CASE STUDY

Breaking Convention with Wood Offices

Wood framing creates inspirational work environments that are code-compliant, cost effective and sustainable

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Great solutions often lie beyond convention. Consider that most offices in the U.S. could be built with a wood structure yet very few are. Many designers assume they're limited to concrete and steel for workplace environments—because that's the common default—but, in fact, wood systems can accommodate the space and performance needs of office occupancies, while providing advantages such as cost savings, versatility, ease and speed of construction, and a lighter carbon footprint.

Office designers considering wood have a range of options.

For some, creating a unique, interesting space is the priority goal—both to impress clients and, increasingly, potential employees. As businesses compete for staff, many seek to attract top talent with a workplace that fosters creativity and teamwork while also reflecting the company culture. To achieve this, there is a trend toward customizable space with open floor plans and exposed 'honest' structure that attracts tenants looking to inspire their workforce. Heavy and mass timber building systems, utilizing products such as solid wood, glued-laminated timber (glulam), cross-laminated timber (CLT), and nail-laminated timber (NLT), are ideally suited to meeting these objectives.

For others, budget is a top priority. More than 90% of offices constructed in 2017 are four stories or less, and about three quarters are under 50,000 square feet. Wood offers one of the most cost-effective options for achieving buildings this size.

This series of project examples focuses on common considerations for office design, such as layout flexibility and market classification, in the context of wood structural solutions permitted under the 2015 International Building Code (IBC). Topics include code opportunities related to fire and life safety, structural design and layout, acoustics, vibration, and cost.

Using Wood to Build Class A and B Office Space

The commercial real estate industry classifies office space based on quality, location, amenities, age, and other factors. Classifications allow realtors to compare spaces for potential tenants; Class A buildings are most desirable, often garnering higher lease rates and more culture-conscious tenants than Class B spaces. Classifications are not directly related to the structural material; they are driven by building performance and quality of space. Wood buildings can be designed to meet all performance levels, often with cost savings over concrete and steel. (See page 14, Tables 1-3.)

The Rocky Mountain Institute estimates that more than half of all office space is owner-occupied or built-to-suit, making customized designs, energy efficiency and a productive environment key considerations. The other half is speculative and often driven by upfront cost and marketability.

Because it is such a versatile material, designers and developers are increasingly using wood to construct both custom and speculative Class A and B office spaces. Light-frame, heavy timber and mass timber construction can all be used to cost-effectively provide high-quality infrastructure, flexible space, desirable interior aesthetics and energy efficiency.

Diamond Foods Innovation Center
Salem, OR

ARCHITECT: ZGF Architects

STRUCTURAL ENGINEER: KPFF Consulting Engineers

The 7,350-square-foot Diamond Foods Innovation Center was built to house a team of specialists who drive new product offerings, from R&D through manufacturing and delivery. With the need for expensive interior components such as state-of-the-art kitchens and labs, the structure itself had to be relatively low cost. Multiple value engineering exercises led to a Type VA wood-frame system—with dimension lumber walls, I-joists and glulam floors, and a light-frame truss and glulam roof.

Photos (pages 2 and 3): Eckert & Eckert Photography

Light-Frame Construction

Light-frame construction is one of the most affordable options and lends itself well to irregularly-shaped, custom designs. There is no need to limit this type of construction to smaller-scale residential projects. Wood-frame buildings have significant allowances for heights and areas—a fact that has many communities using wood to build higher density multi-family projects. The success of this trend is motivating some designers to explore the possibilities for other occupancy groups and settings such as large commercial office developments.

Roof and floor framing components can consist of repetitive framing members such as I-joists, structural composite lumber, glulam, solid sawn lumber and wood trusses with plywood or oriented strand board (OSB) decking. These are typically paired with dimension lumber stud walls with wood structural panel sheathing to form easy-to-construct buildings.

Offices built with light-frame construction can have finished interiors, or they can leave the roof and floor framing exposed in the ceiling.

Heavy and Mass Timber Construction

Heavy-timber and mass timber framing is growing in popularity for multi-story offices because it offers market distinction while cost-effectively addressing the performance criteria for Class A buildings. Offices built using post-and-beam construction lend themselves particularly well to larger scale, mid-rise structures featuring open layouts. They can be designed as Type III, IV or V construction.

In these buildings, glulam columns and beams are most often paired with roof and floor decks of CLT, NLT, or tongue-and-groove decking over glulam sub-purlins. Many office developers assume they need open interiors free of columns or bearing walls for space flexibility. However, while heavy and mass timber systems can be built efficiently with ample column spacing (in the range of 30 x 30 feet), wood columns can be a desired feature without hindering flexibility—which can lead to smaller column grids and further economy. Exposed wood framing on the interior provides a distinctive feel that is increasingly popular, particularly among tenants seeking creative professional environments. For offices requiring column spacing closer to 40 feet on center, wood-concrete composite systems offer an efficient mass timber solution.

David and Lucille Packard Foundation
Los Altos, CA

ARCHITECT: EHDD

STRUCTURAL ENGINEER: Tipping Mar

The David and Lucile Packard Foundation, a two-story, 49,000-square-foot Type VB structure, showcases the versatility and high performance capabilities of light-frame construction. The architect left wood trusses and other elements exposed, expressing the form of the building and communicating transparency via the working environment. Wood gives the design a relaxed feel, adding warmth with its subtle variation in tone and texture. The result is a LEED Platinum, net zero-energy building that reflects the goals of the organization in its commitment to the environment.

Photo: Jeremy Bittermann courtesy EHDD

The Bullitt Center
Seattle, WA

ARCHITECT: The Miller Hull Partnership

STRUCTURAL ENGINEER: DCI Engineers

When built in 2015, the 52,000-square-foot Bullitt Center was described as the 'greenest commercial building in the world.' The six-story Type IV building features four stories of heavy timber framing over two levels of reinforced concrete. The wood-frame portion combines Douglas-fir glulam beams and columns with NLT floor and roof decks. Relatively shallow floors—achieved by using solid 2x6 wood floor panels instead of deeper floor joists—helped to increase daylight penetration. By spanning the 10-foot-6-inch dimension between glulam purlins, the 2x6 deck also eliminated the need for a perimeter beam. This allowed the windows to extend to the bottom of the decking, improving daylighting even further.

Photo: John Stamets

Karuna at One North
Portland, OR

ARCHITECT: Holst Architecture

STRUCTURAL ENGINEER: Froelich Engineers

This 85,540-square-foot project includes a five-story Type IIIB building and separate four-story Type VA building, both with offices above ground-level retail. Both feature heavy timber post-and-beam construction over a concrete podium. Fire retardant-treated wood (FRTW) shear walls were used as part of the lateral-resisting system, and sprinklers were added on the exterior to allow the structure to exceed the 40-foot combustible exterior finish limit. Costs were estimated at between $175 and $225 per square foot, and the developer said rental rates surpass those of offices in downtown Portland.

Photos: Andrew Pogue

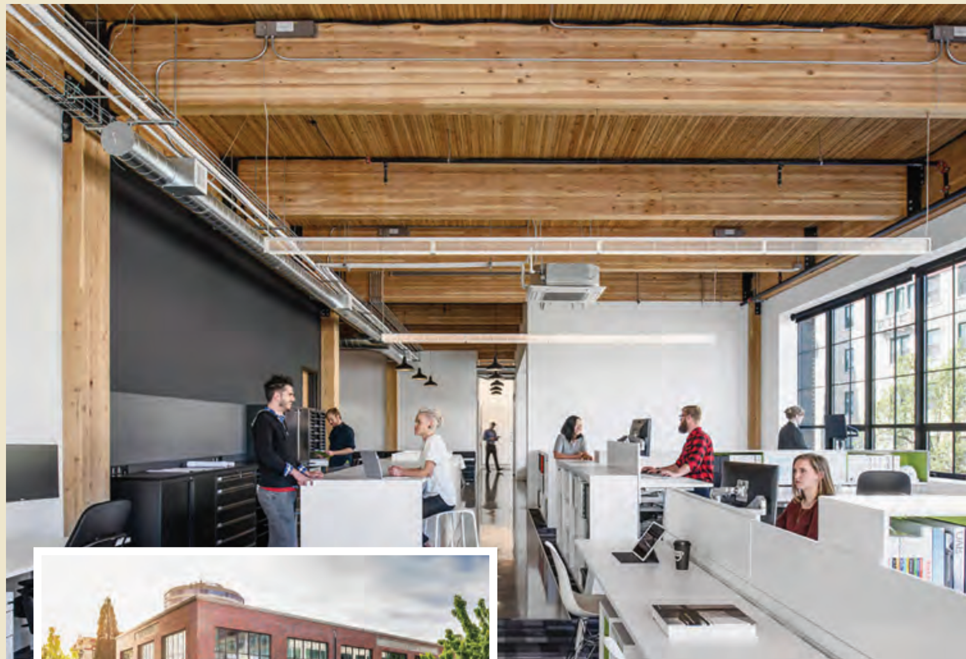
The Hudson
Vancouver, WA

ARCHITECT: Mackenzie

STRUCTURAL ENGINEER: Mackenzie

CONTRACTOR: Turner Construction Company

Designed to evoke a contemporary industrial feel, this three-story, Type VB structure features a structural brick exterior, expansive glass entrances and exposed wood columns, beams and ceilings. Columns and beams are designed on a grid of 25 x 25 feet. The floor and roof system includes NLT decking, offering a modern interpretation of traditional wood construction. In addition to aesthetics, the texture in the exposed wood ceilings reduces noise reflection and helps with acoustics—an important consideration for Class A buildings.



Photos: Christian Columbres

Mixed and Hybrid Systems

In some cases, the most appropriate solution is to mix wood structural systems or wood and other materials. For example, while light-frame systems can be the most cost-effective choice for everyday professional spaces that also offer scale, structures that include more than one wood system—such as light-frame combined with mass or heavy timber—can be an affordable way to incorporate the aesthetic of exposed wood. Hybrid systems using different materials for different parts of the structure, such as mass timber paired with elements of concrete or steel, allow designers to showcase wood while also achieving other design objectives. Composite systems are another option that optimize materials within the same system for enhanced performance; for example timber-concrete composite floors can improve vibrations in long floor spans.

Regardless of the option chosen, these systems give designers more ways to create distinctive environments using wood.

Rocky Mountain Innovation Center
Basalt, CO

ARCHITECT: ZGF Architects

STRUCTURAL ENGINEER: KPFF Consulting Engineers

For its 15,600-square-foot Innovation Center, the Rocky Mountain Institute combined light wood framing and mass timber to provide both structure and a high-performing building envelope. The roof and exterior walls are made from structural insulated panels (SIPs), and floors are CLT manufactured from wood killed by the Mountain Pine Beetle. The project is designed on a grid of 20 x 20 feet. Four-foot-wide CLT panels, centered on a row of glulam columns at 20-foot spacings, span across the building. On top of this, a secondary layer of CLT panels spans the opposite direction, forming the substrate for a concrete topping layer. Between the lower CLT panels, a chase is created for running MEP items. These items are concealed by inlaid wood panel ceiling systems, easily removable for access and maintenance to the MEP items as needed.

Reflecting the organization's mission to tackle global energy challenges, the structure was designed to meet ambitious goals: utilize sustainable construction materials while providing a net-zero, adaptable, commercial office building with a 100-year design life in one of the country's harshest climates.

Photo: Tim Griffith

Design Considerations | *Aesthetics*

There is a reason more designers are using exposed wood in office construction. Aesthetics are a priority objective for Class A office space—but aesthetic choices can also elevate everyday professional spaces. In whatever form it takes, there is nothing like exposed wood to create warm, welcoming and productive workplace environments.

As those words imply, the benefits of an exposed wood office encompass more than just looks. Biophilia, which is the innate human attraction to nature, has been extensively studied, and research has shown that the presence of visual wood in a room has impacts similar to the presence of plants and natural views. This includes reduced stress, improved cognitive function and creativity, and overall well-being. For office design, these benefits can translate to improved productivity and employee satisfaction.[1]

A 2015 study[2] of 7,600 office workers from 16 countries found that people who worked in environments featuring natural elements reported a 15 percent higher level of well-being, a 6 percent higher level of productivity and a 15 percent higher level of creativity. In addition, 33 percent said the design of an office would affect their decision to work for a company. An increasing number of design professionals are realizing that investments in creative, unique office space will provide a positive return.

Code requirements for wood interior finishes are covered in IBC Sections 803.3 and 803.11, which govern flame spread and smoke index, and IBC Table 601, which covers protection of exposed framing and connections. Most wood species and products easily meet Class B finish requirements, which typically govern office interiors. Class A finishes are not required in sprinklered office buildings and would only be required in exit passages and stairways in un-sprinklered conditions.

Design Considerations | *Construction Types, Heights and Areas*

Building codes allow wood structure in a variety of construction types, all of which can be used to build attractive, functional and affordable offices.

Type III construction is often associated with multi-family light-frame buildings; however, the heights and areas afforded by this construction type can also accommodate other large light-frame or post-and-beam structures. For business occupancies, Type IIIA buildings are permitted to have up to six stories of wood construction for office use and total building areas in excess of 250,000 square feet.[3] While FRTW[4] or non-combustible framing is required for exterior walls, interior building elements may be of any material allowed by code, including light-frame, heavy or mass timber, and mixed-wood systems.

Type IV construction, also known as heavy timber, may include the use of solid or laminated wood members such as glulam and wood decking—provided minimum sizes and restrictions on concealed spaces are met. Concealed cavities are only permitted in partitions; they may be of solid wood or 1-hour fire-resistant construction, which would allow rated wall construction with a cavity to house mechanical, plumbing or electrical systems. Similar to Type III construction, FRTW can be used to frame exterior walls with fire ratings of 2 hours or less, although in many cases non-combustible curtain walls or glazing systems are wrapped around the timber post-and-beam frame. This was the approach taken with The Bullitt Center (see page 5). Mass timber is permitted in floors, roofs and walls in Type IV buildings, including exterior walls when protected by a non-combustible material on the outside face; however, mass timber is not limited to this construction type.

Type V construction may use untreated wood throughout. Exposed light-frame construction, often Type VB, is becoming increasingly popular as a cost-effective way to create a modern industrial aesthetic for office buildings up to three stories with more than 27,000 square feet per floor (with an NFPA 13-compliant sprinkler system).

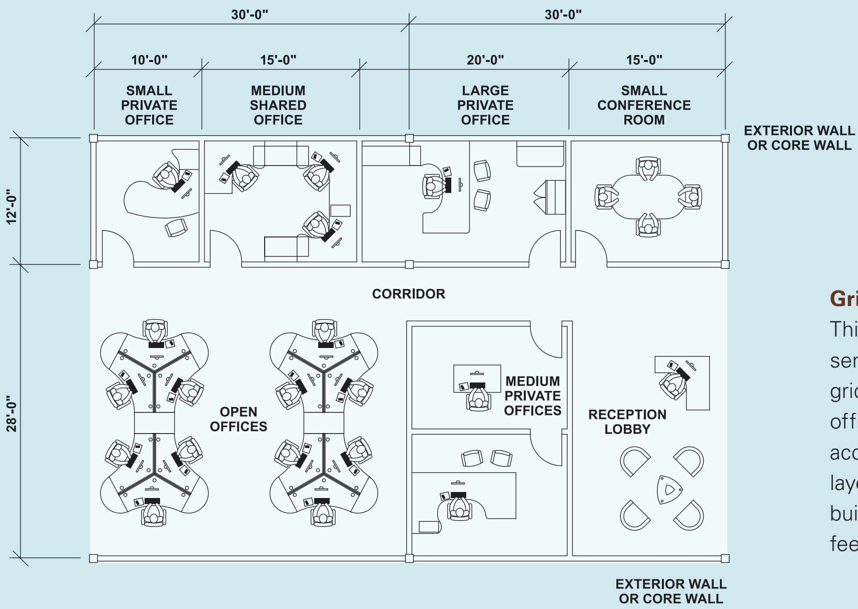
There are several options for using wood to more affordably achieve the scale of a Type IIA or IIB building (see table below). For example, Types IIIB and VA can be used to achieve the same height and number of stories as Type IIB, with a slightly smaller per-story area. Similarly, Type IIIA or Type IV structures allow heights, stories, and per-story area that are comparable with Type IIA. With these alternatives, architects accustomed to designing Type II structures can increase their options to include cost-effective wood structure and the aesthetics of exposed wood.

Deciding which construction type makes sense for a project depends on factors beyond these allowances. The degree of exposed wood structure and strategy used for fire resistance often plays a significant role in this decision.

In addition to the allowable building sizes discussed above and shown in the table below, IBC Sections 507.4 and 507.5 allow unlimited area, one- or two-story group B occupancy buildings of any construction type when the building is equipped throughout with an NFPA 13 sprinkler system and is surrounded and adjoined by public ways or yards not less than 60 feet in width.

Multi-Story Business Occupancy: Allowable Building Sizes	Common Construction Types: 3-4 Stories				Common Construction Types: 5+ Stories		
	Steel/Concrete	Wood Framing			Steel/Concrete	Wood Framing	
Construction Type	IIB	IIIB	VA	VB	IIA	IIIA	IV
Stories[a]	4	4	4	3	6	6	6
Height *(feet)*	75	75	70	60	85	85	85
Maximum Story Area[b] *(square feet)*	69k	57k	54k	27k	112.5k	85.5k	108k
Total Building Area[c] *(square feet)*	207k	171k	162k	81k	337.5k	256.5k	324k

[a]Assumes: NFPA 13 sprinklers throughout (IBC 504.2)
[b]Assumes: NFPA 13 sprinklers throughout (IBC 506.3), multi-story building, no frontage increase
[c]Assumes: 3 or more stories (IBC 506.4), no frontage increase



Grid and Layout Flexibility

This graphic shows an option for a semi-open office layout on a 28 x 30-foot grid, which is common in speculative office space. Wood framing systems can accommodate many grid systems and layout configurations conducive to office buildings, including grids up to 30 x 40 feet and beyond.

Design Considerations | *Grid*

Flexibility of space plays an important role in offices where tenants are continually modifying workstation layouts to accommodate work flow. For this reason, the structural grid of a building is an important factor in office design. Wood's ability to achieve the flexibility needs of an office occupancy is often underestimated.

A common goal is to maximize interior ceiling heights while minimizing overall building height. In many cases, wood floor framing members can be designed with equivalent depths to steel and concrete in a rectangular grid. In other situations, long spans must be balanced against the need for deeper structural members; this balance can be achieved in a number of ways. Light-frame wood construction using I-joists or open-web trusses for floor systems allows mechanical, electrical and data lines to run through the joist cavity without having to install a drop ceiling, which is common in concrete and steel structures. For these light-frame systems, spans up to 32 feet can be cost-effectively accommodated, usually with trusses or I-joists in the range of 24-28 inches deep.

Exposed heavy timber and mass timber systems may seem more challenging when it comes to accommodating these types of utilities, but there are many solutions.[5] For example, contractors for The Radiator, a five-story mass timber building in Portland, Oregon, installed a 4-inch raised wood panel structure above the floor as a data/electrical/phone plenum, which eliminated the need to install surface-mounted conduit. This inventive approach gave the exposed wood ceilings a cleaner aesthetic while providing sound separation between floors and improved access to electrical and data lines.

There are several grid options for mass and heavy timber systems. As noted, column spacings of 30 x 30 feet or larger are often desired in office environments. For these conditions, glulam subpurlins are used, usually at spacings that allow thinner floor panels (3-ply or 5-ply CLT panels or 2x6 NLT panels are common), which results in more cost-effective solutions. The same concept applies for 2x or 3x decking systems, although allowable spans may be shorter than with CLT or NLT panels.

For The Hudson, lighting and sprinklers were mounted directly to the NLT wood deck floor, while hard mechanical ducting was strategically placed in the hallways and core to match the industrial aesthetic. Floor-to-floor height was important on this project, but the NLT allowed two feet of additional ceiling height from the bottom of the beam to the bottom of the deck. This helped overcome the deeper beam member requirement for the large grid spacings.

Photo: McDonald Law

William Clyburn Center for Primary Care

Aiken, SC

ARCHITECT: Hughes, Beattie, O'Neal, Law & Associates

STRUCTURAL ENGINEER: J.E. Stewart Engineering

The Willian Clyburn Center for Primary Care is a Type VB, two-story structure. Because of the requirement for multiple medical exam rooms, the design team chose a wood bearing wall system with I-joist floors and roofs, creating an affordable, 26,000-square foot office building for a finished cost of just $150 per square foot. Wood was chosen as the primary framing material in part because of its relative low cost and ready availability.

Photos: Christian Columbres

Clay Creative
Portland, OR

ARCHITECT: Mackenzie

STRUCTURAL ENGINEER: Kramer Gehlen & Associates

CONTRACTOR: Turner Construction Company

Clay Creative may look like a Type IV heavy timber building, but it's actually permitted as Type IIIA. The 90,000-square-foot project features exposed glulam beams and columns along with NLT floor decking that provides a 1-hour fire rating. The built-up floors provide a 16-inch space for easy access to mechanical, electrical and plumbing utilities. The structure has a footprint of roughly 80 x 200 feet. There is 8 to 9 feet of clearance between the finish floor and bottom of the exposed girder beams overhead, and up to two feet of additional ceiling space to the bottom of the floor deck above. Grid spacing varied; the designer used a 30 x 30-foot grid at the center of the building, but shifted to a 25 x 30-foot grid at the perimeters, providing a flexible open floor plan. The developer of this project reported that tenants were willing to pay $7 more per square foot than a similar non-wood structure located across the river downtown, presumably because of the Hudson's unique interior aesthetic.

Bonner General Health
Sandpoint, ID

ARCHITECT: John Eixenberger

STRUCTURAL ENGINEER: Hoit Engineering

As a medical services office, Bonner General Health had unique needs which impacted the grid spacing. Originally designed in steel, this three-story, 50,000-square-foot project needed to maximize column spacing to allow for unobstructed rooms and large, adaptable spaces for medical machine placement. The design team used 28-inch-deep wood I-joists at 16-inches on center to allow 32-foot floor spans, all of which created flexibility for current and future medical tenant use. This saved the project time and money in part by reducing the structural weight and thus foundation size.

Photos: Redbuilt

Design Considerations | *Lateral Systems*

Another design consideration is type of lateral system, which varies based on compatibility with the vertical system and building layout.

For a one- to five-story structure, using a light-frame bearing shear wall system with a code-defined flexible diaphragm is a common choice, and the most straightforward to analyze. This approach is compatible with custom designs and buildings with less glazing, since ample perimeter walls are typically needed for lateral resistance in this type of system.

For heavy timber-frame systems with more than three stories, a lateral-resisting core is a viable choice—whether comprised of mass timber or light-frame shear walls, concrete or CMU shear walls, or steel brace frames. Engineering analysis requires a rigid or semi-rigid diaphragm and stair or elevator shafts located centrally or somewhat symmetrically within the building. Another alternative is to use interior and/or exterior steel moment frames. Exterior glazing and curtain walls should be checked for deflection compatibility with the lateral systems.

Photos: Joshua Jay Elliot

Framework
Portland, OR

ARCHITECT: Works Progress Architecture

STRUCTURAL ENGINEER: TM Rippey Consulting Engineers

Designers of Framework,[6] which includes four stories of Type V wood over a one story concrete podium, used a series of interior shear walls for lateral resistance. Since the stair and elevator shafts are located along one side of the building, a core lateral system wasn't an option. The design called for a glazing wall system on three sides of the structure, so the design team used four light-frame interior shear walls in alternating directions. This allowed them to function similar to a core system without being wrapped around the shafts. The shear walls were sheathed on both sides with architectural grade plywood and left exposed.

Design Considerations | *Fire Safety*

Quantifying fire resistance may become part of the analysis when exposing wood structure and opting for a construction type other than Type IV. If there are no occupancy separation requirements, it is relatively easy to meet the requirements with sub-type B, or unprotected, construction because Types IIIB and VB both allow unprotected floors, roofs and primary frame based on IBC Table 601. While 1-hour fire rating requirements exist for these same elements in sub-type A, or protected, construction, the protection can be achieved without encasement by providing charring calculations as permitted by IBC Section 703.3.

Fire Protection by Design

One of the great virtues of a Type IV heavy timber structural system is the natural fire resistance inherent in the large wood members. Wood burns, but it does so at a relatively slow and predictable rate. In a fire situation, members char but are large enough in cross-section to maintain structural capacity long enough for occupants to vacate the building and the fire department to arrive.

If timber-sized elements are used in other construction types, the charring effect is the same but the duration of the fire resistance is no longer prescriptive and must be quantified. In order to use exposed timber to achieve a 1-hour fire rating, a char calculation must demonstrate that the member's cross-section will be able to carry the design loads for the required amount of time during a fire. Most structural members are at least slightly oversized for the design load and therefore may not need to be upsized much or at all depending on size, loading and exposure.

Sprinklers

Per Chapter 9 of the IBC, office occupancy is one of the few occupancy types not required to have automatic sprinklers. Type IIIB, VA and VB construction can often be used without sprinklers for offices up to three stories, with allowable areas per story ranging from 9,000 to 19,000 square feet, not accounting for any potential frontage area increase. Type IIIA and IV construction can be used without sprinklers for office buildings up to five stories, with a maximum of 28,500 to 36,000 square feet per story, not accounting for any potential frontage area increase. Total building area for 3-, 4- or 5-story unsprinklered Group B buildings is 85,000 square feet for Type IIIA and 108,000 square feet for Type IV, not accounting for any potential frontage area increase.

According to IBC Table 506.2 *(Automatic Sprinkler System Increase)*, when a building is equipped with an approved automatic sprinkler system, designers are allowed three times the tabulated floor area for multi-story buildings and four times the tabulated floor area for single-story buildings. IBC Tables 504.2 and 504.3 allow buildings equipped with an automatic sprinkler system to have an increase in height of 20 feet and an increase of one story in addition to the area increases.

Most office tenants need to run data, electrical and other utilities in their ceiling or floor cavities. In buildings that require sprinklers throughout (either for height, area or due to Chapter 9 requirements), the concealed space in floor cavities also require sprinklers when the cavity contains combustible materials but does not have fire stops partitioning the space to 160 cubic feet or less. Screened or perforated ceiling systems are not considered a concealed space.

Fire Protection of Connections

While the building code does not specifically prescribe fire protection of connections for any materials, the connection should be capable of the same fire endurance as the framing member. Since Type IIIB, IV and VB structures have no fire protection requirements for the primary frame, protection of the connections for a gridded post-and-beam system is not necessary; however, exposed connections in a similar Type IIIA or Type VA structure do require protection. In general, it is good practice to place beams and columns in direct bearing so loads can be directly transferred from beams to columns in a fire. Depending on the loading and construction sequencing, it may also be necessary to rely on steel connections to transfer vertical loads in shear. In these circumstances, designers need to consider the connection performance under fire.

There are several methods of protecting connections, one of which is using wood plates or wood hole plugs. For an example of this option, see the interior Clay Creative photo on page 10.

Fire Rating of Structural Elements	IIA	IIB	IIIA	IIIB	IV	VB
IBC Table 601						
• Exterior bearing walls *(hours)*	1	0	2	2	2	0
• Interior bearing walls *(hours)*	1	0	1	0	1	0
• All other elements *(hours)*	1	0	1	0	HT	0
IBC Table 602						
• X < 10 feet	1	1	1	1	1	1
• 10 ft ≤ X < 30 feet	1	0	1	0	1	0
• X ≥ 30 feet	0	0	0	0	HT	0
IBC Chapter 7						
• Shaft walls (IBC Section 713.4)[a]	2 max	2 max	2 max	2 max	2 max	2 max
• Fire walls (IBC Section 706.4), B Occupancy	2	2	3	3	3	2

[a]Shaft walls are constructed as fire barriers (IBC Section 707.3.1). Shaft enclosures require a 2-hour rating when connecting 4 stories or more (1 hour for less than 4 stories).

Photos: LEVER Architecture

Albina Yard
Portland, OR

ARCHITECT: LEVER Architecture

STRUCTURAL ENGINEER: KPFF Consulting Engineers

Albina Yard is a four-story, Type VA building, but it could have been built as Type IIIB. A Type IIIB designation would have made it easier to expose the underside of the CLT floors, but the structure would then have needed FRTW exterior walls for the increased fire rating. Architects used a glulam timber frame and CLT panels to create a flexible space with high ceilings and natural light. Taking advantage of CLT's rigidity as a diaphragm, the design incorporates a wood shear wall lateral-resisting core. This allowed an open front glazing wall, which allowed the design team to bring the structural columns inside and made room for angled cantilevers on the exterior. Inside, the CLT floor panels incorporate electrical conduit for lighting below, poured into lightweight gypsum topping for a clean aesthetic on the underside of the ceiling.

Design Considerations | *Acoustics and Vibration*

Minimizing noise transfer and vibration are important considerations in the design of offices, and can be achieved with light-frame, heavy timber and mass timber systems. Class A office space, in particular, is expected to have minimal floor vibration and good sound insulation despite the fact that neither of these design parameters is dictated by code.

A number of techniques can be used to address vibration by controlling mass and/or stiffness. One common option is to add a non-structural concrete topping; the added mass will also help with acoustics and provide additional opportunity for sound isolation between the structure and topping.

Vibration of light-frame wood floor construction in offices can be an issue when designers size the members to minimum code requirements. There are two common methods for analyzing floor performance: reducing member deflections and evaluating system frequency. Limiting deflection is a simple, prescriptive method of limiting vibration, usually to higher criteria than required by the IBC (Section 1604.3), which allows total load deflections up to L/240 and live load deflections up to L/360. This method, commonly called the uniformly distributed load (UDL) deflection method, attempts to control vibrations by limiting the static deflection of a floor under a uniform design load. Some designers opt to reduce live load deflections to L/480 or L/600, which may increase the size of the floor member and should therefore be weighed against the tenant/owner's tolerance for floor vibration.

Evaluation of floor system frequency often involves testing by the product manufacturer. For example some engineered wood and truss manufacturers have tested their systems to provide a maximum permissible span for a given level of performance, with options for increasing the allowable span if blocking, bridging, strong backs or other stiffening measures are used. Some manufacturers have developed proprietary software that includes floor performance ratings based on perceived acceptance of a floor's vibration performance.[7]

There are a number of cost-effective ways to achieve excellent acoustic performance for both floors and walls; the addition of a lightweight concrete topping slab, acoustical underlayments, insulation and resilient channels can all dramatically improve Sound Transmission Class (STC) ratings. The choice of flooring material has a large impact on a floor's Impact Isolation Class (IIC) rating, which can be the bigger issue in offices with hard flooring surfaces. However, design assemblies that include a raised floor or a dropped ceiling to accommodate electrical and data also offer opportunities to decouple the structure from the source of sound and improve both STC and IIC ratings. Additional resources related to acoustic performance include the WoodWorks technical paper, *Acoustical Considerations for Mixed-Use Wood Frame Buildings* (www.woodworks.org), and the *Cross-Laminated Timber Handbook* (www.thinkwood.com/clthandbook) and *Nail-Laminated Timber: U.S. Design & Construction Guide* (www.thinkwood.com/nltguide) available from Think Wood.

Average Cost by Construction Type

Published $/Square Foot of Building Area

Table 1

	CONSTRUCTION TYPE								
Occupancy Group	IA	IB	IIA	IIB	IIIA	IIIB	IV	VA	VB
B Business	192	185	179	171	156	150	164	137	131

Structural Wood Framing Allowed

Table 2

	CONSTRUCTION TYPE		
Occupancy Group	IIA	IIIA	Difference
B Business	179	156	$23/sf

Table 3

	CONSTRUCTION TYPE		
Occupancy Group	IIB	VA	Difference
B Business	171	137	$34/sf

Source: ICC Building Valuation Data, February 2018

Green Office Building
Berkeley, CA

ARCHITECT: Marcy Wong Donn Logan Architects

STRUCTURAL ENGINEER: Gregory P. Luth Associates

Architects for this two-story, 15,000-square-foot office chose to expose the wood framing, reflecting the owners' commitment to sustainability, energy efficiency and a healthy work environment. Two perpendicular building wings were joined by an industrial stair that leads to the second level landing. The wings were designed with narrow floor plates, allowing daylight to reach throughout the building interiors, while continuous window walls allow natural light and views. Open web trusses add to the spaciousness, while a shaded arcade and walkway along the south exterior façade provides additional energy savings by protecting the interior from direct summer sun.

Photo: Billy Hustace Photography

Design Considerations | *Cost and Value*

Facility costs and lease rates are always a consideration, but the single greatest cost to employers is the salaries of employees who occupy the space. If a building can be designed to improve productivity—by providing better lighting or improving comfort, for example—the process of optimizing building performance can improve the company's bottom line. Wood systems can do this directly by creating warm and welcoming spaces that motivate a positive biophilic response. They can also contribute indirectly—e.g., by eliminating cold surfaces at exterior walls with a reduction in thermal conductivity or allowing large expanses of glazing for light and views through the use of centralized lateral-resisting systems or thin floor plates.

Construction type also has a significant impact on cost. Under the IBC, structural wood framing is permitted in Types IIIA, IIIB, IV, VA, and VB. The IBC specifies allowable height and area for each, and each has different requirements, largely related to fire protection. As shown in Tables 1-3 on page 14, which highlight information from the International Code Council (ICC) Building Valuation Data, February 2018, the average cost for each construction type also varies widely.

Table 2 highlights the difference in cost between two construction types commonly used for office buildings—Type IIA, which doesn't allow structural wood framing in most applications, and Type IIIA, which is typically wood-frame. Both have similar allowable heights and building limitations (see table on page 8), but the average Type IIIA building costs $23 per square foot less.

In Table 3, Type IIB construction is compared to Type VA—also commonly wood-frame—and shows an even larger savings of $34 per square foot for the wood building. Allowable heights and areas remain similar, except that slightly greater height is allowed for Type II.

Conclusion

Wood's performance and design versatility create a wide range of opportunities for developers and building designers looking to create beautiful offices that are also cost effective. Light-frame, heavy timber, mass timber and hybrid wood systems can all be used to create open structures that meet the need for space flexibility, with heights and areas that are comparable to mid-rise steel and concrete structures. For more information, or to discuss the needs of a specific office project, WoodWorks – Wood Products Council offers free technical support. Visit woodworks.org to contact your local Regional Director or email us at help@woodworks.org.

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1 *Wood in the Human Environment: Restorative Properties of Wood in the Built Indoor Environment, David Fell, 2010; Wood and Human Health, FPInnovations, 2011*

2 *Human Spaces: The Global Impact of Biophilic Design in the Workplace, Interface, 2015*

3 *The height and area allowance assume NFPA 13 sprinklers throughout and three or more stories in height.*

4 *FRTW is permitted in place of non-combustible exterior wall framing when the fire rating requirement is 2 hours or less.*

5 *More information on accommodating MEP in mass timber buildings can be found in the Ask an Expert section of the WoodWorks website: www.woodworks.org/experttip/mep-accommodated-exposed-mass-timber-buildings-e-g-clt-nlt-wall-floor-roof-panels/*

6 *The four-story Framework in this case study is a different project than the 12-story Framework designed with cross-laminated timber, also in Portland.*

7 *More information about calculating floor vibration can be found in the Ask an Expert section of the WoodWorks website: www.woodworks.org/experttip/what-methods-exist-for-checking-floor-vibration-of-light-frame-wood-structures/*

Volume of wood products used:
24,526 cubic feet

U.S. and Canadian forests grow this much wood in:
2 minutes

Carbon stored in the wood:
545 metric tons of CO_2

Avoided greenhouse gas emissions:
1,158 metric tons of CO_2

TOTAL POTENTIAL CARBON BENEFIT:
1,703 metric tons of CO_2

EQUIVALENT TO:

325 cars off the road for a year

Energy to operate a home for 145 years

Source: US EPA

Based on research by Sarthre, R. and J. O'Connor, 2010, A Synthesis of Research on Wood Products and Greenhouse Gas Impacts, FPInnovations. Note: CO_2 on this chart refers to CO_2 equivalent.

Carbon Footprint and Sustainable Office Design

Sustainability is often a priority for office design, whether to reflect the values of the building's owner or design team, or to attract prospective tenants.

When The Bullitt Foundation began developing a new headquarters (see page 5), its objective was a building that aligned with its mission 'to safeguard the natural environment by promoting responsible human activities and sustainable communities in the Pacific Northwest.' The Bullitt Center was designed to be the world's most energy-efficient commercial building and to meet the highest benchmark of building sustainability—Living Building Certification.

After conducting life cycle assessments on various structural systems, the design team chose five stories of heavy timber framing over a concrete podium. They'd been expecting to use a reinforced concrete frame, because they thought they needed it for thermal mass, but this didn't turn out to be the case. Wood helped the project meet its energy-efficiency goals and, when the team considered the embodied energy and carbon footprint of the concrete, they decided timber was a better environmental solution.

Wood lowers a building's carbon footprint in two ways. It continues to store carbon absorbed during the tree's growing cycle, keeping it out of the atmosphere for the lifetime of the building—longer if the wood is reclaimed and reused or manufactured into other products. When used in place of fossil fuel-intensive materials such as steel and concrete, it also results in 'avoided' greenhouse gas emissions.

The chart on the left illustrates the carbon-related advantages of using wood in The Bullitt Center. The information was estimated using the WoodWorks Carbon Calculator, based on the volume and types of wood in the structure. The calculator is available (free of charge) to anyone who wants to evaluate the carbon footprint of a wood building design (www.woodworks.org/design-and-tools/design-tools/online-calculators/).

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