Wood Industrial Buildings

Why wood?

Building one's own headquarters is the dream of many small business owners. When a rented facility becomes too small, or is unfit to house the next step of production, a business owner is faced with two options: rent a larger facility, or start construction of a new, custom building. Either option may be a good solution, but with strong growth and adequate cash flow, a new building that is tailored to the production equipment is often the preferred choice. The stock of existing and available commercial buildings in northern communities in Western Canada is low, so a new building is often the only available option in this region.

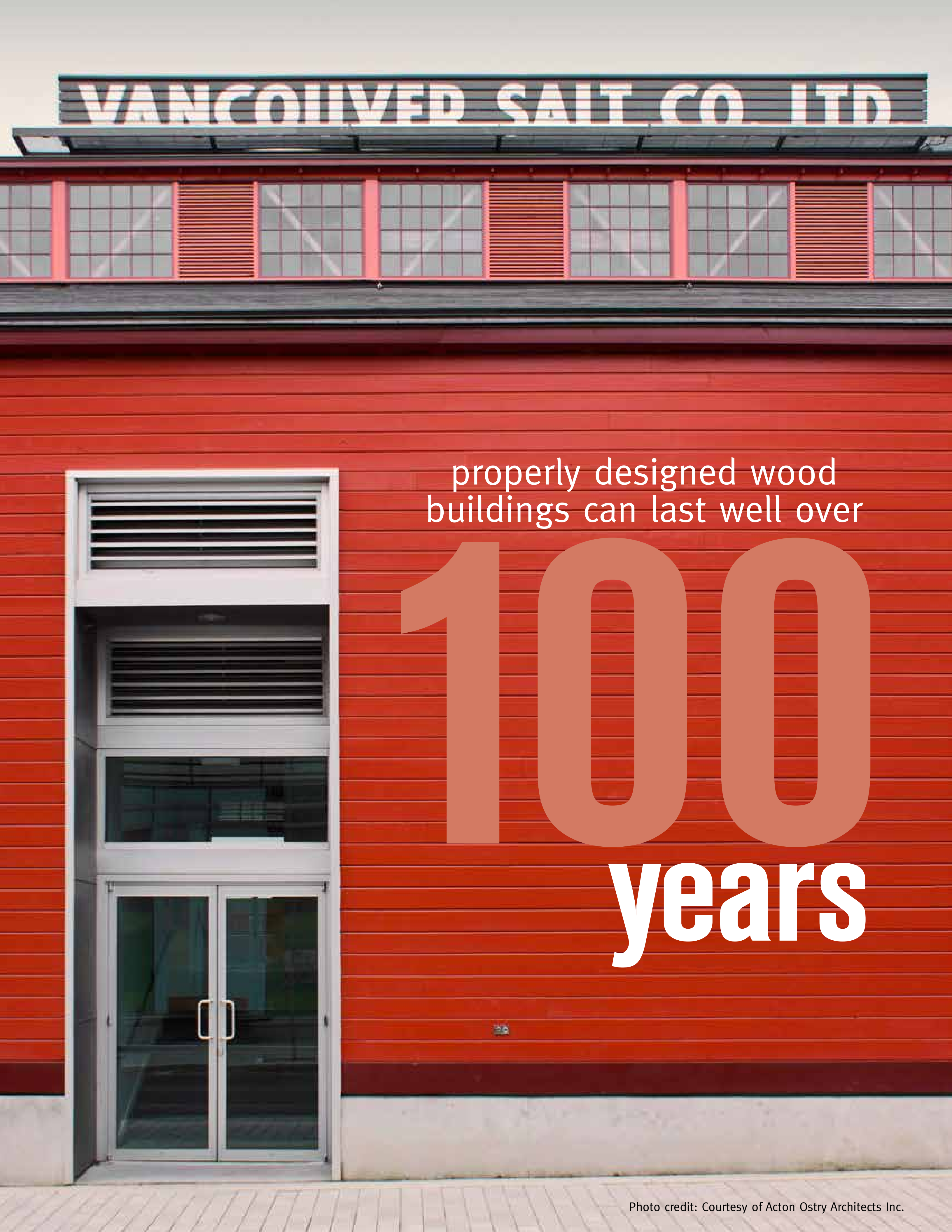
Once a business owner has decided to construct a new building, the next step is for them to educate themselves about the available building types. The production process used will be key in defining the functional requirements and from these, the owner will begin to consider the structure. The foundation system is almost always concrete slab on grade with perimeter strip footings, but what about the building sitting atop the foundation? There are a few options commonly available. The most economical solution is often perceived to be a prefabricated steel frame with SIP panels. Another common industrial building type is a masonry building with steel beams or trusses, open web steel joists, and steel decking. A variation on these masonry buildings use precast concrete "tilt-up" panels as walls instead. Masonry and tilt-up are commonly used for storage facilities and large warehouses.

This report introduces a third option with a wide variety of applications: prefabricated industrial timber buildings. With newly developed technologies that are available today, and applying prefabrication concepts used in the concrete and steel industries, timber can compete in price with steel, concrete, and masonry options for many buildings.

The wood design and construction industries have undergone major changes in the last 25 years. The introduction of computer aided design and drafting and robotic CNC machinery have transformed the industry. Today, modern timber buildings arrive on site with all timber pieces pre-cut. Structural members are pieced together in a similar way as a steel building. In fact, in comparison to steel, the construction of a timber building often takes less time and the work of other trades is made easier. A new timber product called Cross Laminated Timber (CLT) can be used for walls and roofs to achieve a similar durability to a masonry or concrete wall. When a robust surface is not required, prefabricated timber panels can provide an economical and energy efficient option.

The cost of a wood industrial building

This report describes wood systems for industrial buildings, and provides as examples two recent projects in BC. The first example is an extension of a production facility for Structurlam Products in Okanagan Fall, and the second is “Die Halle,” a new home for BC Passive House, a prefabricated housing plant in Pemberton. In both cases, wood was chosen because it was cost effective. Many other reasons supported the use of wood in each case: speed of construction, use of local resource, energy efficiency, aesthetics of final product, and flexibility of space. Both business owners assessed their needs carefully, and found solutions that resulted in a final product that allowed them to expand their business into a new and better home. Most importantly, they were able to do so affordably and get a product that they were happy with.



properly designed wood buildings can last well over

100 years

Photo credit: Courtesy of Acton Ostry Architects Inc.

How does wood compare?

Wood is not new to industrial buildings in BC. From the mid-1800's to the mid-1900's, wood was a building material of choice in Canada due to its availability. Early multi-storey industrial buildings used a "brick and beam" technique, with heavy timber beams and columns, and masonry exterior walls. Examples of these buildings can still be found in major cities throughout Canada, still in use, though many have been converted to residential or commercial occupancies. One of the most prominent examples of early low rise industrial construction is Granville Island in Vancouver, BC. This cluster of early 20th century timber industrial buildings has been converted into one of the top tourist attractions of the city. The authors of this report worked on adaptations of these old structures to suit new occupancies, and can confirm that properly designed wood buildings can last well over 100 years. In the last few decades, timber engineering has advanced enormously in terms of structural capacity and fire design, and there is good reason to return to timber for our industrial buildings.

The most common industrial buildings we see today in BC are prefabricated steel and tilt-up concrete. These are perceived to be the most inexpensive options for industrial, particularly light industrial, however when the entire picture is considered, this is often not the case, and wood can be an excellent option. Take prefabricated steel for instance: The steel product itself is inexpensive, but the quotes do not consider foundations and finishes.

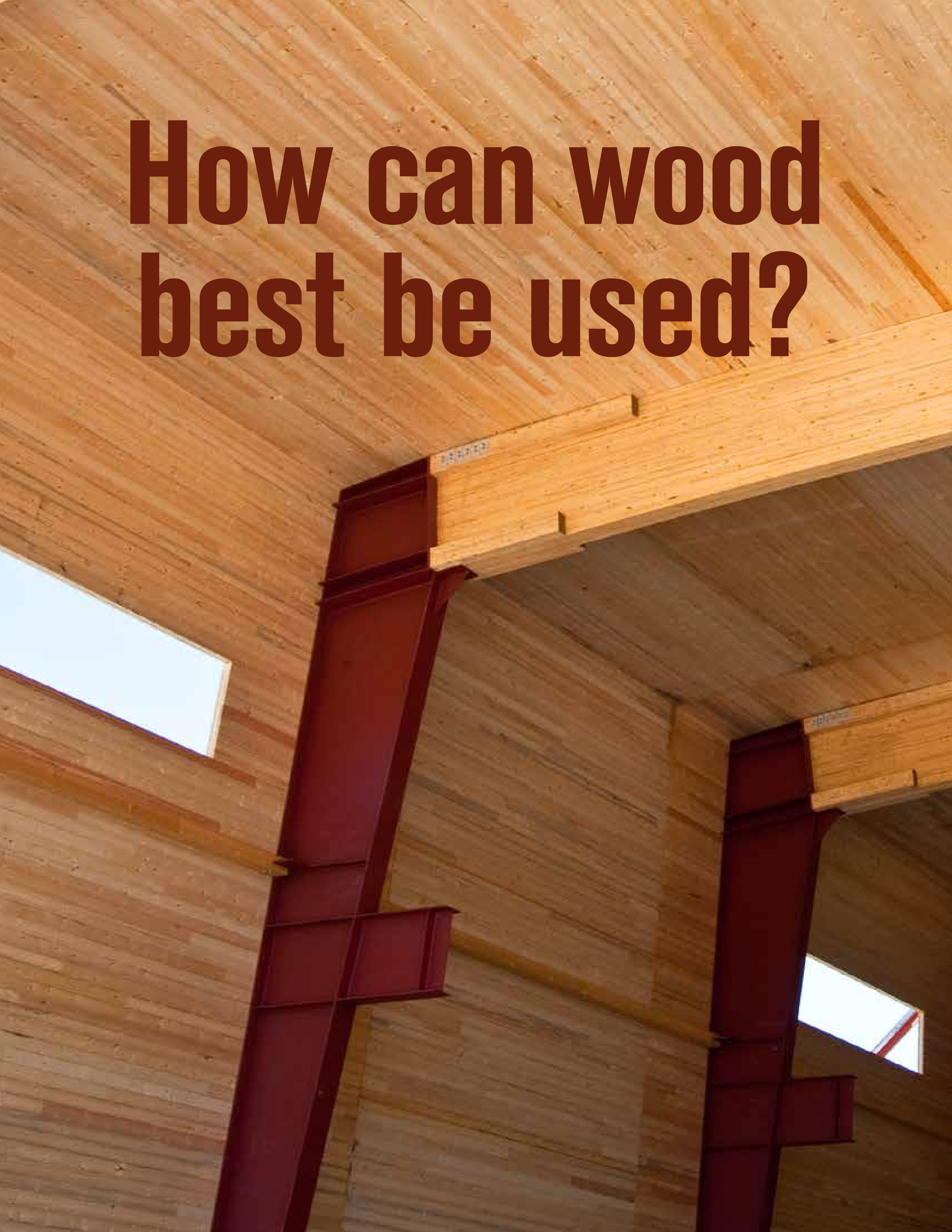
Alternatively, tilt-up concrete or masonry are chosen for their fast erection, low cost materials, and high resistance to impact. Wood competes well with these materials: it is very quick to erect, and it can be highly prefabricated, reducing site work. Tilt-up concrete has the advantage that once the walls are up the building can be quickly enclosed and finished. Wood has the exact same advantages. CLT walls can also provide resistance to impact loads if banging is expected.

There is endless flexibility when building with wood. From traditional stick framing to mass timber products such as glulam and CLT, there are options to suit every need. Long open span structures are within reach of wood. Multi-storey structures are possible. Wood can be combined with other materials to create trusses and frames that were once limited to steel or concrete buildings. Mass timber can be used in ways similar to concrete and masonry to create robust and stiff walls, but at a fraction of the weight. Today, wood offers highly-engineered products that can meet the needs of industrial buildings.

There is a natural warmth and attractiveness to a timber building. Though in many industrial buildings, appearance may be secondary to function, both can be achieved with wood. Wood also means that meeting, office, or conference rooms held within otherwise industrial buildings can benefit from inviting and warm materials.

Using wood means using a product that is harvested and manufactured close to home. By building with BC wood we are supporting our economy, and we are standing up for the environment. Wood is the only major structural material grown by the sun. With adequate reforestation, we maintain a carbon negative, renewable resource.

How can wood best be used?



Long Span Elements

The three most common ways to span large open spaces in wood are with beams, arches, or trusses. Beams generally provide the most cost efficient solution for areas with low to medium snow load areas or for shorter spans. Glulam beams are currently produced by several BC manufacturers, and they are easy to transport and erect with no need for additional bracing required by truss and arch systems. Using multiple supports results in a continuous beam that can be more efficient than a single span.

For longer spans and high snow loads, larger beams would be required, which can significantly increase material and handling costs. In these cases, glulam trusses are often preferable. The most cost efficient truss uses parallel top and bottom chords with diagonal wood members taking compressional loads and vertical steel rods taking tension loads. Typically, trusses are prefabricated in the glulam plant and shipped on flat-bed trucks with all connections pre-installed. The increased transportation cost for larger structural components is offset by quicker installation. The additional height of the trusses creates a larger volume inside the building, however this means that the perimeter walls need to be built higher to enclose the space between the trusses.

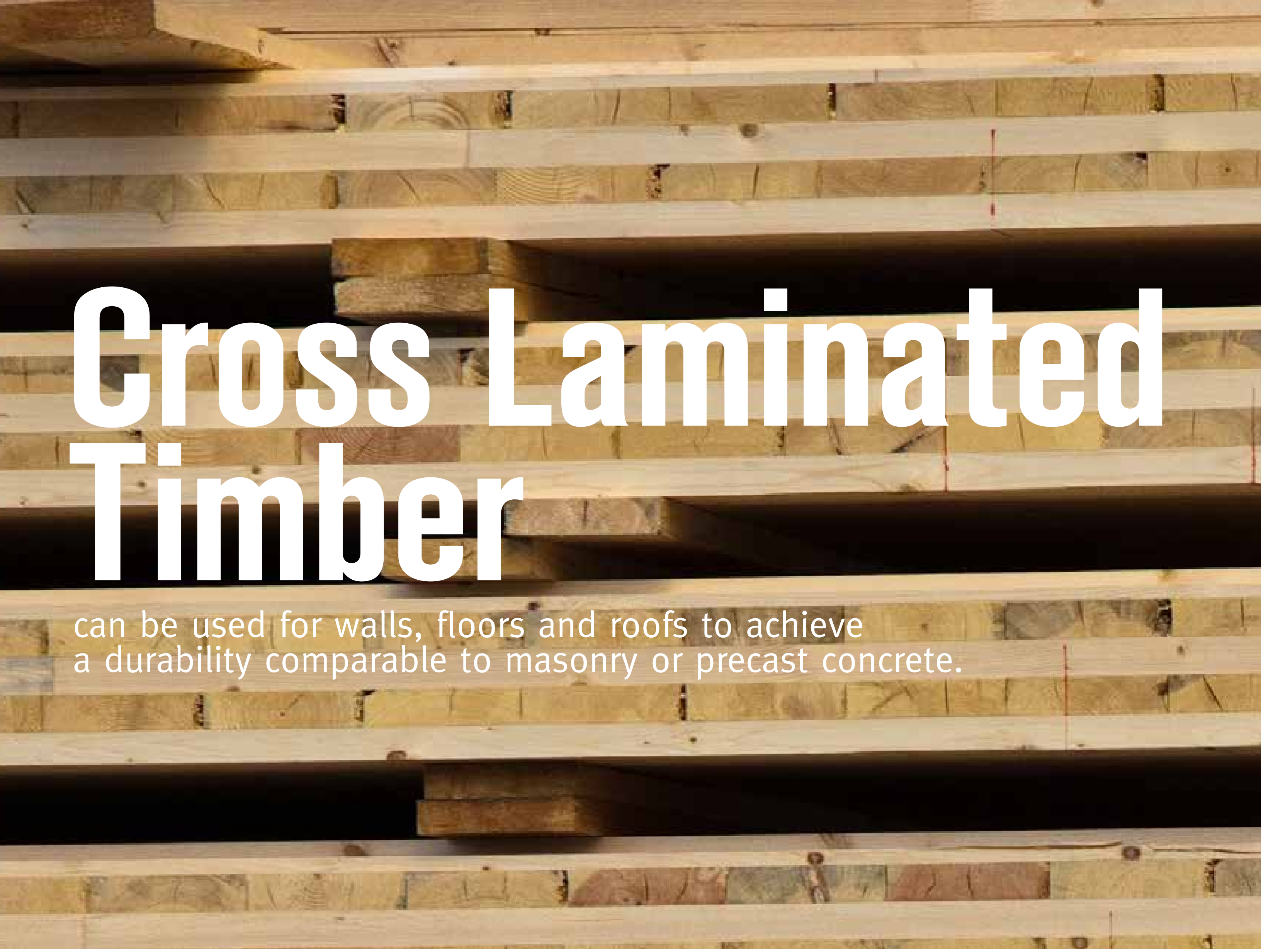
Arches provide a curved roof shape and higher interior space without extending the exterior perimeter walls. As the arch tries to push out its supports, it must be prevented from doing so with horizontal restraints at both ends, either by the foundation or a tie element. The curvature and steel ties add to the cost of this system, however arches can provide very economical and elegant solutions. A great example of wood arches is a potash storage warehouse built in Saskatchewan in 2006 that consists of a series of deep, long span glulam arches.

Hybrid elements

Playing to the inherent strength of each material, we can come up with hybrid elements using wood together with steel or wood together with concrete to achieve even more with wood. For example, concrete topping can be used with mass timber panels to create timber-concrete-composite floors that can span further than wood alone, and are lighter in weight than concrete alone. Many trusses are wood-steel hybrids because we use steel bars for the tension elements. Most connections in timber require some use of steel.

Even in high-seismic zones, wood can provide safe buildings that meet the performance required by our codes. Many wood products and systems have been well tested to ensure that they can withstand the design earthquake that is expected for many parts of BC. In high-seismic zones, more shearwalls may be necessary compared to low-seismic zones, although moment frames and braces are also viable options.

Wood buildings can be designed for a variety of loadings, from industrial processes to climate loads. In parts of BC that can expect heavy snow loads, shorter spans or deeper trusses might be better suited to handle the loads. Vibrations and impact loads due to equipment and machinery can be accounted for in a building designed with wood.



Cross Laminated Timber

can be used for walls, floors and roofs to achieve a durability comparable to masonry or precast concrete.

Wood offers many options for many different applications. The following is a description of wood products and technologies that allow us to build more with wood than ever before:

Materials

The simplest and most familiar material when it comes to wood are studs also known as stick framing. 2 by 4, 2 by 6, and 2 by 10 are the most commonly milled wood elements. Used horizontally they can be joists and hold up our floors or our roofs. Used vertically with plywood sheathing they can be structural walls. Many of us who live in single family homes or low-rise multi-family buildings live in stick-framing.

Glulam is a well-established engineered wood product. Glued-laminated timber is used where regular lumber cannot be used, for example if a span is too large. Glulam is made by stacking a series of planks on top of each other to make a beam. The wide face of each plank is glued and pressed to the one above and below it. Using glulam, timber can span as far as steel for open-span buildings.

CLT, or cross-laminated timber, has been made in BC over the past few years. It is made by gluing, stacking, and pressing layers of standard 2x lumber planks on the flat. Each layer is laid at 90 degrees to the previous layer to create one solid element. CLT panels are produced in sizes up to 10’ by 40’ and can be very rapidly erected as roofs, walls, and floors.

A range of other engineered wood products exist, available as beams and increasingly as panels. These include LVL, LSL, PSL, and I-joists, and are made from wood veneers or strands glued and pressed together to form wood products stronger than regular lumber.

Connections

Connecting stick-frame construction to glulam and CLT is simple. Generally, the same types of connections can be used – screws, nails, and brackets. As for regular stick-frame buildings, these connectors are readily available and do not require specialist knowledge; however suppliers can offer advice on installation if needed.

Modern engineered connections are also possible, which allow us to push wood further than ever before. Connectors such as self-tapping screws, glued-in plates or rods, tight-fit pins, and aluminum dovetail connectors can provide a range of connections ranging from pinned to rigid, and can achieve a desired look and fire performance.

Possible Applications

The choice of a building is highly dependent on the functional requirements of the space. What sort of footprint is required? Is an open-span absolutely necessary, or will a multi-span building with interior columns suffice? Are cranes required? Based on the project requirements, the best solution at the lowest cost can be determined.

Warehouse or Storage Facility

Warehouses will often contain large, open spaces with tall ceilings for easy storage and access for equipment. Often these buildings will need to accommodate big openings for truck access. A good example of a warehouse is Structurlam's CLT extension, built with wood moment frames in Penticton.

Manufacturing or Mill

In a manufacturing facility or a mill, intermediate supports are usually acceptable, as long as they don't interfere with the workflow of the building. Supports should be sparse to allow for plenty of work room and room for equipment and machinery. Many glulam and CLT plants in Europe are wood and still meet the needs of the business.

In Pemberton, a timber plant for BC Passivehouse that is currently under construction will provide the space and layout needed to make prefabricated timber panels.

Food or Chemical Processing

In some industrial buildings with harsh environments, wood can be an excellent choice. Wood is resistant to caustic chemicals in a way that steel is not. In a severe environment, wood can be made more durable by pressure treating it, which will slow or prevent decay and prolong the structure's life. A potash storage facility was built in 2006 in Saskatchewan with glulam arches because wood was well-suited to the highly-corrosive environment. In this case, any steel for connections was recessed into the wood and plugged to avoid exposing steel to the environment.

Workshop

A small workshop can be erected quickly using traditional stick framing techniques, or even more quickly if the structural elements are pre-manufactured off-site.

Showroom

A showroom needs to be open, inviting, and attractive. Wood can provide the warmth and openness that can best showcase the goods on display.

Example: Manufacturing

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Achieving an Affordable Building

There are more decisions than choice of material when it comes to constructing an industrial building. There will be a series of decisions that an owner will need to make, each of which will have an effect on the cost and the quality of the end product. These decisions need to be based on a reasonable and frank consideration of how a building will be used and the needs of the owner. Some of these considerations are:

How big does the building need to be to house the equipment, materials, and the process? The answer to this question will begin to form the requirements and define where the building falls within the building code. For instance whether or not sprinklers are required by code may be defined by the footprint of the building.

How will my requirements for interior space impact the cost of the building? The owner should consider whether an open plan is required (an interior space free from columns) or whether interior columns can be tolerated. The obvious benefit to an open plan is that it is easier to move around within the building and there is more flexibility in terms of layout. However by simply bringing interior columns into the space, the building costs are significantly reduced. If the industrial process can accommodate interior columns, this will almost always be the most efficient solution, and is easily achievable in wood.

Will there be equipment or machinery banging against the walls, requiring a higher level of durability? Often the assumption is that where resistance to impact is required, concrete or masonry are the only options, however CLT will perform equally well. Where resistance to impact is not required, prefabricated wood panels will provide walls that are durable and long lasting. In highly caustic industrial environments, wood can be advantageous because it doesn't rust. The building exterior envelope will provide most of the building's durability against the elements, regardless of the structural material chosen.

How important is the aesthetics of the building's interior and exterior? There is no question that timber interior spaces tend to be warmer and more inviting than structural steel or concrete. Consider the environment in which employees will be working. Will clients be visiting the building?

Is a high level of energy efficiency a big asset for this building? If so, prefabricated wood panels can be built off-site already insulated, and can achieve extremely high energy efficiencies.

If there are separate office areas or meeting rooms, is sound insulation a big concern? The quality of sound insulation is largely a function of the detailing of the wall and floor assembly. With adequate detailing, wood assemblies have been shown to achieve acoustic performance ratings that meet code requirements.

Can a crane be used in a wood building? A crane can be used within a timber building, supported by wood or steel rail beams.

Lets have a look at our two examples and how the building owners determined their space requirements:

Structurlam needed their building to produce, cut, and store CLT panels. Because of the panel sizes, an open plan was required, and there was no way around it. Though they still found wood to be the best solution for their building, it was more costly than having interior columns because of the steel-wood hybrid frame that the building required.

On the other hand, *BC Passive House* initially determined that their building also required an open plan. However, after research into similar facilities elsewhere, the owners concluded that they could make do quite easily with a row of columns down the middle, which made wood an extremely affordable option.

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building layouts

There are two basic types of industrial buildings: open span with open interior space and structural supports at the perimeter of the building, and multi span buildings with interior columns. Deciding which of these layouts should be used depends on the requirements of the production process. Some processes require long spans and full flexibility of the interior layout, and others can easily accommodate one or two rows of internal structural supports.

Multi span buildings with internal supports almost always offer the more economical solution, however a typical small business owner will usually prefer the flexible layout that the open span building provides. The owner should take the additional costs as well as the industrial process into consideration when deciding whether the building layout can accommodate interior columns.

This report presents two recently completed projects: An open span option and a multi span option.

Open Span Building

Structurlam Products, a leading glulam fabricator, expanded its manufacturing into Okanagan Falls and acquired existing prefabricated steel buildings. For their expansion, however, they decided to use a wood/steel hybrid solution.

The building is 42 meters long with typical bays at 8.8 meters on center and with a free span of 29 meters. The total area is 1220 square meters. The clear height required for the production was 11.5 meters. The structural system supporting the 29 meter span is a moment frame, which uses rigid connections between the top of the column and end of the roof girder. This type of frame greatly reduces the overall height of the girder in comparison with a traditional simply supported beam approach, and adds the rigidity needed at each frame to resist lateral loads like earthquakes and wind.

Tall perimeter columns that support both the roof girders and an overhead crane are made of custom steel girders to minimize the weight and cost of the material and to provide a base for the moment connection with the glulam girders. The long span beams are cambered upwards to eliminate dead load deflection and to maintain the slope of the roof surface. Cross Laminated Timber (CLT) is used as secondary framing for both the walls and the roof. CLT provides both the strong and durable exterior surface and the lateral load resistance in the long direction of the building.

Multi-Span Building

BC Passive House (BCPH) needed a fabrication facility in Pemberton, B.C. The owners were initially considering a single span structure to achieve a flexible layout for the fabrication process that had yet to be fully determined. During a review of similar plants in Europe, it became obvious that a long open span was not a critical requirement. Most fabricators of similar products used buildings with spans around 17 meters. BCPH decided to use two 16.9 meters spans with a total width of 33.8 meters and 7 bays spaced at 6.1 meters.

The shorter spans enabled the use of simple, cambered glulam beams on glulam columns. After a cost comparison between single and double span beams, single spans were chosen because of considerably lower material, handling and transportation costs of shorter members. The most cost efficient roof framing in this high snow load area consists of prefabricated framing panels sheathed with plywood. Double 2x10 joists and 5/8" plywood were prefabricated in 8'-0" wide panels and supported on ledgers screwed to the glulam beams.

The production of large scale prefabricated panels requires a robust wall surface in the fabrication area of the building. 3-ply Cross Laminated Timber (CLT) panels were chosen as secondary wall elements providing both wind and seismic resistance in and out of plane of the outside walls. 2.4m x 6.1m CLT panels were screwed from the outside to the perimeter glulam post. The architectural requirement for a full perimeter band of glazing at the top of the wall created a challenge for transferring of lateral loads from the roof diaphragm to the lower perimeter shear walls. Steel cross bracing was used to infill this gap in the load path as it was the least intrusive option that maximized the natural light inside the building.

Funding for this report was provided to BCWood and FPInnovations on behalf of the Wood Enterprise Coalition (WEC) by Forestry Innovation Investment (FII). Any results, findings, conclusions or recommendations are those of the author, and do not necessarily represent those of BCWood, FPInnovations, WEC - and it's partners, FII or the Province of British Columbia.

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