



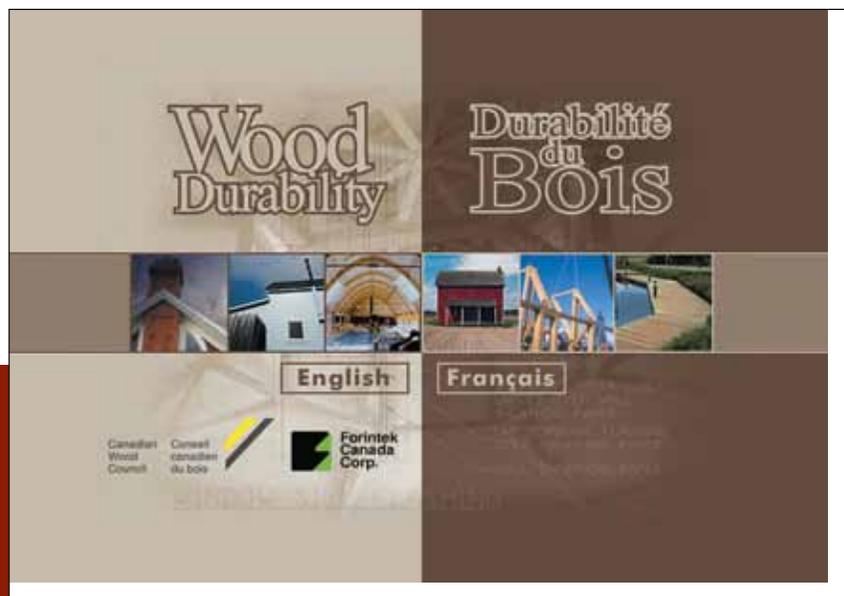
Canada Wood
Produits de bois canadien



Moisture and Wood-Frame Buildings

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Introduction



PHOTO 1: Wood products adorn this splendid reminder of an earlier era. Routinely maintained, wood lasts the test of time.

Throughout history, wherever wood has been available as a resource, it has found favor as a building material for its strength, economy, workability and beauty, and its ability to last has been demonstrated again and again.

From the ancient temples of Japan and China and the great stave churches of Norway to the countless North American and European buildings built in the 1800s, wood construction has proven it can stand the test of time. The art and technology of wood building, however, has been changing through time.

It's a common misconception that water is wood's enemy. That's not necessarily true, since many wood buildings exist in rainy and humid places. It's a matter of knowing how to manage water in buildings. Protection of buildings from water is the important design criterion, as important as protection from fire or structural collapse.

Designers, builders and owners are gaining a deeper appreciation for the function of the building envelope (exterior walls and roof). This includes the performance of windows, doors, siding, sheathing membranes, air and

PHOTO 2: Stave Church at Urnes, Norway – Norway's oldest stave church that dates back to the early 12th century in its present form. Wooden components of an even older church were used to build it.

vapour barriers, sheathing, and framing. The capabilities and characteristics of wood and other construction materials must be understood, and then articulated in the design of buildings, if proper and durable construction is to be assured.

Wood and water are typically very compatible. Wood can absorb and release large quantities of moisture without problems, and it's only when wood gets too wet for too long that there may be problems. If buildings are properly constructed to shed water, wood performs

well as a building material in all types of climates. As an example, 90% of North American homes are built with wood.

The primary focus of this publication is to address the control of rainwater penetration in exterior walls, which is the major source of moisture issues for all building materials, particularly in climates subject to high rainfall.





PHOTO 3: Wood-Frame Condominiums

Modern condominiums go the extra mile

Designed and built expressly for the wet West Coast climate of Vancouver, Canada, these wood-frame condominiums go the extra mile by applying state-of-the-art design and construction incorporating advanced moisture protection systems. Key features include what the developer describes as ‘umbrella architecture’ that emphasizes large overhangs and sloping roofs, combined with a multi-layer rainscreen wall system. On-site testing, quality inspection during construction and working with a team of engineers and building envelope experts were also integral parts of this state-of-the-art building approach.

Key construction details:

Wall flashing to direct water away from the building envelope,

Durable bevel cedar siding and fire retardant treated No.1 red cedar roof shingles,

Pressure treated 19 x 38 mm wood strapping on the walls, creating a 19 mm airspace and drainage plane,

9.5 mm softwood plywood on the walls, with top and bottom venting of each stud cavity,

Kiln dried framing materials including 38 x 89 mm finger-jointed studs for exterior walls and party walls, and S-P-F floor joists, and

New generation engineered wood products, including laminated veneer lumber, parallel strand lumber and wood roof trusses.

Moisture and Wood

Understanding the moisture content of wood is crucial for the following reasons:

- Varying moisture content leads to shrinking and swelling of wood members, and
- High moisture content can lead to the growth of mould and decay fungi. Moisture content (MC) is a measure of how much water is in a piece of wood relative to the wood weight. MC is expressed as a percentage and calculated by dividing the weight of water in the wood by the weight of that wood if it were in an oven dry state.

Two important MC numbers to remember are:

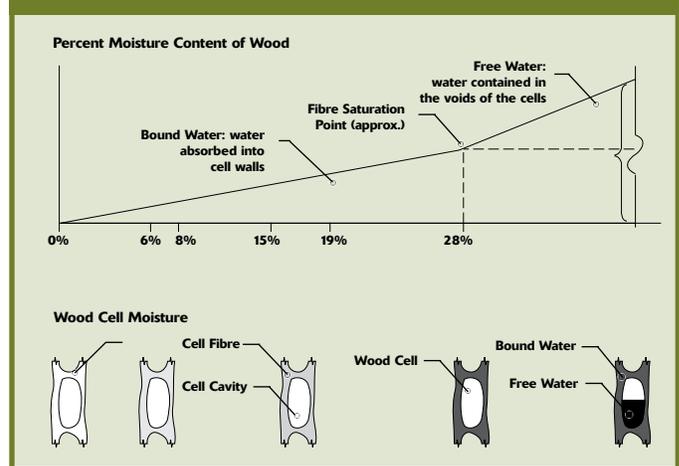
1. 19%: We tend to call a piece of wood “dry” if it has an MC of 19% or less (see Figure 1). This

type of lumber is grade marked as S-DRY for surfaced dry, or dry at time of manufacture. (Note: Some lumber is also marked KD for kiln-dried, and this also means dry at time of manufacture).

2. 28%: This is the average fibre saturation point for wood where all the wood fibres are fully saturated. At moisture contents above the fibre saturation point, water begins to fill the cell (see Figure 1). Decay can generally only get started if the moisture content of the wood is above fibre saturation for a prolonged period of time. The fibre saturation point is also the limit for wood swelling.

Wood shrinks or swells as its moisture content changes, but only when water is taken up or

FIGURE 1: Moisture Control of Wood

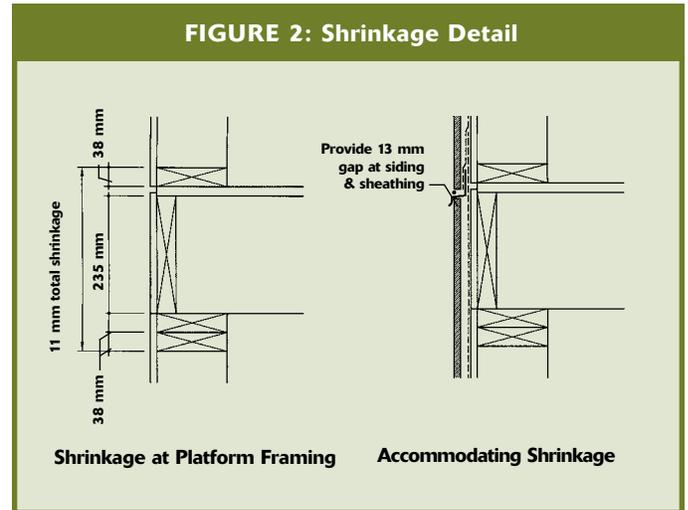


given off from the cell walls. This only occurs when wood changes moisture content below the fibre saturation point. Wood used indoors will eventually stabilize at 8-14% moisture content; outdoors at 12-18%.

Shrinkage and Swelling

Wood shrinks or swells when it loses or gains moisture below its fibre saturation point. The amount of dimensional change is estimated at 1% of the width or thickness of lumber for every 5% change in moisture content.

Shrinkage is to be expected in lumber across its width while longitudinal shrinkage is likely to be negligible, such as the vertical shrinkage of a wall stud. In a wood-frame structure, shrinkage occurs primarily in horizontal members such as wall plates and floor joists. In buildings designed to three, four or five stories, the effects of cumulative shrinkage can affect the building envelope, such as the exterior cladding (see Figure 2). Special consideration must be given to designs that allow for shrinkage. (Visit www.cwc.ca and try deltaCALC, a software tool for determining the amount of shrinkage and



Shrinkage in Tall Wood-Frame Buildings

In taller wood-frame buildings, design of the joints between building envelope components must allow for differential shrinkage. At this window on the third floor of a wood-frame building, a 25 mm wide sealant joint has been installed between the window frame and the masonry sill. As the wood framing shrinks, the joint allows the window to move downward with the framing to which it is attached. If the joint was only 13 mm wide, it is possible the window frame would bind and rack on the top edge of the concrete sill.

Specification of dry lumber is an important step towards minimizing shrinkage. One advantage of using dry lumber is that most of

the shrinkage has been achieved prior to purchase (wood does most of its shrinking as MC drops from 28 to 19%). It will also lead to a more predictable in-service performance as the product will stay more or less at the same dimension it was upon installation.

Another way to avoid shrinkage and warp is to use composite wood products such as plywood, OSB, finger-jointed studs, I-joists and structural composite lumber. These products are assembled from smaller pieces of wood glued together. Composite products have a mix of wood orientations within a single piece, so one part constrains the movement of another. For example, plywood achieves

this crossbanding form of self-constraint. In other products, movements are limited to very small areas and tend to average out in the whole piece, as with finger-jointed studs.

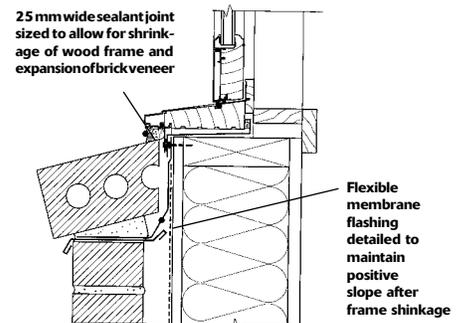




PHOTO 4: Weather-resistant barriers, used together with flashing around windows and door openings, help to keep buildings dry.

swelling in wood.) For example, when a wood-frame structure is combined with a brick veneer, a concrete block elevator shaft or stair tower, or a steel-frame building element, the cumulative effects of differential movement in a multi-story building must be accounted for in the detailing and specifications.

Decay

Wood is a natural, biodegradable material. The primary durability hazard with wood is biodeterioration. Wood in buildings is a potential food source for a variety of fungi, insects and marine borers. These wood-destroying organisms have the ability to break down the complex polymers that make up the wood structure, but they usually can't do so without water. In normal construction conditions, moisture content is well below the safety limits for fungi to grow. Only when building failure lets large amounts of water enter does wood run the risk of decay.

The wood-inhabiting fungi can be separated into moulds, stainers, soft-rot fungi and wood decay fungi. The moulds and stainers discolour wood, however, they do not damage the wood structurally. Soft-rot fungi and wood decay fungi

can cause strength loss in wood, with the decay fungi responsible for deterioration problems in buildings.

Decay is the result of a series of events including a sequence of fungal colonization. The spores of these fungi are ubiquitous in the air for much of the year, but only lead to problems under certain conditions. Wood decay fungi require wood as their food source, an equable temperature, oxygen and water. Water is normally the only one of these factors we can easily manage. In general, decay fungi cannot infect or be active in wood with a moisture content below 20%. In typical building or protected locations, wood is below 20% MC at all times of the year.

Wood decay fungi also have to compete with other organisms, such as moulds and stainers, to get a foothold in wood materials. It is easier to control decay fungi before decay has started since these pre-conditions can inhibit growth rates at the start.

Decay and mould are terms that are often used interchangeably in the context of moisture-related wood damage. It is important to understand the distinction. Mould fungi can grow on wood (and many other materials), but they do not eat the structural components of the wood.

Therefore, mould does not significantly damage the wood, and thus mould fungi are not wood-decay fungi. However, some types of moulds have been associated with human health problems, so the growth of mould in sufficient quantity and exposure to occupants is of potential concern regardless of physical damage to building products. Unfortunately, the relationship between mould and health is not yet fully understood. We live safely with some moulds in the air all the time, so clearly there are issues of thresholds, individual sensitivities, and other variables that still need to be determined by health experts and building scientists.

Decay fungi, a higher order of fungi than moulds, break down basic structural materials of wood and cause strength loss. Decay fungi are not associated with any human health problems.

Mould and decay do not necessarily occur together, nor are they indicators of each other. There tends to be a gradual transition from moulds to decay fungi if moisture conditions continue to be wet.

Moisture Load

Design for durability begins with an understanding of moisture loading and how this interacts with building materials. Where does water come from? How is it transported? How can it be controlled? How can it be removed?

Moisture flows within any building must be managed to prevent water accumulation or storage that may lead to premature deterioration of building products. Water will lead to deterioration by corrosion in steel products, by spalling and cracking in concrete products, and by fungi in wood products.

Moisture Balance

There are two general strategies to moisture control in the building envelope:

- Limit the moisture load on the building, and
- Design and construct the building to maximize its tolerance to moisture, to a level appropriate for the moisture load.

The key design objective is to keep building envelopes dry, and to achieve moisture balance, where wetting and drying

mechanisms are balanced to maintain moisture content levels at or below the tolerance level.

The concept of “load” is well established in structural design, where dead loads, live loads, wind loads, seismic loads and thermal loads are fundamental to the design process. Similarly, moisture loads are placed on a building and these loads must be accounted for and balanced in the building envelope design. The nature and magnitude of the loads will vary greatly depending upon the climatic situation, as well as occupancy of the building. The following section describes the most common moisture sources that create these moisture loads on buildings.

Moisture Sources

Moisture sources in and around buildings are abundant. Interior moisture sources include building occupants and their activities. Some studies have concluded that a family of four can generate 38 liters of water vapour per day.

Exterior moisture sources include precipitation, irrigation systems and groundwater. Water vapour is also present in the exterior environment and may significantly affect the building envelope in some climates.

An additional source of moisture is often called construction moisture. This is water contained in concrete, grout, wood and other building materials during the time of construction. This amount of moisture can be substantial and allowance must be made for drying before or after the building envelope is enclosed.

Finally, rainwater, especially wind driven, is the moisture source that impacts the performance of the envelope most, and is the focus of this publication.

Moisture Transport Mechanisms

The migration of moisture into and through building assemblies generally takes place by any of four moisture transport mechanisms: liquid flow, capillarity, convection or diffusion. Liquid flow and capillarity into the building envelope occur primarily with exterior source moisture such as rainwater and groundwater, whereas movement of moisture into the building envelope by diffusion or air movement can occur with interior or exterior source moisture.

Liquid flow is the movement of water under the influence of a driving force (such as gravity,

or suction caused by air pressure differences).

Capillarity is the movement of liquid water in porous materials resulting from surface tension forces. Capillarity, or capillary suction, can also occur in the small space created between two materials.

Air movement refers to the movement of water vapour resulting from air flow through spaces and materials.

Diffusion is the movement of water vapour resulting from a vapour pressure difference.

Of the four transport mechanisms, liquid flow and capillarity are the most significant. Thus, it is not surprising that rain penetration and groundwater control has been the primary focus of builders and designers for generations. Air movement and vapour diffusion are important, though less significant and obvious contributors to moisture problems.

Exposure

The design of building envelope assemblies must be based on an evaluation of the probable exposure to moisture. More protective designs are required in high exposure regions. For exterior walls, design exposure and

moisture load is primarily a function of three conditions:

1. Macro-climate: regional climate norms,
2. Micro-climate: site-specific factors such as siting, solar exposure, wind exposure, relationship to surrounding buildings, vegetation, and terrain, and
3. Building design: protective features such as overhangs and cornices.

The levels of exposure can vary significantly on a single building, and the design of exterior wall assemblies can reflect these differences. Because moisture exposure is so complex, however, it is preferable to measure it in terms of the climate alone; i.e., separately from the building.

A simple way to characterize the degree of exposure in different climates is through rain exposure zones. Average annual rainfall data is readily available and has been used to define exposure

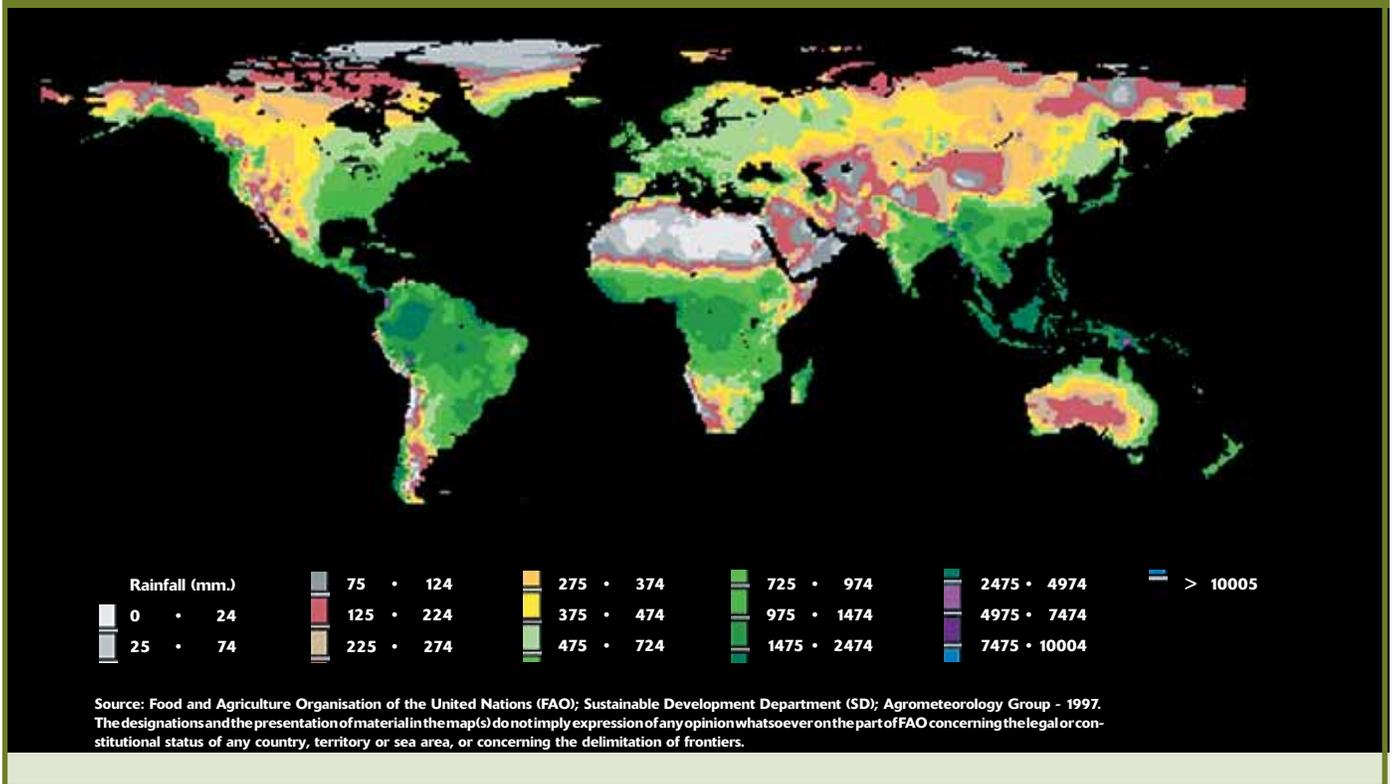
classes in many regions (see Figure 3). However, this approach has limitations in that some regions have long periods of wind-driven rain with little drying, while other regions have short periods of vertical rain followed by long drying periods. The approach can be improved by also considering wind effects, which often increase the moisture load.

Other more detailed methods of determining the degree of exposure, such as developed by

building scientist Joseph Lstiburek and others; consider rain, temperature, humidity, and the interior climate. Together, these factors define the environmental load acting on the building envelope, and provide the designer with the necessary criteria for wall type selection.

Overall, as the exposure level increases, adequate moisture control strategies must be selected to ensure ideal performance of the building envelope assembly.

FIGURE 3: Annual Average Rainfall Total (mm)



Moisture Design for Wood-Frame Buildings

The moisture sources and transport mechanisms that impact buildings are numerous and complex. Control strategies must be developed to effectively deal with each of these sources and mechanisms.

A number of recent studies have concluded that the primary failure mechanism with respect to moisture is rainwater penetration through exterior walls. Development of strategies for rain penetration control is the first priority in design for durability.

Rain Penetration Control

There are two general strategies for rain penetration control:

- Minimize the amount of rainwater contacting the building surfaces and assemblies, and
- Manage the rainwater deposited on or within assemblies.

The dynamics of rainwater penetration are well established. Water penetration through a building assembly is possible only when three conditions occur simultaneously:

1. An opening or hole is present in the assembly,

2. Water is present near the opening, and

3. A force occurs to move the water through the opening.

The minimum size of opening which will allow water penetration varies in relation to the force driving the water.

To control water penetration, it is necessary to understand the underlying driving forces that may be present. These can include gravity, surface tension, capillary suction, momentum, (kinetic energy) and air pressure differences (see Figure 4).

(kinetic energy) and air pressure differences (see Figure 4).

It follows that water penetration can be controlled by eliminating any of the three conditions necessary for penetration. Building design and detailing strategies can be developed that:

- Reduce the number and size of openings in the assembly,
- Keep water away from any openings, and
- Minimize or eliminate any forces that can move water through openings.

FIGURE 4: Main Driving Forces for Rainwater Penetration

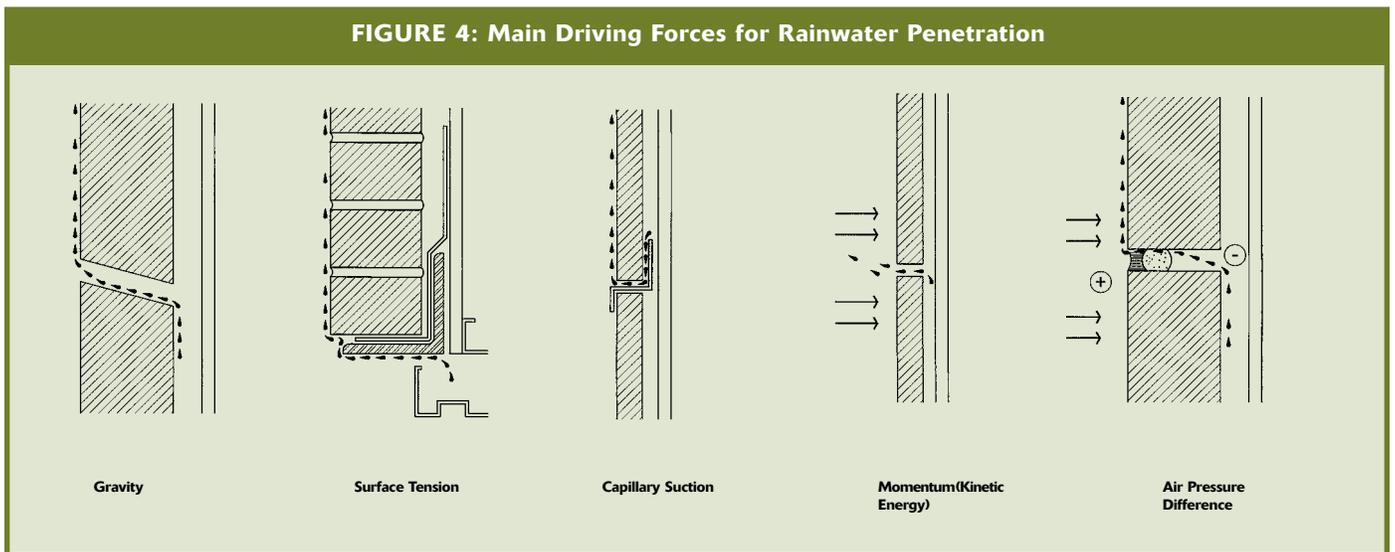
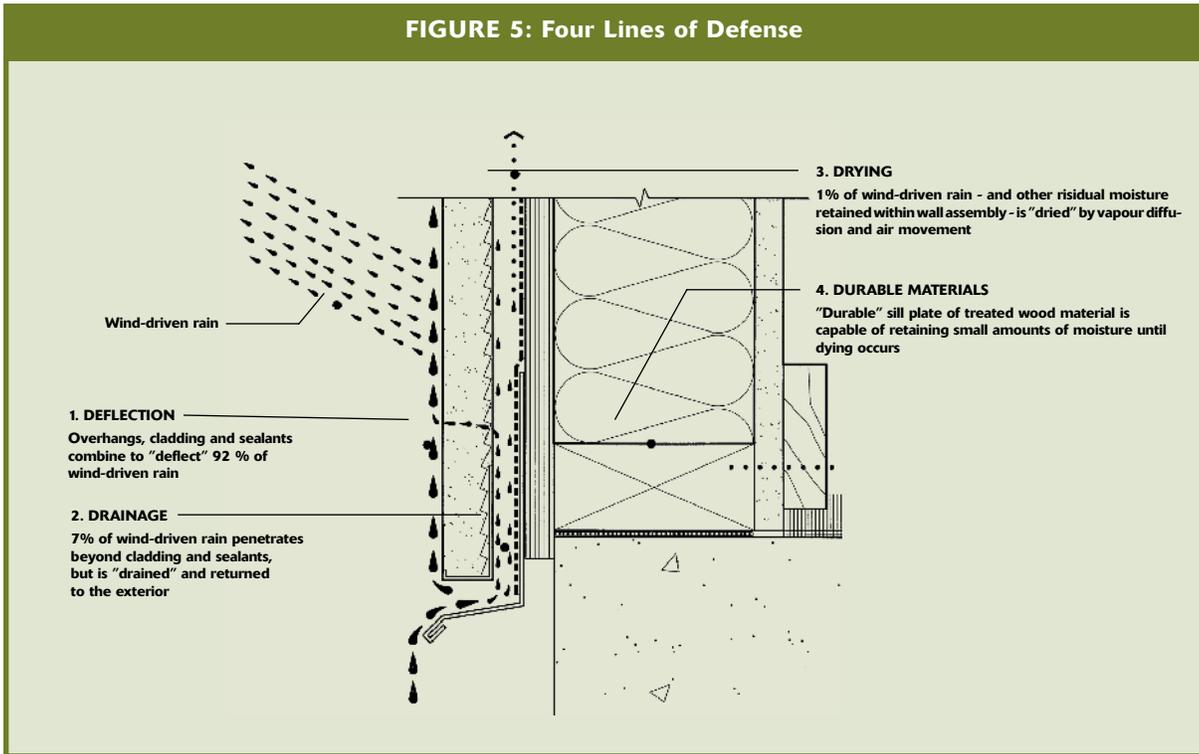


FIGURE 5: Four Lines of Defense



The 4Ds

These general water management strategies have been further articulated into a set of design principles called the 4Ds: deflection, drainage, drying and durable materials (see Figure 5).

With respect to rain penetration control, deflection refers to design elements and details that deflect rain from the building minimizing rainwater loads on the building envelope. Drainage, drying and durable materials are principles that

deal with the management of water once it has reached or penetrated the envelope.

These principles can be applied to design at two distinct scales. At the macroscale, there are design patterns that involve the manipulation of building and roof form, massing, siting, material expression and even issues of style. At the microscale, there are detail patterns, which determine whether water management works or does not work. Detail patterns involve the relationships between materials, installation

sequencing, constructability and economy of means. Many of these patterns, developed empirically by trial and error, have been used by builders for centuries, whereas others have been developed more recently as a result of scientific research and testing. The principles are also applied to material selection.

In most exposures, effective rain-water management is accommodated by multiple lines of defense. This is often referred to as redundancy. The concept of redundancy involves recognizing

the inherent limitations of the design and construction processes. Perfection is not easily achieved and errors in design and construction do occur.

Where the degree of moisture hazard is high, these errors may have significant impacts on the envelope performance. Redundant systems provide for back-up protection, in the likely event errors are made. The 4Ds can be understood as four separate lines of defense against rain penetration and the problems that can result.

Deflection

Deflection is the first principle and main priority of water management. The intent is to keep rainwater away from the building facade and to minimize the potential for water penetration into the envelope. The deflection principle is evident in many building design patterns that have historically proven effective at reducing the amount of rainwater on exterior walls.

These include the following examples:

1. Placing the building so it is sheltered from prevailing winds,
2. Providing sizable roof overhangs and water collection

devices at the tops of exterior walls, and

3. Providing architectural detailing that sheds rainwater. A pitched roof with sufficiently wide overhangs is the singular design element that can help ensure the long-term durability of wood-frame buildings in high-hazard moisture areas (see Figure 6). Deflection is applied at the smaller scale in detail patterns such as projecting sills, flashings and drip edges. Cladding and sealants are also considered to be part of the deflection line of defense. A water management strategy that relies only on deflection may be at risk in regions of the world where the hazard condition is high.

PHOTO 5: Girvin Cabin – This wood-frame studio and house located on Decatur Island, Washington uses pronounced overhangs that are both functional by deflecting rainwater from a window wall and architectural to suit the surrounding environment.

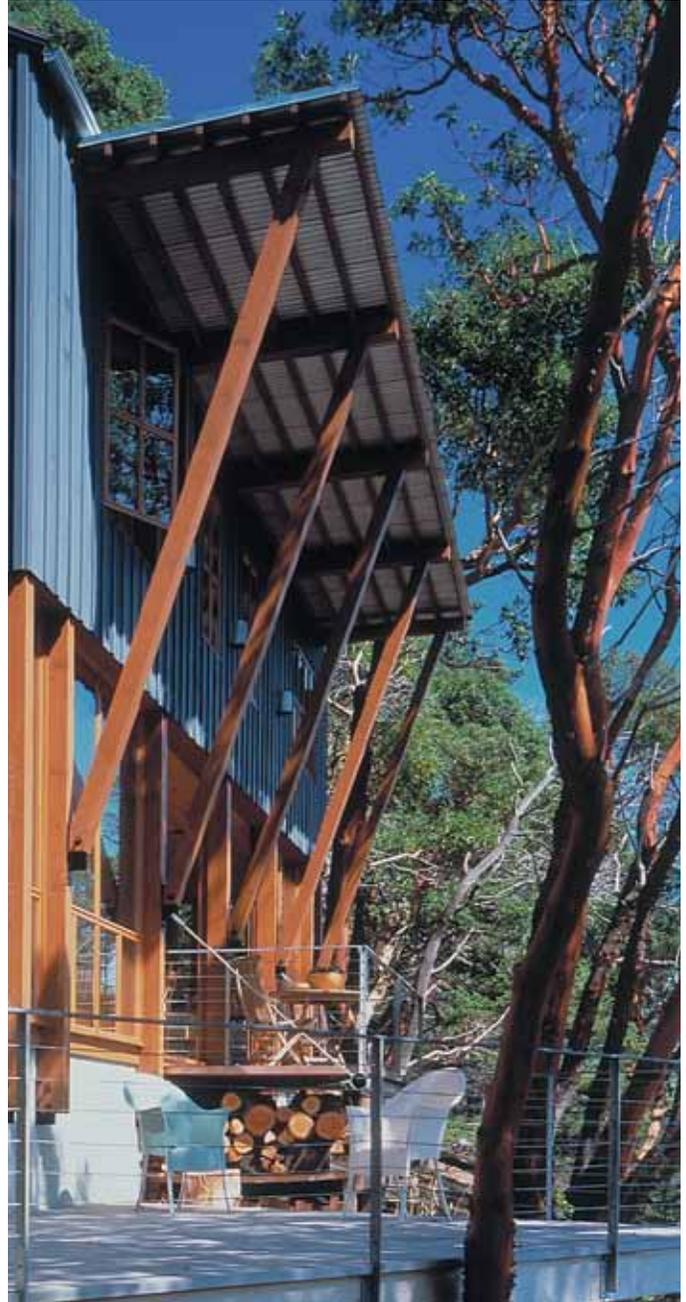
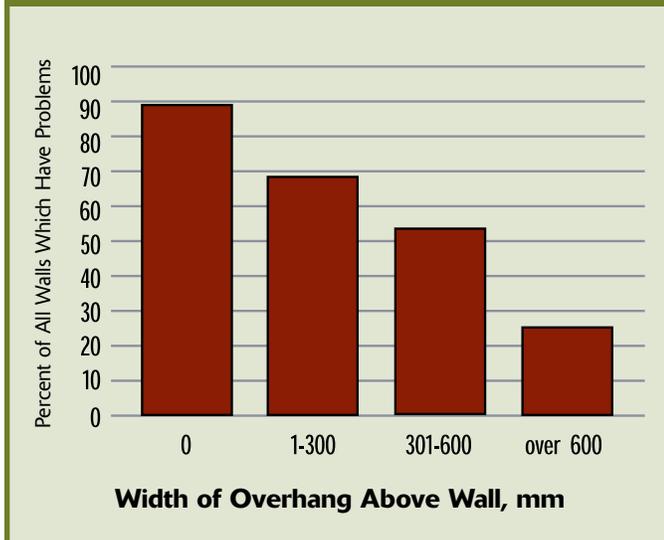


FIGURE 6: Effect of Overhangs on Wall Performance



Drainage

Drainage is the next principle of rain penetration control, second only to deflection in terms of its capacity to manage rainwater. Building design patterns that incorporate the drainage principle include pitched roofs and sloped surfaces at horizontal elements.

At the detail level, drainage is accomplished by collecting incidental moisture accumulation in the wall assembly and returning it to, or beyond, the exterior face of the cladding

by means of gravity flow. In its simplest form, this is achieved by adding a drainage plane within the assembly, between the cladding and the sheathing. In wood-frame construction, the drainage plane typically consists of a moisture barrier (building paper, felt, or housewrap), and most importantly how they work in combination with window and door flashings. Drainage is generally the primary means of providing redundancy in a wall assembly.

A drainage cavity is a more elaborate feature that introduces an airspace between the cladding and the drainage plane/sheathing. The airspace serves as a capillary break to prevent water from excessively wetting the drainage plane. In addition, the airspace, particularly when it provides a pressure-equalization function, can also be seen as another means of deflection, in that pressure-equalization neutralizes the primary driving force behind rain penetration (air pressure differential), and thereby reduces

the amount of moisture being driven through the cladding into the drainage cavity.

Drying

Drying is the mechanism by which wall assemblies remove moisture accumulations by venting (air movement) and vapour diffusion. The drying potential of both the cladding and the wall sheathing/framing must be considered. Cavities introduced for drainage purposes also offer a means to dry the



PHOTO 6: Cross cavity flashing at the floor line joint helps to return moisture to the exterior.

cladding material by back venting. Drying of sheathing and framing is often a separate matter and is greatly affected by the selection of moisture barrier and vapour barrier materials. Exterior wall assemblies must be designed to allow sufficient drying to either the exterior or the interior. The permeability of cladding, moisture barrier, vapour barrier and interior finish materials will greatly affect the overall drying potential of the wall. This is an area currently under study by researchers.

Durable Materials

Durable materials must be selected for use at all locations where moisture tolerance is required. Where deflection, drainage and drying cannot effectively maintain the moisture content of wood components below 20%, the decay resistance of the wood must be enhanced. For wood framing components, this is achieved by pressure treatment with wood preservatives. The use of treated wood where sill plates are in contact with

concrete foundations is a common detail pattern that follows this principle.

Building design patterns involving architectural expression should be reconciled with long-term durability considerations. Weathering properties and maintenance requirements should be considered. For example, face brick applied to wood-frame walls must be rated for exposure, and masonry wall ties must be sufficiently corrosion-resistant. Wood siding and trim with

direct exposure to weather should be either naturally decay-resistant or treated wood materials.



PHOTO 7: The Windgate townhouses near Choklit park in Vancouver, BC use decorative exterior fascia boards at the floor level, combined with sloping roofs and overhangs as part of a moisture management strategy.

Rainwater Management Strategies for Exterior Walls

There are three basic exterior wall type options for wood-frame buildings, each based on a distinct conceptual strategy for rainwater management: face seal, concealed barrier and rainscreen. When designing exterior walls for a given building, there is a need to select an appropriate system and be consistent through the design and detailing phase and to clearly communicate the details of the system to the construction team (see Table 1).

Putting it All Together

Face seal walls are designed to achieve water tightness and air tightness at the face of the cladding (see Figure 7). Joints in the cladding and interfaces with other wall components are sealed to provide continuity. The exterior face of the cladding is the primary – and only – drainage path. There is no redundancy. The “face seal” must be constructed – and must be maintained – in perfect condition to effectively provide rain penetration control. However, such reliance on perfection is questionable at walls exposed to rainwater. As a rule, face seal walls should only be used where

very limited amounts of water will reach the cladding surface, such as wall areas under deep overhangs or soffits or in regions where the degree of moisture hazard is not high.

Concealed barrier walls are designed with an acceptance that some water may pass beyond the face of the cladding (see Figure 8). These walls incorporate a drainage plane within the wall assembly, as a second line of defense against rain penetration. The face of the cladding remains the primary drainage path, but secondary drainage is accomplished within the wall. An example of a concealed barrier wall is wood siding installed directly over an asphalt-saturated

felt moisture barrier and plywood sheathing. The water-resistant felt constitutes the drainage plane. Vinyl siding and drainage EIFS (exterior insulated finish system) installed over a moisture barrier should also be considered concealed barrier walls, although drainage in these cladding systems is enhanced by provision of some airspace – however discontinuous – behind the cladding. A concealed barrier strategy is appropriate for use on many exterior walls and can be expected to perform well in areas of low to moderate exposure to rain and wind. Performance in high to severe exposure conditions, however, is not assured. In all cases, the integrity of the second line of defense is highly

TABLE 1: Performance Expectations for Exterior Wall and Window Moisture Control Strategies

Exposure Level	Face Seal	Concealed Barrier	Rainscreen	Pressure Equalized Rainscreen
High	Poor	Poor	Fair	Good
Medium	Poor	Poor	Good	Good
Low	Fair	Good	Good	Good
None	Good	Good	Good	Good

Source: Best Practices Guide for Wood-Frame Envelopes in the Coastal Climate of British Columbia – Canada Mortgage & Housing Corporation, www.cmhc-schl.gc.ca

dependent on correct detailing by the designer and proper installation by the builder. To maximize performance and service life of the assembly in high exposure conditions, consideration should be given to the use of a rainscreen assembly.

Rainscreen walls take water management one step further by incorporating a drainage cavity (9.5 mm minimum width) into the assembly, between the back of the cladding and the building paper (see Figure 9). The drainage cavity offers enhanced protection from water intrusion by acting as a capillary break, thereby keeping most water from making contact with the moisture barrier. The airspace also serves to ventilate the backside of the cladding, which facilitates drying of the cladding, and mitigates against potential moisture accumulation in the wall framing caused by reverse vapour drive. Examples of rainscreen walls include brick veneer (usually installed with a one or two-inch airspace) and stucco cladding installed over vertical strapping (typically pressure-treated 19 x 64 mm at 400 mm on center). Rainscreen walls are appropriate for use in all locations where high exposure to rain and wind is likely.

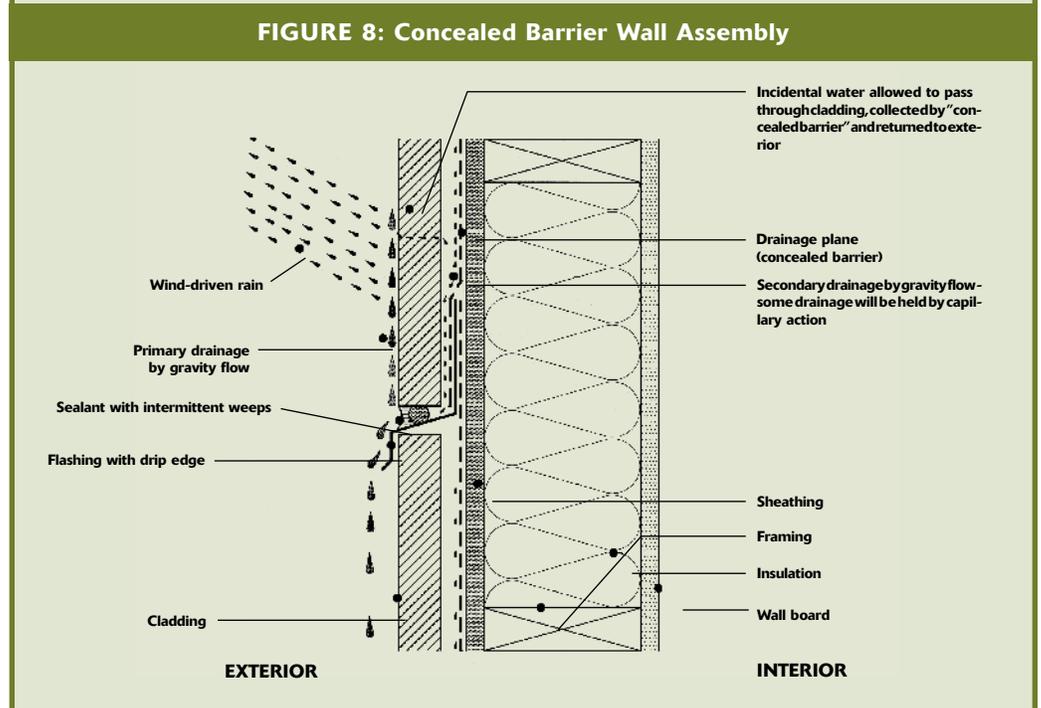
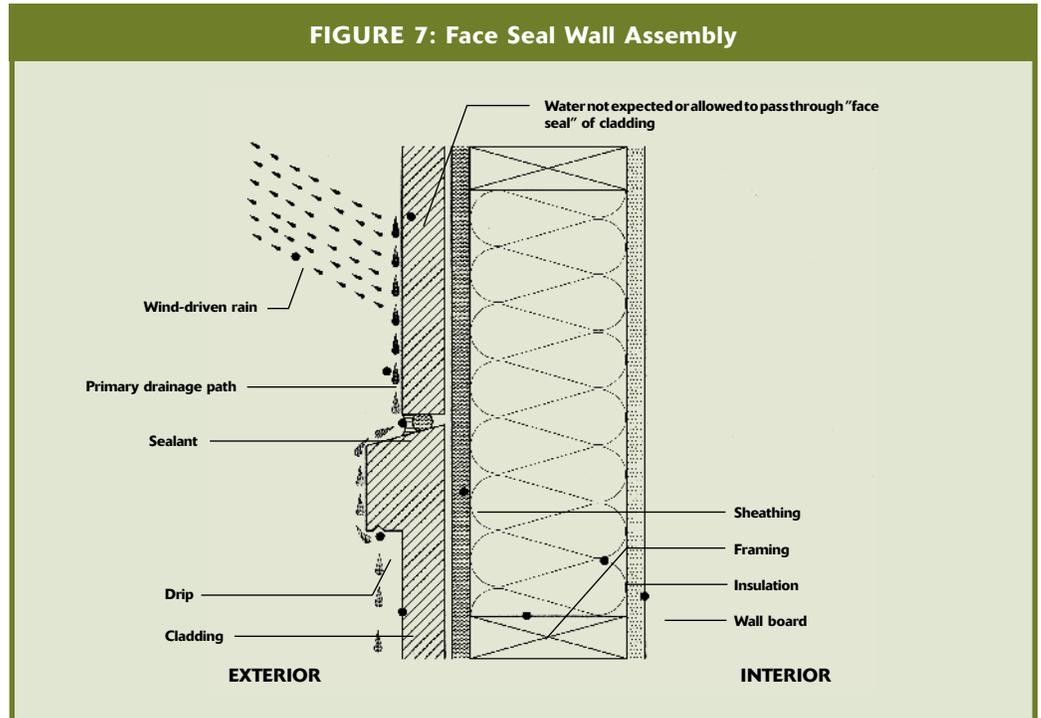


FIGURE 9: Rainscreen Wall Assembly

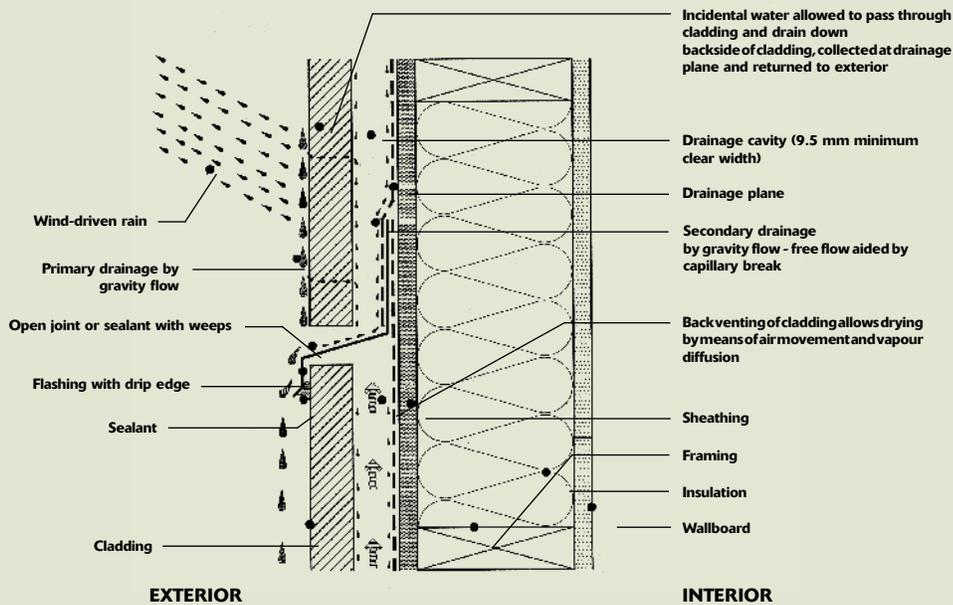
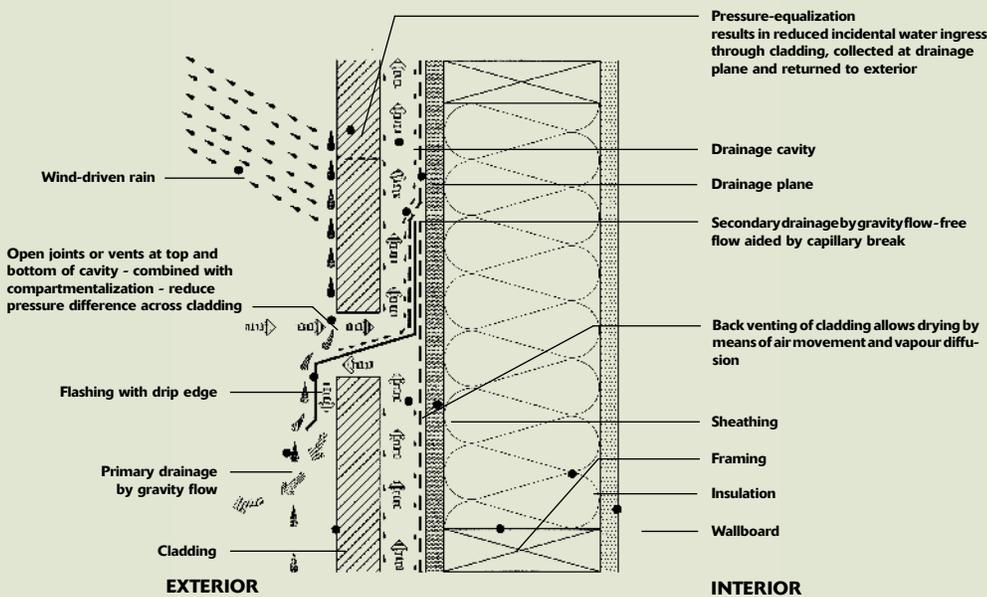


FIGURE 10: Pressure Equalizer Rainscreen Wall



Pressure-equalized rainscreens

represent an advancement of the basic rainscreen strategy (see Figure 10). These walls incorporate compartmentalization and increased venting of the drainage cavity to improve performance. As wind blows on a wall face, air passes through vents into the cavity behind the cladding. If this air is contained appropriately by subdividing the drainage cavity with compartment seals, an equalization of pressure occurs across the cladding, thereby eliminating one of the key driving forces behind water penetration. This strategy is most commonly applied to brick veneer walls, though conceptually it is possible to enhance any rainscreen assembly with this technology. Pressure-equalized rainscreens are appropriate for use on all exposures and offer the highest performance potential with respect to water management.

Quality Assurance

Long-term durability is a function of the quality of design, construction, operation and maintenance of a building. To achieve durability, quality assurance is essential at every stage in the life of the building.

Quality assurance is defined as all those planned and systematic actions needed to confirm that products and services will satisfy specified requirements. A fundamental principle of quality assurance is that all persons accept responsibility for the

standard of their own work. In order to avoid durability problems, adequate and coordinated quality control obligations should be imposed upon all persons involved and during all phases in the process of defining, planning, building,

operating and maintaining the structure until the end of its service life (see Table 2).

In Canada for example, the Canadian Standards Association (CSA) S478-95 – Guideline on Durability in Buildings, published

TABLE 2: Quality Assurance and the Building Process

Stage Building Life Cycle	Quality Assurance Activity
Conception	<ul style="list-style-type: none"> • establish appropriate levels of performance for building and components
Design - detail - specify	<ul style="list-style-type: none"> • prescribe performance criteria for materials, components, and assemblies • confirm acceptability and achievability of performance • specify test options (prototype, in situ, etc)
Tendering	<ul style="list-style-type: none"> • review design documents, including performance specifications • accept requirements (contractor) • accept tender(s) (owner)
Construction	<ul style="list-style-type: none"> • control through <ul style="list-style-type: none"> - review of process and product - sampling and testing - correction of deficiencies - certification of work
Handover	<ul style="list-style-type: none"> • commissioning <ul style="list-style-type: none"> - verification of performance of completed building by testing under operational loads
Operation and Maintenance	<ul style="list-style-type: none"> • monitor performance • inspect for deterioration or distress • investigate problems • certify work
Renovation	<ul style="list-style-type: none"> • same as for Conception and Design, above

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in 1995, contains an extensive outline of quality assurance procedures for building design, construction, operation and maintenance. Other standards organizations, including the International Organization for Standardization (ISO) and the American Society for Testing and Materials (ASTM), are also beginning to address durability issues in their standards.

Construction Quality Control

Proper design alone will not ensure the delivery of a durable building to the owner. Therefore, the construction process must follow through with the design intent. This begins in the design phase with construction documentation.

The design of the building envelope should be clearly communicated to the entire construction team. The various moisture control strategies should be communicated, perhaps as a narrative description and concept drawing on the cover sheet of the drawings. Critical details, including both typical and non-typical conditions, should be provided to installers.

Details should be adequately considered with respect to constructability and the overall water

management strategy of the wall. Large-scale drawings, and in some cases three-dimensional drawings, are needed to visibly indicate the relationships of various components in the assembly. In particular, the drainage plane (moisture barrier and flashings) must be clearly articulated in the detailing. If the design intent and assumptions are not clearly articulated, it is quite possible that installers will misinterpret the details during construction.

The builder should develop a rigorous set of procedures for quality control during construction. Coordination of the work is essential to ensure long-term performance, particularly with the building envelope, where many different trades must interface. Submittals, shop drawings and pre-installation meetings are all tools that should be used during the construction phase to clarify, refine and verify the design.

Mock-ups are another useful tool, allowing the designer and builder to work with the various trades involved in the building envelope construction and resolve issues related to constructability and sequencing. Once tested and approved, mock-ups can be used to establish a visible and tangible standard for the work that follows.

Material Handling

Control of moisture during construction is also important. Even when dry lumber is purchased and delivered to the jobsite, it can be wetted prior to or during construction. Procedures should be developed to:

- Keep wood-based materials dry while in storage onsite,

- Minimize wetting of installed materials, and

- Promote drying of materials with venting, heating or dehumidification.

Wood materials that are exposed to wetting should be dried to 19% moisture content or less prior to enclosure within assemblies. On buildings that are exposed to significant

PHOTO 8: Overhangs protect end-grain of beams from moisture.



Conclusion

wetting during construction, schedules should provide an allowance for proper drying to framing and sheathing materials. Moisture barriers, installed soon after assemblies are framed, can be used to minimize exposure to weather. Mechanical measures, such as provision of artificial heat and/or dehumidification, can be utilized to speed the drying process.

Wood-frame buildings have an established record of long-term durability. Wood will continue to be the material of choice due to its environmental advantages, ease of use and cost competitiveness. With the correct application of building envelope design principles, all materials can perform well with regards to durability.

The imperative for durable construction goes beyond creating healthy buildings as we must build durably to minimize the environmental impacts of our society. In fact, wood buildings perform well against other materials when considered from a life cycle cost perspective that factors things like greenhouse gas emissions, water pollution index, energy use, solid waste

and ecological resource use. However, the environmental advantages of wood can only be achieved if the building is designed and constructed for long-term durability.

With passion and eloquence, the architect James Cutler has spoken of “honouring the wood” through the building design and detailing process. This would include the concept of protecting wood from moisture, which is the essence of designing for durability.

Credits

Front cover

Architect – CBT Architects
Photographer – Edward Jacoby

Photo 1:
Photographer- Klaus Brinkmann

Photo 2:
Designer – William Hughes
Photographer - Environment Canada

Photo3:
Developer – Polygon Lanesborough Development Ltd.
Architect – Neate Staniszki Doll Adams Architects
Building Envelope Engineer – Morrison Hershfield Ltd.

Photo 4:
Introduction to Wood Building Technology – Canadian Wood Council

Photo 5:
Architect – Miller / Hull Partnership
Photographer – Michael Skott

Photo 6:
Wood Design & Building magazine, Summer 2000

Photo 7:
Architect – Nancy Mackin Architecture
Photographer – Anthony Redpath & Peter Powles

Photo 8:
Architect – James Cutler
Photographer – Art Grice

Figure 1:
Wood Reference Handbook – Canadian Wood Council

Figure 6:
Survey of Building Envelope Failures in the Coastal Climate of British Columbia – Canada Mortgage & Housing Corporation, www.cmhc-schl.gc.ca



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