Institute
- The January 17, 1994 Northridge, CA Earthquake An EQE Summary Report*, March 1994, www.lafire.com/famous_fires/1994-0117_NorthridgeEarthquake/quake/00_EQE_contents.htm
- Construction and Experimental Seismic Performance of a Full-Scale Six-story Light-frame Wood Building*, J.W. Van de Lindt, Department of Civil, Construction, and Environmental Engineering, University of Alabama, S. Pei, Department of Civil and Environmental Engineering, South Dakota State University, S.E. Pryor, Simpson Strong-Tie, 2011
- U.S. CLT Handbook*, FPIInnovations, 2013; co-published by the USDA Forest Service and Binational Softwood Lumber Council
- Network for Earthquake Engineering Simulation (NEES) CLT Planning Project
- 2015 NDS, Section 2.3.2.1
- Summary Report of Building Performance, 2004 Hurricane Season*, FEMA 490, 2005, www.fema.gov/media-librarydata/20130726-1445-20490-5343/fema490.pdf
- Mitigation Assessment Team Report—Spring 2011 Tornadoes: April 25-28 and May 22 (2012)*, FEMA P-908, www.fema.gov/medialibrary/assets/documents/25810?id=5633
- www.resilientcity.org, an open, not-for-profit network of urban planners, architects, designers, engineers and landscape architects (no longer updated)
- Survey on Actual Service Lives for North American Buildings*, FPIInnovations, Proceedings, 10th International Conference on Durability of Building Materials and Components, 2005
- Resilient by Design*, Erik Kneer, SE, LEED AP BD+C, Greenbuild, October 24, 2014
- Life Cycle Environmental Performance of Renewable Building Materials in the Context of Residential Construction*, Phase 1 (2005) and Phase II (2010), Consortium for Research on Renewable Industrial Materials; *Wooden Building Products in Comparative LCA: A Literature Review*, International Journal of Life Cycle Assessment, F. Werner, K. Richter, 2007

QUIZ

1. The concept of resilience covers the need to anticipate and prepare for which of the following adverse situations?
 - A. Natural disasters, such as earthquakes and hurricanes
 - B. Effects of climate change
 - C. Deliberate attacks
 - D. All of the above
2. For wood design, the International Building Code is supported by all of these referenced standards EXCEPT which one?
 - A. National Design Standard® (NDS®) for Wood Construction
 - B. Fine Woodworking Guide to Safety
 - C. Special Design Provisions for Wind and Seismic
 - D. Wood Frame Construction Manual
3. Which of the following characteristics of a wood-frame structure does not contribute to its effective seismic performance?
 - A. Light weight
 - B. Ductile connections
 - C. Redundant load paths
 - D. Structural irregularities
4. In a series of tests evaluating the use of rocking mass timber shear in high seismic regions, the test wall was able to meet how many inches of displacement while maintaining its ability to self-center back to a vertical position?
 - A. 10
 - B. 14
 - C. 18
 - D. 22
5. In a FEMA report on building performance during the 2004 hurricane season, what reason was given for the fact that loss of roof decking on newer homes was rare?
 - A. Buildings built per the 2001 Florida Building Code accounted for load path throughout the structure, including connection of the roof deck to supporting trusses and rafters
 - B. Hurricanes in 2004 primarily affected areas with older homes
 - C. Most new roofs met LEED or Green Globes standards
 - D. Most new roofs accommodate the rules of capacity design
6. True or False: It is generally agreed that a building properly designed and constructed for higher wind speeds has a good chance of withstanding winds of weaker tornadoes, which statistically comprise 95 percent of all tornadoes.
7. In a study of buildings demolished in Minnesota, why were most buildings demolished?
 - A. Changing land values
 - B. Changing tastes and needs
 - C. Lack of maintenance of non-structural components
 - D. All of the above
8. Which of the following is not a passive fire safety feature?
 - A. Fire-resistant floors
 - B. Fire-resistant walls
 - C. Automatic sprinklers
 - D. Open space
9. A mix of performance-based design and life cycle assessment involves working to identify a design solution that meets what objectives?
 - A. Engineering
 - B. Societal
 - C. Environmental
 - D. Economic
 - E. All of the above
10. ICC Chief Executive Officer Dominic Sims recently said, "There is no more important contributor to reducing communities' risks from earthquakes than ____."
 - A. government funding
 - B. community support
 - C. adoption and application of modern building codes and standards
 - D. collaboration between government and communities

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