



# BUILDING ENVELOPE REHABILITATION

CONSULTANT'S GUIDE



HOME TO CANADIANS  
Canada

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# Building Envelope Rehabilitation

## Consultant's guide

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# Foreword

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The Building Envelope Research Consortium (BERC) was instrumental in providing overall direction and guidance for this book.

BERC is made up of representatives of a wide cross-section of the building construction community in British Columbia, including architecture and engineering associations, research organizations, federal, provincial and municipal governments, developers, contractors and building product manufacturers' associations.

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# Abbreviations and glossary

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Abbreviations and definitions of terms used in this *Guide*.

## ACEC

Association of Consulting Engineers of Canada

## Addendum

A change to the bid package (usually a modification of the drawings and specifications) issued during the bid period and before execution of the contract.

## Air barrier

Materials and components that together control the flow of air through an assembly and thus limit the potential for heat loss and condensation due to air movement.

## AIBC

Architectural Institute of B.C.

## APEGBC

Association of Professional Engineers and Geoscientists of B.C.

## Assembly

The collective layers of components and materials that together comprise the complete, cross-section of the wall or roof.

## ASTM

American Society for Testing and Materials.  
The ASTM website is: <http://www.astm.org/>

## B.C. BC

British Columbia Building Code 1998

## Balcony

A horizontal surface exposed to outdoors and intended for pedestrian use, but projected from the building so that it is not located over a living space or acting as a roof.

## Barrett Commission

A commission of inquiry into the quality of residential construction. Led by former B.C. premier Dave Barrett, the commission was established in April 1998. The Barrett Report recommended action by all three levels of government, the building industry and various professions to strengthen consumer protection and restore confidence in the residential construction industry.

## Base flashing

The part of the roofing that is turned up at the intersection of a roof with a wall or another roof penetration. It may be made of the same material as the main roofing membrane or of a compatible material.

## BEP

Building Envelope Professional. The Building Envelope Professional reviews the building envelope design and reports to the project architect or co-ordinating registered professional with respect to environmental separation and the performance of materials, components and assemblies of the building envelope. For more detail about the BEP's role, see Appendix A.

## Bid

An offer made by the contractor to enter an agreement with the owner for a price indicated on the bid form and forms a bid contract until the period for acceptance is over.

## Bond

A financial security for the performance of an obligation; usually a written document supported by a pledge of collateral.

## Building envelope

Now called an environmental separator in building codes, the building envelope is the parts of the building that separate inside, conditioned space from unconditioned or outside space, such as windows, doors, walls, roofs and foundations.

## Cap flashing

Sheds water from the tops of walls. Cap flashing must be sloped toward the roof to prevent staining of the exterior cladding. It is difficult to make cap flashing waterproof at the joints and intersections and it requires a continuous and waterproof membrane below it.

## CCAC

Committee of Canadian Architectural Councils

## CCDC

Canadian Construction Documents Committee

**Cladding**

A material or component of the wall assembly that forms the outer surface of the wall and is exposed to the full force of the environment.

**Concealed barrier**

A strategy for rain penetration control that relies on the combination of the cladding as well as a moisture barrier (sheathing paper or membrane) located further into the assembly to limit water ingress.

**Co-ordinating Registered Professional (CRP)**

A co-ordinating registered professional is a registered professional who co-ordinates all design work and field reviews of the registered professionals required for a building project. The British Columbia Building Code (B.C.BC), 1998, requires the owner of a building to retain a co-ordinating registered professional before obtaining a building permit.

**Counter flashing**

Prevents water from penetrating behind the top edge of base flashing. Counter flashing consists of a separate piece of flashing placed over the top of the base flashing. It is usually made of sheet metal.

**Cross-cavity flashing**

Intercepts and directs any water flowing down the cavity of a wall assembly to the exterior.

**Deck**

A horizontal surface exposed to the outdoors, located over a living space and intended for pedestrian use in addition to performing the function of a roof.

**Deflection**

A water management principle that uses features of the building and assembly geometry to limit the exposure of the assemblies to rain.

**Drainage**

A water management principle that uses surfaces of the assemblies to drain water away from the assembly.

**Drip flashing**

Directs water flowing down the face of vertical elements, such as walls or windows, away from the surface so that it does not continue to run down the surface below the element.

**Drying**

A water management principle that incorporates features and materials that facilitate diffusion and evaporation of moisture from materials that get wet.

**Durability**

The ability of a material, components, assembly or building to perform its required functions in its service environment over a period of time without unforeseen maintenance, repair or renewal.

**Envelope**

An environmental separator, generally between the inside and the outside of a building (including the ground), but also between dissimilar environments within the building.

**Face seal**

A strategy for rain penetration control that relies solely on the elimination of holes in the exposed exterior face of the assembly.

**Field applied preservatives**

Wood preservatives commonly applied at the job site using brush, spray, roller or other non-pressure method for protection against wood decay.

**Flashing**

Materials used to deflect water make water proof connections and protect underlying membranes from physical damage.

**FSR**

Floor-Space Ratio. Determined by dividing the gross, or total, floor area by the lot area.

**Housewrap**

A sheet-plastic material, which is used as a breather-type sheathing membrane, generally between the wall sheathing material and the exterior cladding. At one time a proprietary term, housewrap now represents a generic group of materials. One common housewrap is made of spun-bonded polyolefin (SBPO), another of perforated polyethylene.

**HPO**

The Homeowner Protection Office. The HPO is a provincial Crown corporation formed in response to the recommendations of the Barrett Commission

report on the quality of condominium construction in British Columbia. The HPO was created under the Homeowner Protection Act, passed on July 28, 1998. The HPO officially opened Oct. 1, 1998.

The HPO is responsible for:

- Residential builder licensing.
- Establishing the framework for and monitoring the provision of mandatory third-party home warranty insurance.
- Administering a no-interest repair loan program and PST Relief Grant for owners of leaky homes.
- Research and education to benefit the residential construction industry and consumers.

**Maintenance**

A regular process of inspection, minor repairs and replacement of components of the building envelope to maintain a desired level of performance for the intended service life without unforeseen renewal activities.

**Moisture content**

The weight of water contained in the wood. It is expressed as a percentage of the weight of oven-dry wood.

**Movement joint**

A joint on a wall, which provides capability for differential movement of portions of the building structure (expansion joint) or prevents or localizes cracking of brittle materials such as stucco (control joint).

**Operation**

Of the building or envelope. Refers to normal occupancy of the building where the envelope is affected by interior space conditioning, changes to light fixtures, signs, vegetation and planters and accidental damage or vandalism.

**Penetration**

An intentional opening through an assembly through which ducts, electrical wires, pipes and fasteners are run between inside and outside.

**Pressure treatment**

The injection of wood preservatives into the wood at high pressure for protection against wood decay and termite attack.

**Quantity surveyor**

A quantity surveyor calculates the amount and cost of materials and labour needed for a building project and oversees financial contract administration during the project. A quantity surveyor can work for a contractor or for the client.

**Rainscreen**

A strategy for rain penetration control. It relies on deflecting most of the water at the cladding, a cavity that provides a drainage path for water that penetrates past the cladding and airtightness, which limits pressure differentials across the cladding, with the assembly to the interior of the cavity.

**Rehabilitate**

A program of comprehensive, overall improvements to building envelope assemblies and details so the building can fulfil its originally intended functions.

**Renewals**

Activities associated with the expected replacement of worn out components or materials of a building envelope and are typically for items with life cycles in excess of one year.

**Repair**

Replacement or reconstruction of envelope assemblies, components or materials at specific localized areas of the building envelope so that it can fulfil its originally intended functions.

**RFP**

A Request for Proposals (RFP) is a document defining the objectives for a project and asking for an anticipated scope of services, a list of staff who will be assigned to the project, a list of references, a schedule for carrying out the work and fee proposal.

**Saddle**

The junction of small horizontal surfaces, such as the top of a balcony guardrail or parapet wall, with a vertical surface, such as a wall.

**Service life**

The actual period during which building envelope materials, components and assemblies perform without unforeseen maintenance and renewals costs.

**Sheathing**

Materials, generally oriented strand board (OSB) or plywood, used to provide structural stiffness to the wall framing and to provide structural backing for the cladding and sheathing paper.

**Sheathing membrane**

A material in an exterior wall assembly intended to provide a water-shedding surface. This material limits penetration of water further into the structure once past the cladding. Waterproof-type sheathing membranes can also act as an air barrier and a vapour barrier. Materials include both breather-type sheathing membranes, such as sheathing paper and housewraps, and waterproof-sheathing membranes.

**Sheathing paper**

Asphalt-impregnated organic sheet material (breather-type sheathing membrane) that creates a water-shedding surface behind the cladding.

**Stepped flashing**

Is installed at the junction between a sloping roof and a wall running parallel to the slope. Both base and counter-flashing are overlapped and installed in pieces following the slope to form the complete stepped flashing.

**Strapping**

Vertically oriented lumber (usually pressure treated 1 x 2s or strips of pressure-treated plywood) that form the cavity between the cladding and the sheathing paper in a strapped cavity rainscreen wall assembly.

**Strata corporation**

Similar to a condominium corporation. The Strata Property Act replaced the Condominium Act of B.C. in 1999. The strata corporation has a legal obligation to repair and maintain the common property, common facilities and assets of the strata corporation.

**Strata council**

A group of owners elected to carry out the duties of the strata corporation.

**System**

Describes a combination of materials and components that perform a particular function, such as an air-barrier system or moisture-barrier system.

**Through-wall flashing**

A waterproof membrane or metal flashing placed under segmented precast concrete, stone masonry or brick units—known as copings—close to the tops of masonry walls to prevent water from entering the wall at joints in the coping. Through-wall flashing is also used to prevent capillary transfer of moisture through porous materials, such as concrete or masonry, if they extend from high-moisture locations, such as below grade.

**Valley flashing**

Installed in the valleys of sloping shingle roofs to give continuity to the roofing system.

**Vapour barrier (also vapour diffusion retarder)**

A material with low-vapour permeability, located within the assembly to control the flow of vapour through the wall assembly and limit the potential for condensation due to diffusion.

**Walkway**

A corridor exposed to outdoors that provides pedestrian access between suites and stairwells or elevators. It may or may not also be a roof.

**Warranty**

An agreement that provides assurance by a warranty provider (insurance program or contractor) to the owner that the warrantor will assume stipulated responsibilities for correction of defects and failure to meet specific performance criteria within a stated period.

# Chapter I—Introduction

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# Chapter I—Introduction

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## 1.1 Background

The *Survey of Envelope Failures in the Coastal Climate of British Columbia* (the *Survey*) identified the cause of the problems and created a focus for the development of solutions. The *Best Practice Guide—Wood-Frame Envelopes in the Coastal Climate of British Columbia* provides much-needed design and construction guidance and will go a long way to eliminating problems in new construction.

However, there are still many moisture-troubled buildings that must be rehabilitated. The fact that some of these moisture-troubled buildings have been previously repaired and now require a second, more extensive rehabilitation underscores the need for a guide to effective repair and rehabilitation. Inconsistencies in the way consultants assess performance problems, make recommendations, detail and specify repairs and implement larger rehabilitation projects are other factors contributing to the need for this *Guide*.

Rehabilitation can be costly and cause great financial hardship for owners. This *Guide* establishes strategies and procedures for cost-effective rehabilitation of moisture-troubled buildings.

## 1.2 Other documents

The *Guide* reflects current best practice. It addresses the differences between new and rehabilitation construction, but is consistent with, and draws on, information in the *Best Practice Guide—Wood-Frame Envelopes in the Coastal Climate of British Columbia*, published by Canada Mortgage and Housing Corporation (CMHC) in 1999.

This *Guide* is one of three publications about repairing and rehabilitating wood-frame buildings in coastal B.C. The companion to this *Guide* *Building Envelope Rehabilitation — Owner–Property Manager Guide*—focuses less on technical detail and more on process and understanding technical concepts.

*Managing Major Repairs*, published jointly by CMHC, the Homeowner Protection Office (HPO) and B.C.'s Ministry of Municipal Affairs (now called the Ministry of Municipal Affairs and Housing), focuses on rehabilitation in the context of the strata corporation and legal issues. *Managing Major Repairs* also provides an overview of some technical aspects.

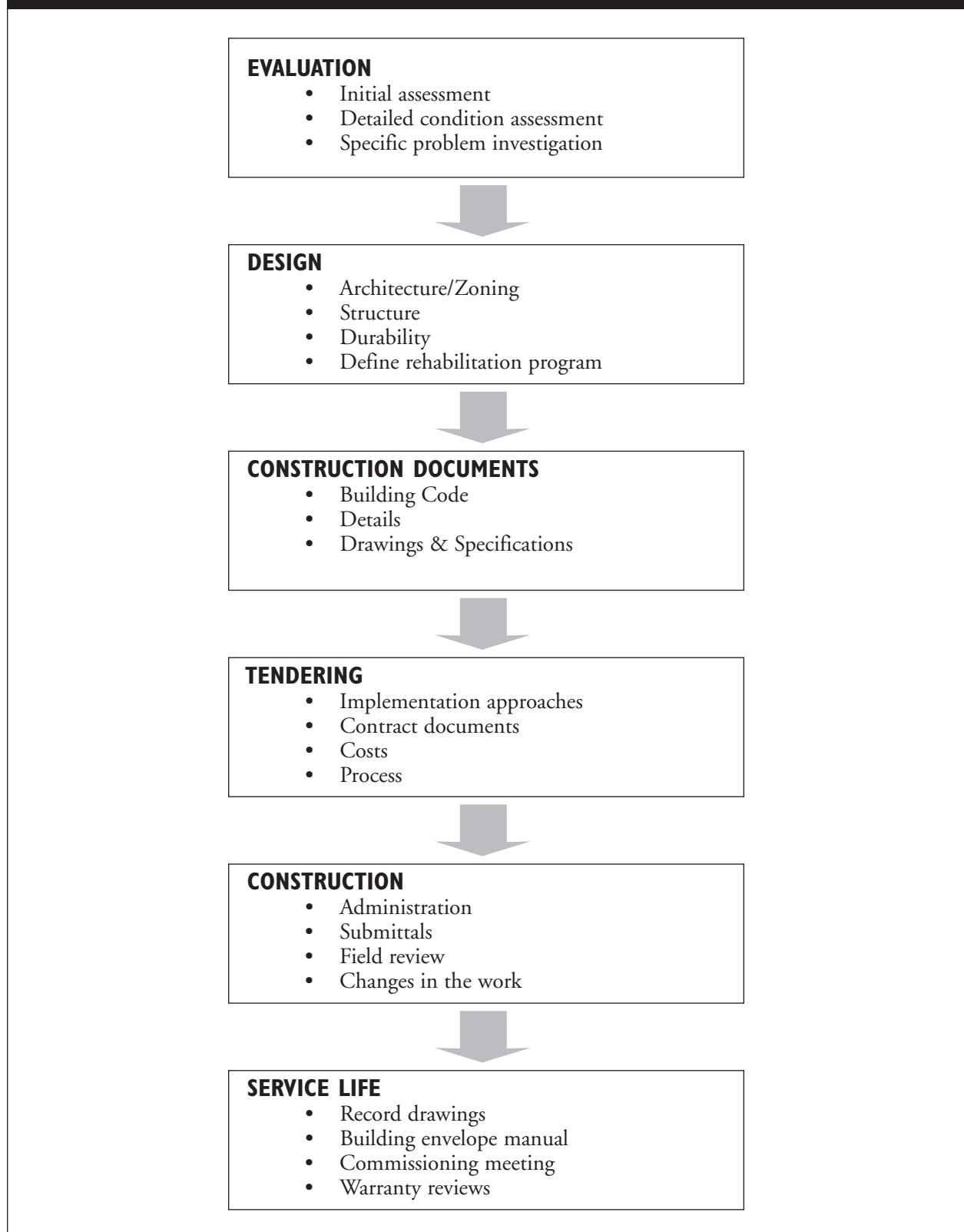
Another useful document is CMHC's *Quality by Design: A Quality Assurance Protocol for Wood-Frame Envelopes in British Columbia*. Published in 1999, it provides a series of guidelines, recommendations and templates for use throughout the design, construction and maintenance of new or rehabilitated wood-frame envelopes.

## 1.3 Rehabilitation

There are many stages in rehabilitating a wood-frame building and consultants and owners must make decisions at each stage. Because the building is usually occupied during rehabilitation, the process is more complicated in some ways than new construction. Figure 1-1 is a flow chart outlining the process and some of the tasks that could be involved at each stage. The organization of this *Guide* follows the flow chart.

It is important to recognize that consultants must assist owners through the entire process, not just at one stage. The consultant and consultant's team must reflect the particular physical needs of the building as well as the process for each stage. This may mean a different team of consultants at different stages.

**Figure I-1—Building envelope rehabilitation process**



## 1.4 Cost-effective

The context of the term "cost-effective" is key to decisions made with the assistance of this *Guide*. Does cost-effective mean cost-effective within a five-year warranty period or cost-effective in the life cycle of the building? The life-cycle context is most relevant to this *Guide*. It is not at odds with a phased approach to rehabilitation or strategies representing higher risk to building owners if these risks are understood and acknowledged.

The context for cost-effective is viewed differently by the many different stakeholders. In fact, even within a strata corporation owner group views are likely to differ depending on the individual owner's financial status and long-term interest in the building. These different perspectives include:

- A strata owner who is planning to sell as soon as possible.
- A strata owner who plans to be a long-term owner.
- The strata council in responding to corporation and director obligations under the *Strata Property Act* (1998) and the *Strata Property Amendment Act* (1999) and regulations to the acts.
- Lending institutions for first mortgages.
- Lending institutions or guarantors for second mortgages to finance rehabilitation.
- Parties involved in the original design and construction of the building who may be asked to contribute to the rehabilitation.
- The rehabilitation consultant and contractor and their exposure to risk of future failure.
- Future buyer of a strata unit.

Consultants must be able to present a range of alternatives to the owners with costs and performance risks for each alternative. Owners must make decisions about alternatives and consultants must help them understand the level of risk for each alternative. Owners must also understand that deciding to pursue a certain rehabilitation strategy is related to the value of their potential claims against parties involved in the original design and construction.

## 1.5 The Guide

The *Guide* is mainly guidance for consultants about repair and rehabilitation of building envelopes of multi-unit wood-frame buildings in the coastal climate zone of B.C. The terms "repair" and "rehabilitation" are interchangeable. In this *Guide* "repair" is replacement or reconstruction of envelope assemblies, components or materials at specific areas of the building envelope. "Rehabilitation" is comprehensive, overall improvement to building envelope assemblies and details. In both cases the intent is to improve the building envelope so that it can perform its originally intended functions.

The *Guide* may be useful to builders and other stakeholders, helping them to understand the consultant's role and tasks throughout rehabilitation.

Much of the material in the *Guide*, particularly process-related information, may apply to other climate zones and building types. However, some analysis of the impact of different climate factors and specific building attributes must be considered before using the *Guide*.

The *Guide* is intended to reflect good practice in general. Its primary focus is moisture management, but it also provides guidance to the structural and life-cycle safety issues inherent in rehabilitation.

The *Guide* reflects current recommended design and construction practice. There are certainly many aspects of the rehabilitation process and technology, which could benefit from further research and development efforts: that is not the purpose of this *Guide*.

The *Guide* does not replace professional advice. When this guidance is incorporated into buildings, it must be reviewed by knowledgeable consultants and reflect the specific unique conditions and design of each building. Use of the *Guide* does not relieve consultants of their responsibility to comply with local building codes, standards, bylaws and professional obligations.

# Chapter 2—Evaluation

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# Chapter 2—Evaluation

## 2.1 Introduction

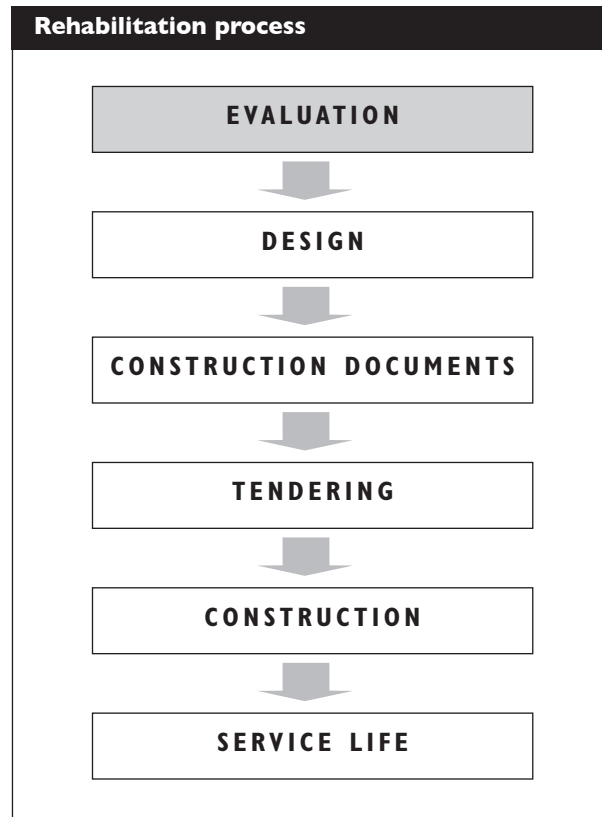
The suspicion of a moisture-related performance problem initiates an evaluation process that ultimately determines the scope of required repairs or rehabilitation. The consultant's main activities in the evaluation stage are:

- Contact with the owner to identify nature of the concern.
- Undertaking initial assessment to determine appropriate follow-up (condition assessment, specific problem investigation, or maintenance and renewal planning).
- Assessing conditions or investigating specific problems.
- Developing repair or rehabilitation recommendations (including alternatives, as appropriate) and cost estimates.
- Preparing maintenance and renewal plans.
- Presenting report(s) and recommendations to owners.

A call, or repeated calls, from occupants about moisture-related damage is usually the first sign of a possible building envelope problem. This usually initiates a process that begins with the assessment of the reported symptoms.

Is the symptom related to a readily identifiable moisture source that can be easily repaired or does it indicate a widespread, systemic problem with the building? If it is an isolated problem, then is the cause readily apparent or does it require further investigation before determining an appropriate course for repairs?

The answers to these questions, whether explicitly considered or not, often determine the effectiveness of all the rehabilitation efforts that follow. Therefore, if not considered or not



answered correctly, there may be a rehabilitation response that results in wasted effort and money and a possible delay in fixing the real problem—which results in more damage.

For example, unsuccessful initial attempts at repairs—short-term fixes with a tube of caulking or application of a coating—often result from a poor evaluation of the symptoms. It is common for consultants to be called in after a considerable amount of money has already been spent in the hope that the problem was small and the fix was easy. For this reason, someone knowledgeable about building envelope performance should do the initial assessment. In a short time on site a knowledgeable individual can provide appropriate direction to start dealing with the problems, whether they are small or large.

Owners are becoming increasingly concerned about the condition of their building whether or not they are experiencing moisture problems. They may ask an initial assessment to find out if they should be concerned. If they do not, the assessment may give them some guidance in identifying moisture problem symptoms or maintenance strategies to reduce the likelihood of problems. The evaluation techniques and guidance in these cases is similar, in level of effort, to the initial assessment of buildings with known moisture problems.

The deliverable for the initial assessment should define the nature of any reported or observed performance problems (symptoms) and outline recommended follow-up action. This action could, in the case of small problems, be a description of required repairs, a rough estimate of costs and the names of contractors with the skills for the work. Alternatively, it could be a recommendation for follow-up investigation with a defined scope or focus. If the symptoms indicate a potentially systemic or widespread moisture problem, the recommendation is likely to be a detailed condition assessment. If there are no apparent moisture problems and the assemblies and details suggest that the building is at low risk, the recommendations may simply be appropriate renewal and maintenance activities.

The flow chart in Figure 2-1 describes the evaluation process and factors that may start assessment, through to detailed condition assessments or specific problem investigations. The following sections describe the three assessment categories in more detail.

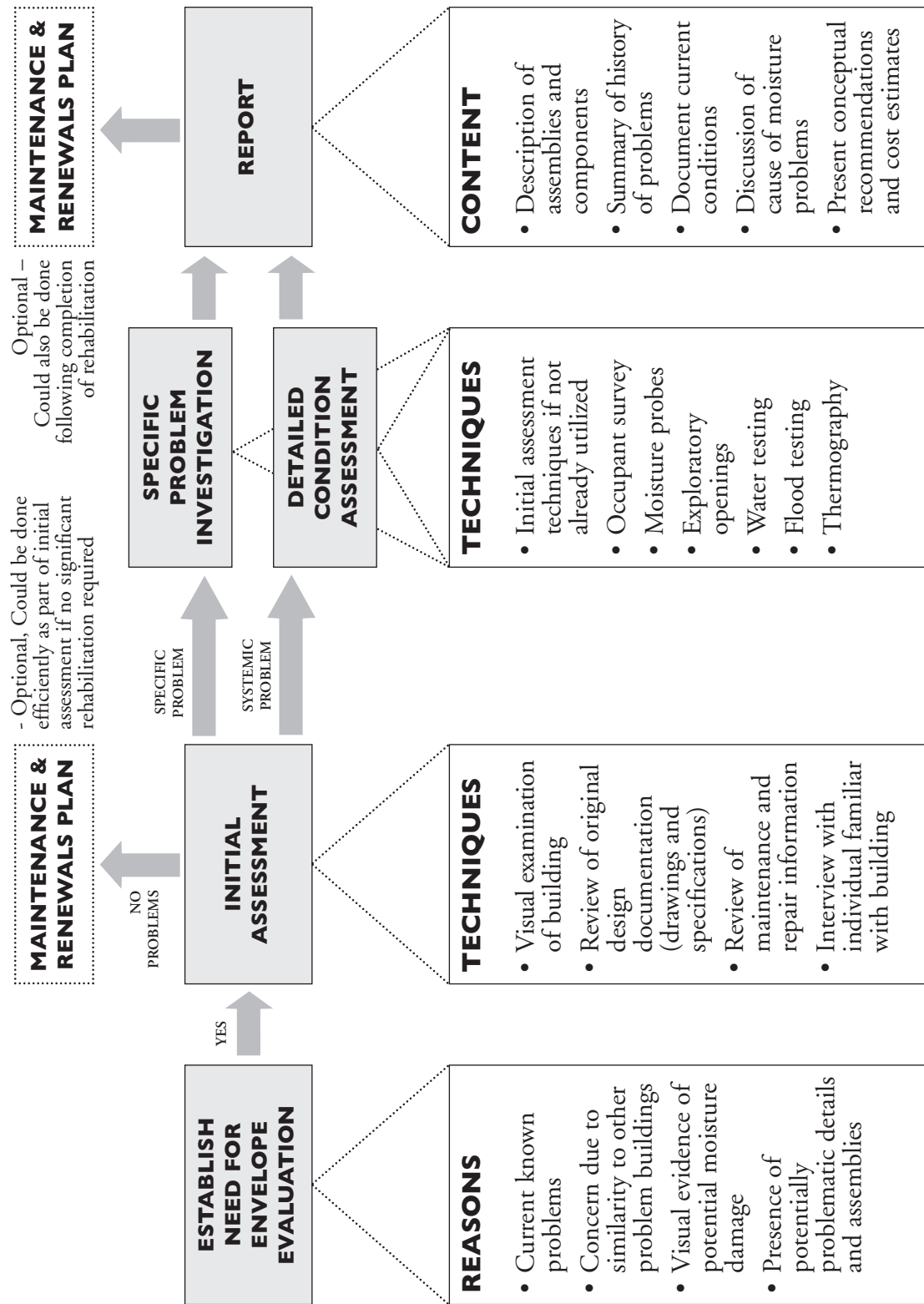
The consultant's conclusions and recommendations should be based on sound evaluation procedures, sufficient and appropriate sampling to reach conclusions and judgment based on experience. This chapter establishes a typical protocol for techniques to evaluate a building envelope's condition.

Evaluation methods used may be categorized as indirect or direct. Direct methods verify and provide physical evidence that a performance failure of the building envelope has occurred and that there is deterioration. Indirect methods indicate that there may have been a performance failure or that there is a significant risk of failure. Indirect methods do not directly verify or provide evidence of deterioration or failure of building envelope components. Both indirect and direct techniques require that the consultant use good judgment, based on the data gathered, to reach appropriate conclusions.

Figure 2-1 gives specific evaluation techniques that can be used during the initial assessment or during a condition assessment or specific problem investigation. Individual situations may dictate that a different combination of techniques be used. For example, it is common to conduct an occupant survey as part of the initial assessment although this task is shown as being part of the condition assessment or specific problem investigation.



Figure 2-1—Evaluation process



### 2.1.1 Initial assessment

As outlined in the Introduction to this chapter, there are two types of initial condition assessment: those prompted by a current moisture-related problem (preliminary assessment) and those prompted by a general interest in knowing the risk of future problems to help plan maintenance and renewal (risk assessment).

Initial assessment relies exclusively on indirect evaluation. Typically, this includes a visual examination of the building, a review of the architectural drawings, maintenance and repair documents and an interview with an individual who knows the history of the building well. The conclusions from an initial assessment cannot be used in place of more direct evaluation.

In the case of a risk assessment where there are no reported moisture problems, the consultant uses the information gathered about exposure, building form, assemblies, details, components and materials to form an opinion about the level of risk to the owners. It may be that some areas or assemblies in the building are high risk and others are low risk. In this case recommendations may focus on a detailed condition assessment of the higher risk areas. Maintenance and renewal recommendations can be made for the low-risk elements. The format and issues related to maintenance and renewal planning are described in Chapter 7—Service life and in *Best Practice Guide—Wood-Frame Envelopes in the Coastal Climate of British Columbia*.

If the preliminary assessment of a known moisture problem reveals a small, localized problem, there are several options. The consultant could oversee the work of a contractor to make repairs. It is also possible that a good contractor will be able to go ahead without a consultant by refining

the initial cost estimate and undertaking the work, but getting the consultant involved if a more significant problem becomes apparent on site.

If the initial assessment cannot determine the cause and appropriate conceptual rehabilitation strategy for a reported moisture problem, then the appropriate recommendation is a more detailed investigation using direct evaluation tools.

Similarly, if the initial assessment suggests a systemic failure due to widespread moisture problems then the appropriate recommendation is to undertake a detailed condition assessment.

If the building does not have typical problem assemblies, components and details and there is no visual evidence of moisture-related problems or reports of problems, there may be no need for further detailed assessment or investigation. In these instances the information gathered through the initial assessment process could be used to develop or update a maintenance and renewal plan.

The effort for this initial assessment will vary depending on the size of the unit and the scope of the assessment. The scope could include the entire envelope (walls, glazed assemblies, roofs, balconies, decks, walkways, as well as at-or below-grade waterproofing) or could focus only on select elements of the building.

### 2.1.2 Detailed condition assessment

The initial assessment may identify the need for a detailed condition assessment. The purpose of this work may be multi-faceted but usually includes some combination of the following:

- Determine extent and severity of the damage or symptoms of systemic moisture problems.

- Determine the cause(s) of systemic moisture-related problems.
- Determine appropriate conceptual rehabilitation work strategies.
- Develop and outline construction cost estimates and implementation plans.

Clearly, the level of investigative work changes if information is gathered to support litigation. Unless specifically requested, this is not normally the purpose of the condition assessment report. However, the factual information in the report may be used to later support opinions about the factors contributing to envelope failure. The condition assessment report, therefore, documents the current condition of elements of the building envelope. It may also provide information related to the specific sources of moisture or other physical factors that have resulted in the conditions.

The condition assessment report is not intended to give opinions about actions or services which may have contributed to or caused the conditions. If asked to provide opinions about the cause of failures, the consultant must be careful to give only opinions he or she is qualified to give. For example, a building envelope engineer may give an opinion about a detail's ability to perform its intended functions, but cannot say whether the original architects fulfilled their obligations and prepared acceptable details.

The proposal submitted before starting to assess the condition should reflect the purpose(s) of the work, the extent of the review—part of the building or some of the assemblies—and the proposed methodology. The following represents a generic scope of work for a condition assessment that focuses on the development of a rational rehabilitation work plan:

- Review the history and nature of the building envelope problems with occupants, available records and the building manager. This review will lead to a more effective and focused investigation.
- Distribute an occupant survey to help determine the history, extent and nature of any moisture related performance problems. See Appendix A, Owner–occupant questionnaire.
- Review available original design and construction documentation about the building envelope. This documentation should ideally include full sets of architectural and structural drawings, specifications, documentation of previous repairs, previous reports and any photographs of the building under construction or repair.

It is not usually possible to lay out the exact plan for the field evaluation as findings in the earlier tasks will dictate the focus of the specific field evaluation. In addition, findings early in the field evaluation may indicate a need for greater focus on one aspect of the construction and less emphasis on others. However, typical investigative techniques will include:

- Visually examining typical areas where moisture problems have appeared from the interior of the building. During the investigation the consultant will require access to the building and to selected suites.
- Visually examining all assemblies that form part of the scope of the review. During the visual review the consultant should make a more detailed examination of the areas that are currently experiencing problems.
- Sampling of the moisture content of the wood sheathing at locations throughout the building.

- Making some small exploratory openings from the exterior or interior at the perimeter of windows, edge of balconies and at other locations of high moisture content readings to help confirm details of the construction, the presence of wood decay and potential water ingress paths. The assistance of a contractor is usually required to make and repair the exploratory openings. Normally, openings are temporarily patched until the owners review the report's recommendations. Permanent repairs can be done once direction for a repair or rehabilitation program has been established. The number of exploratory openings depends on the results of the moisture probe survey and visual observations.

Based on the results of the investigation, develop conceptual rehabilitation recommendations, alternative approaches where feasible and construction cost estimates. Cost estimates should identify all project costs including consultants, taxes, contingencies and permits in addition to the construction costs. See the detailed discussion of costs in Chapter 5—Tendering.

Prepare and submit a draft report to the strata council (or building committee) giving the results of the investigation and recommendations. The review of the draft report provides the consultant with input on areas of the report requiring greater clarification, possibilities of phasing the work and considerations about doing rehabilitation work in an occupied building.

Based on the review, revise and submit the final report. It should contain supportive photographs and sketches, where appropriate.

Meet with the owners to discuss the report, recommendations and follow-up activities in detail.

Costs for a condition assessment depend on the size and complexity of the building, as well as the scope of the assessment.

### **2.1.3 Specific problem investigation**

The initial assessment may identify the need for a specific problem investigation. The purpose of this work is usually to:

- Determine the cause of specific moisture problem (problems are only showing up at a few locations or are isolated to one problematic detail).
- Determine appropriate conceptual rehabilitation work strategies.
- Develop construction cost estimates and an implementation plan for conceptual rehabilitation work.

The essential difference between a detailed problem investigation and a condition assessment is the focused nature of the investigation and—in some cases—more extensive direct evaluation. Water testing and larger exploratory openings are more common in a specific problem investigation.

In other respects, methodology and reporting should closely resemble the condition assessment. Costs for a specific problem investigation depend on the extent of required testing and the extent of field exploratory work. Because of the uncertain level of effort, consultants commonly work on a time-and-expense basis. A detailed condition assessment is usually on a fixed-fee basis.

## **2.2 Safety and health considerations**

The first priority in evaluating wood-frame building is the safety of occupants, workers and the public. Safety has to be assessed at all stages of the rehabilitation process but begins during the evaluation stage.

## 2.2.1 Structure

Fungi are microscopic organisms that feed on organic matter. They can develop on wood if conditions conducive to their growth persist.

Moisture content of the host wood plays the greatest role among the factors required for growth of wood-rotting *bacidiomycetes*. The fungi develop from minute airborne spores that germinate when they land on a suitable substrate. They use various parts of the wood's cellular structure both for sustenance and as a substrate for colonization. The consumption of nutrients and spread of the colony in the wood continues as long as there are appropriate conditions—mainly warm temperatures and a supply of suitably wet wood. Destruction of the wood cells reduces the ability of the wood to resist structural stresses and ultimately leads to a loss of structural capacity.

Rapid loss of strength occurs before decay is obvious to the naked eye. Some strength properties are more sensitive to fungi than others. Compressive strength perpendicular to the grain reduces at a fast rate. Compressive strength parallel to the grain reduces at a slower rate. Crushing of wall plates and beams and joists at their points of bearing may precede crushing of vertical compression members such as studs and posts.

Moist, decaying wood can also give rise to insect infestation, which can accelerate deterioration.

*Understanding Biodeterioration of Wood in Structures* by Forintek Canada Corporation—1998 is a more detailed discussion of wood decay and how to identify it.

## Signs of potential danger

Typical potentially dangerous conditions in a building's exterior framing system include:

**Staining**—Dark staining running out from behind cladding is an indication of wood decay resulting from the breakdown of the cellulose fibre that provides most of the wood's strength and stiffness. (Photo 2-1).

**Photo 2-1—Dark staining on underside of balcony**



**Balcony deflection**—Excessive deflection of cantilevered balconies, unusually springy balcony floors and spongy balcony floor sheathing are all indications of possible wood decay. The degree to which the structural integrity of the balcony has been affected cannot be determined from a visual inspection alone (see Photos 2-2, 2-3 and 2-4). It is important to err on the side of caution if you suspect wood decay. Advise building occupants to limit loading or stay off the balconies completely until completion of further investigation.



**Photo 2-2—Deteriorated balcony sheathing and framing**



**Photo 2-3—Framed balcony guardrail**



**Balcony guard movement**—Balconies made of lumber-framed walls with finishes on both sides are prone to decay if they are not adequately waterproofed and vented (see Photo 2-3 and Photo 2-4.) They may have been weakened by decay if they can be easily displaced at the top or at their connection to the balcony structure. Wood or metal open-type guards should also be qualitatively tested by forcing the top back and forth by hand. Movement at the connections to the balcony floor or the building wall may indicate either corrosion of fasteners or decay of the member into which the fasteners are embedded. In wood guards, visible decay in the pickets, posts or rails is an obvious sign of structural deterioration. If there is any doubt about the stability of balcony guards, advise building occupants to stay off the balconies and test the guards.

**Photo 2-4—Wood decay in balcony guardrail walls**



**Exterior wall deformations or cracks**—Bulging or cracked finishes can indicate that the wall framing is compressing due to decay in the wall plates, studs, or edge of the floor framing (see Photo 2-5). Windows and exterior doors that appear to be under excessive vertical load, exhibiting jamming or bulging, may also indicate that the wall framing is compressing (or that lintels are decaying). Sagging floors are another indication of decay-supporting walls. The capacity of such walls to continue to support vertical loads is a judgment call best made by a structural engineer.

If the exterior finish is stucco and is bulging or cracked, there is a danger that the stucco is detaching from the structure and could fall. The fall zone should be barricaded until the investigation can be completed.

Decay within the edge of the floor framing (Photo 2-6) may compromise the vertical load capacity of the floor if the ends of the floor joists are deteriorated at their point of bearing. If this is suspected because of observations such as spongy or sagging floors, install precautionary shoring inside the building to support the joists or barricade the room areas above and below the affected location. A structural engineer should always assess these situations.

**Photo 2-5—Cracked and bulged stucco at floor line**



**Photo 2-6—Decayed rim joist**



**Sagging or settling of isolated members**—Structural damage in isolated members, such as posts, beams and lintels, is often readily apparent from visual observation because of sagging or settling. As there is less redundancy in the structure where such members are involved, precautionary shoring or barricading should be recommended. (Photo 2-7).

**Photo 2-7—Decayed post on walkway with temporary shoring visible behind**



As the evaluation proceeds (exploratory openings), further evidence can be gathered about the condition of the structure by probing members to evaluate the moisture content of the wood and by exposing small areas of framing for examination. The emphasis should be on following the vertical load path through the structure to assess its integrity. Has the remaining sound cross-section of cantilevered joists, lintels and isolated beams been reduced to the point where failure in bending or shear is possible? Have the ends of floor joists deteriorated to the point where they no longer have adequate bearing or sufficient sound cross-section to resist shear forces? Are isolated posts still capable of carrying their design load? Is there a danger of someone stepping through decayed balcony sheathing and are balcony guards still strong enough to protect the occupants?

In addition to structural deterioration, other factors to consider in assessing safety concerns are the redundancy of the structural framing, its over-design or under-design and the expected loading (for instance, a member or wall may have adequate capacity temporarily in the absence of snow load). Another key factor to consider is how long it will be before repairs starts, during which time decay will continue to progress.

### **2.2.2 Mold—general**

There are two broad groups of fungi in water-damaged walls. One group survives by digesting lignin and cellulose in exterior wood sheathing and framing members, resulting in wood decay. Wood decay has made rehabilitation of some building envelopes in coastal B.C. necessary.

The second group of fungi associated with water-damaged envelopes is "molds." In this context, the molds grow on sugars in wood,

the paper and starch in wallboard and other organic material. Aside from damaging building materials, excess exposure to mold may be hazardous to the health of workers removing water-damaged materials. The presence of mold must be recognized and dealt with during both the evaluation and construction stages of a rehabilitation project. Steps must be taken to protect the workers and occupied space during rehabilitation. The required steps are governed by principles laid down by expert committees, most recently by the American Conference of Government Industrial Hygienists (1999). Each project requires adaptation of these principles in accord with Government of British Columbia requirements, including health indications for workers doing such work.

The risk to building occupants of mold in wall cavities is governed by two major factors: how much mold is in the envelope and the rate that it enters and accumulates in the occupied space. Generally, the rate of entry into the occupied space is low, so typically the major controlling factor is the extent that the spores and debris have accumulated. If carpets and other surfaces are vacuumed with machines with very high efficiency filters (HEPA), the rate of accumulation and hence exposure is much reduced. Information on the health issues is available on the Environmental Health Centre page at the Health Canada Web site at [www.hc-sc.gc.ca/ehp/ehd](http://www.hc-sc.gc.ca/ehp/ehd)

In addition to the precautions required during envelope rehabilitation, indoor air quality investigations can evaluate whether the fungi in the indoor air are similar to those in outdoor air. High concentrations of the fungi live on the surfaces of leaves in outdoor air. Samples taken of indoor air should normally contain these same fungi. Procedures have been developed to evaluate whether occupied spaces have unusual mold contamination. These are based primarily



on a careful inspection of the space for water damage and visible mold. Sometimes samples are taken.

Advice from a consultant with appropriate qualifications and experience should be sought in this regard. The consultant should be able to demonstrate expertise and ability to collect mold using airborne, surface and bulk sampling procedures. A lab with American Industrial Hygiene Association (AIHA) certification or equivalent should perform analysis of the samples. A qualified professional with experience in mold in building systems (primarily HVAC and building envelope) should interpret lab results.

Reasons for taking this precautionary step include:

- Occupants or workers suffer from cold or flu-like symptoms, malaise, headaches or rashes and these symptoms diminish when they are not at the building.
- Mold is visible on interior wall, ceiling or carpet surfaces.
- There is a musty, earthy or moldy smell in the building indicating the presence of hidden mold.

### Basic precautions

The building envelope rehabilitation program will eliminate the source of moisture that has led to the presence of mold and most—if not all—the moldy material will be removed. However, there are some basic precautions to minimize the potential for mold-related health problems during rehabilitation.

Provide workers working close to mold with adequate personal protection.

- Respirator with HEPA filter, N95.
- Goggles.
- Gloves.

Other workers may not need to use all personal protection measures.

Minimize the spread of mold by workers to interior spaces and their homes by:

Using clothing that is removed and bagged when leaving the site or moving to a clean space within the building; or

Using Tyvek suits, which are disposed of when leaving the site or moving to a clean space within the building.

Minimize the spread through the air of moldy materials from exterior dirty spaces to interior clean spaces by:

- Creating air barriers to separate clean and dirty space (if none exist).
- Using fans to create flow from clean areas to dirty.
- Minimize transport of moldy material to interior clean spaces by:
- Minimizing dust.
- Not transporting moldy material through clean part of building.
- Bagging moldy material if it is necessary to move it through clean areas.
- Clean up residual moldy material on completion of rehabilitation program by:
- HEPA vacuuming.
- Damp wiping.
- Removing protective coverings.

These basic precautionary measures are based on and consistent with measures for mold rehabilitation in indoor environments published by recognized authorities.

### More information

For more information, refer to:

American Industrial Hygiene Association (AIHA) Biosafety Committee, *Field Guide for the Determination of Biological Contaminants in Environmental Samples*, 227-RC-96, 1996.

American Conference of Government Industrial Hygienists (ACGIH) *Bioaerosols: Assessment and Control*, Cincinnati, Ohio, 1999.

Canada Mortgage and Housing Corporation, *Clean-Up Procedures for Mold in Houses*, Ottawa, Ont., 1993.

Canada Mortgage and Housing Corporation, *Moisture and Air: Problems and Remedies*, Ottawa, Ont., 1989.

Health Canada, Environmental Health Directorate, *Fungal Contamination in Public Buildings: A Guide to Recognition and Management*, Federal-Provincial Committee on Environmental and Occupational Health, Ottawa, Ont., 1995.

New York City Department of Health, Bureau of Environmental and Occupational Disease Epidemiology, *Guidelines on Assessment and Remediation of Fungi in Indoor Environments*, New York, NY, 2000

## 2.3 Indirect methods

### 2.3.1 Visual examination

Visual examination of the exterior and interior surfaces of a building envelope by an experienced consultant can often provide a very accurate initial impression of the probable condition of the envelope assemblies. Direct evaluation is always required to confirm the visual assessment. Table 2-1 gives visual symptoms of potential envelope performance problems.

**Table 2-1—Visual symptoms of potential envelope performance problems**

Visual symptom	Possible cause/source
Staining on concrete foundations below wall or column cladding. See Photo 2-8.	Leaching of wood extractives or breakdown products from within the wall to the foundation.
Staining on wall cladding. See Photo 2-9.	An indication of possible moisture behind the cladding.
Uneven colouring of wall cladding.	May indicate water behind the cladding.
Efflorescence on stucco cladding.	May indicate water behind the cladding.
Staining around deck scuppers and below drain penetration through deck soffits. See Photo 2-10.	Tie-ins of the deck membrane to the scupper may not be appropriate; scupper may be back-sloped to deck redirecting water inside the wall assembly.
Bulging in stucco cladding.	Wood-frame shrinkage causing movement and cracking of the cladding.
Stained or sagging balcony soffits.	Probable indication of a balcony leak.
Deflections of window frames.	Caused by shrinkage of the wood structure or structural inadequacies in the window or the wood-framed structure, possibly because of decay.
Efflorescence or rust staining on the underside of a suspended concrete slab.	Water may be trapped on top of the suspended slab. This water may be from wall or perimeter leakage.
Water staining at window heads.	Water leakage at window perimeter or into the wall assembly above the window.
Extensive cracking of stucco cladding.	A possible point of water ingress.
Mold on interior gypsum board finishes. See Photo 2-11.	Sustained high levels of moisture present within gypsum board.
The presence of towels on windowsills.	Excessive condensation on the window frame or the window is leaking.
Water dripping from the head of windows on the interior.	Indication of water penetrating the walls or windows above the location of the dripping.

**Photo 2-8—Staining on concrete below the cladding**



**Photo 2-9—Staining on the cladding**



**Photo 2-10—Staining at scuppers and saddle interface**



**Photo 2-11—Mold staining on inside surface of interior gypsum wallboard**



**Table 2-2—Details often associated with moisture-related problems**

Description of detail	Possible contribution to moisture problems
Balcony railings installed on a horizontal surface. See Photo 2-12 and Photo 2-13.	Fasteners at mounting plates of deck railings are typical leakage points.
Poor dryer exhaust vent details. See Photo 2-14.	Warm and humid dryer-exhaust air may be discharged within the wall or balcony assembly and cause wood decay.
The method of integration of cap flashing to the wall assembly (saddle connection). See Photo 2-15.	A poor detail at this location can result in water ingress.
Gaps or cracks in the cladding. See Photo 2-16.	Possible source of water ingress past the cladding.
Poor planter wall to main building exterior wall interface detail. See Photo 2-17.	Possible water ingress point.
Control joints or reveal strips in stucco cladding. See Photo 2-18.	Possible source of water ingress behind the cladding.
Back-sloped flashing details. See Photo 2-19.	Allows water to pond and run off the flashing back into the wall assembly.
The method of integration of the windows with in the wall assembly. See Photo 2-20.	Leakage either directly through the joints in the window frame or at the interface between the window frame and the adjacent cladding often provides a path for water ingress into the wall assembly.
Poor chimney-to-roof interface details. See Photo 2-21.	Allows water to accumulate against the interface between roof and wall assemblies, leading to potential water ingress.
Condition of sealant used to seal wall penetrations.	Indicative of the quality of the initial construction or maintenance; potential for water ingress.
Lack of membrane below cap flashing.	Water may leak at joints in the cap flashing and the lack of membrane under the cap flashing means that water will have direct access to the wall assembly.
Poorly lapped sheathing paper and flashing.	Water may gain access to the wall assembly behind the sheathing paper at these locations.
Loose waterproofing membrane on decks.	May indicate movement resulting in torn or separated membrane at the seams and termination points.
Elastomeric coatings on the cladding to correct a water ingress problem.	Although it may provide some short-term relief from water ingress it slows wall drying and may accelerate wood deterioration.
Wood window trim that is installed directly on the building paper at the perimeter of the window.	Provides a potential water ingress point and holds moisture against the sheathing paper and sheathing.
Poor parapet cap flashing details.	Possible point of water ingress into the parapet walls.
Poor chimney vent details.	Possible point of water ingress.



All of these symptoms and potential contributors to moisture related damage should be considered and photographs taken of them during the assessment. Note that the list is not exhaustive. The list gives typical indicators of potential moisture-related problems, not all indicators.

**Photo 2-12—Water ponding and guardrail attachment through membranes**



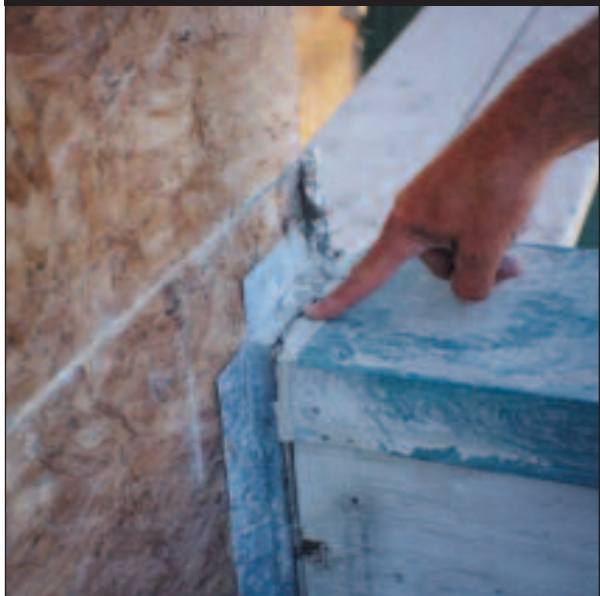
**Photo 2-13—Guardrail attachment through flat cap flashing on balcony upstand wall**



**Photo 2-14—Poor vent assembly; no flanges for tie-in to sheathing paper and screen that can not be cleaned to collect lint and plug exhaust**



**Photo 2-15—Poor cap flashing-to-wall interface detail (saddle); reliant on sealant only to maintain water tightness**



**Photo 2-16—Crack at cladding transition between brick veneer and stucco**



**Photo 2-17—Poor detail at planter interface with wall assembly**



**Photo 2-18—Reveal-strip termination in stucco**



**Photo 2-19—Back-sloped flashing**



**Photo 2-20—Window sill detail at stucco interface; no flashing and no sealant**



**Photo 2-21—No cricket flashing at chimney to roof transition**



### 2.3.2 Interviews

Much useful information can be gathered by interviewing individuals who know the building's performance and repair history. They may have convinced the owners that a building envelope condition assessment is required. Or, they may be the people who know the most about the building's history. This person could be the property manager, the chair of the strata council, the maintenance manager or an owner.

Identifying and interviewing these individuals is probably the quickest—and the most cost-effective—way to obtain information about the building's history, past maintenance and overall performance of the building envelope.

Typical questions include:

- How long have you been associated with this building?
- What can you tell me about the general performance of the building?
- What is the normal maintenance activity at the building?
- Have repairs been made to the building?
- If so, what repairs?
- Who did the repairs?
- What type of problems do the occupants of the building typically report?
- Where?
- When do problems appear?
- What is your sense of why these problems are occurring?

The information obtained should be given in a separate section of the report. Give the name of the person interviewed, the information provided by this person and, finally, what modifications to the scope of work resulted from the information. Efforts to confirm anecdotal information should also be listed.

### 2.3.3 Thermography

Thermography has proven its worth as a way to assess roof conditions. In recent years, consultants have experimented, with varying degrees of success, with thermography as an indirect method of determining if there is water within the exterior walls of a building envelope.

The rationale for using thermography is threefold:

1. Thermal bridging would be increased at points where water is contained within the wall assembly. The additional heat loss would then be visible by an infrared camera.
2. Because a wet wall has a different thermal mass than a dry wall, a wet wall subjected to solar radiation during the day may store more heat than the surrounding materials. A sharp temperature difference between day and night readings may indicate wall defects.
3. Areas of water penetration are easily visible on the interior of a building when the exterior is sprayed with water.

Results of thermographic scanning have varied widely. Thermographic testing should be used with other direct methods, such as moisture probing and exploratory openings. It should never be relied on as the sole method to assess the condition of a wall.

### 2.3.4 Occupant surveys

A survey of occupant perceptions about building envelope performance is useful. Information obtained from an occupant survey includes the identification of symptoms of deterioration which may not be visible from the exterior (mold growth on walls, damaged finishes) and the frequency, location and orientation of reported problems.



Occupant surveys can be misleading. An absence of interior symptoms does not mean that there has not been moisture-related damage. Similarly, mold on interior surfaces may be related to high interior humidity, not exterior sources. However, in most cases some valuable information can be gained from the occupant survey. The consultant is advised to survey occupants as part of condition assessment and verify responses by visiting a selection of suites.

Present the survey results in the condition assessment report or as graphical representations of floor plans or elevations.

Make the occupant survey brief and easy-to-understand. The response rate to an overly complex or long form will be low. Do not ask questions that require occupants to interpret symptoms.

Appendix A is a sample occupant survey form.

### **2.3.5 Relative humidity measurements**

Elevated interior humidity levels may indicate inappropriate use of the space, poor operating conditions, lack of exhaust fans or an exterior moisture penetration problem. Measuring interior humidity is a simple and valuable way to determine potential problems that warrant further investigation. Sustained interior relative humidity levels of 60 to 65 per cent or higher are suspicious and could indicate a building envelope failure. For more information about relative humidity, see *Moisture and Air: Problems and Remedies*, published by CMHC.

### **2.3.6 Smell**

Moisture-related problems can cause a moldy smell in a building. If there are mold odours, investigate further.

## **2.4 Direct methods**

### **2.4.1 Moisture content measurements**

Apart from visual observation, measuring the moisture content of the building envelope's wood components is by far the most widely used and effective assessment technique.

Moisture content is important because wood decay fungi require moisture contents near 28 per cent to initiate growth. However, once established, moisture contents above 20 per cent are sufficient to sustain their growth. Wood is generally considered immune to fungal growth below 19 per cent moisture content.

Moisture content measurements can be made from the interior of the building if an internal test opening is made at the same time, thus providing an opportunity to verify the localized moisture distribution within the wall assembly (exterior sheathing to interior surface of studs.) Typically, however, moisture probing is performed on the exterior of the building.

For exterior moisture probing, drill two, 1/4-in. (6 mm) diameter holes to penetrate the cladding, just into the sheathing behind the building paper. Drill the holes at a standard-gauge distance apart—usually about 3/4-in. (20 mm). Then two electronically isolated probes are inserted through the holes so that their tips penetrate into the sheathing. These probes are insulated with electrical tape, epoxy resin or "shrink wrap" sleeves to isolate them from any moisture other than that detected at the sheathing. The electrical conductivity of the wood sheathing is measured using proprietary equipment calibrated to relate resistivity in the wood-to-moisture content. Higher conductivity values means higher moisture content as water increases the conductivity through the fibre. Photo 2-22 shows typical moisture-probe equipment.



**Photo 2-22—Typical moisture probe equipment**



Non-contact, capacitance-type moisture meters have also been used to measure the moisture content of the sheathing through the cladding. This method of obtaining moisture content data has not been proven accurate in field trials. However, capacitance-type moisture meters have proven useful in determining if water has penetrated exterior insulation finish system (EIFS) claddings.

### Density and location of moisture probing

The following influence the density of moisture probe readings on a building elevation:

- The exposure of the building elevations.
- The complexity of the building configuration.
- Visual symptoms of building envelope distress.
- The presence of suspect details.
- The leakage history of the building.

The consultant should determine density of moisture-probing sites. As a general guideline, one moisture-probe reading every 40 m<sup>2</sup> (430 sq. ft.) of building wall surface area is typical.

Locations to survey for moisture include:

- Below window corners.
- Below joints in cladding materials.
- Below laps in cross-cavity flashings.
- At locations where staining is evident on the cladding.
- Below the interface between balcony guard walls and walls (saddles).
- Below the intersection of deck waterproofing membranes and walls.
- Above stains that are apparent on concrete foundations.
- At cracks and unusual bulging in the cladding.
- Below the ends of back-sloped window head flashing.
- As a control, an area that is not exposed to the weather.

### Equipment calibration

Moisture meters should be calibrated at least twice a year, but accuracy is not critical since results should always be used with exploratory openings to verify actual conditions. In fact hourly, daily, weekly and seasonal fluctuations dictate that moisture content readings be used only as an indication of moisture content in the wood material, not an absolute reading. Correction factors for temperature and wood species also need to be obtained. It is usually available from the manufacturer of the moisture meter.

### Seasonal variations in moisture content

Moisture-content measurements in the summer may not accurately represent the state of the exterior walls during wet or winter conditions. This is because of redistribution of moisture within the wall from the sun's effect and overall drying of the wall assembly. There is a high risk of incorrect assessment from summer moisture content readings.

While findings of dry sheathing in summer do not necessarily indicate health, a high degree of moisture in the sheathing is a definite indication of problems. It is common to find severely deteriorated wood that tested dry with the moisture probe.

Ideally, moisture-content probing should be done between Nov. 1 to April 30. Clearly indicate if moisture probing results were obtained between May and October, and interpret them carefully.

It is not advisable to probe for moisture on the exterior of a building in wet weather, as there is a possibility of contamination by rainwater. As well, applying sealant in holes drilled through the cladding may also be compromised, possibly causing water to get into the walls.

### Moisture-content measurement in copper-based, pressure-treated woods

Manufacturers of meters that measure moisture content from the electrical conductivity of wood between two points report that readings may be influenced by copper-based wood preservatives and other ions, such as calcium or iron, from other building materials.

Until there is more research, moisture content results from probing treated wood should be include a qualification that pressure treatment may affect the readings. When accurate readings are truly required, obtain them by determining moisture content through a weight comparison with oven-dried samples.

### Moisture probing in oriented strand board (OSB) and plywood

Manufacturers of moisture meters report variations in accuracy in readings from OSB and plywood because of the variability of wood species, orientation of the wood grain and the conductivity of the glues used in manufacturing. So far, there is no way to deal with the accuracy of readings in OSB. However, it is unlikely that this phenomenon is a significant variable in the usefulness of moisture probing as an evaluation technique.

### Presentation of moisture-content measurements

The most common technique now used for reporting moisture probe results is colored dots on a drawing or photo of the building elevations. See Figure 2-2.

**Figure 2-2—Presentation of moisture probe results on representation of the wall elevations**



The following grading scheme, which is consistent with the *Best Practice Guide—Wood-Frame Envelopes in the Coastal Climate of British Columbia*, is recommended.

**Zero to 19 per cent moisture content—**

Green dots. Readings are considered normal and not suggestive of moisture-related problems. Wood is generally immune to fungal attack.

**20 to 28 per cent moisture content—**

Yellow or blue dots indicate exposure to an unusually high amount of moisture at levels that can maintain fungal growth. This moisture-content range is a caution reading that usually requires intervention to deal with the source of the excessive moisture.

**28 per cent and higher moisture content—**

Red dots indicate conditions where decay fungi will germinate and flourish. It is a danger reading and wood components will likely deteriorate if the source of moisture is not treated.

Note that moisture content readings above 28 per cent are typically imprecise and should simply be indicated as >28 per cent.

On black and white photocopies, use dots of different shapes to show moisture contents. It is useful, in both coloured and differently shaped dot schemes, to summarize results in a table.

In addition to interpretations of moisture content readings, some qualitative assessment of conditions can be made based on the ease of penetration of the moisture meter probes into the wood sheathing and the appearance of the wood shavings removed from the drilled holes.

## 2.4.2 Exploratory openings

Exploratory openings are made to assess the condition of the wood components of the building envelope, to verify which materials were used and the general arrangement of materials. Exploratory openings also provide the opportunity to collect samples of materials for possible laboratory analysis.

In the past it was common to retain consultants near the end of a warranty period to make exploratory openings to determine whether structural damage had occurred as a result of water ingress and to demonstrate the extent of the damage. Although this may continue to be one reason for exploratory openings, their primary purpose is to gather knowledge of conditions and details of construction so the consultant can make rehabilitation recommendations or develop an effective maintenance and renewal plan.

Photo 2-23 and Photo 2-24 show conditions at two types of exploratory openings.

**Photo 2-23—Typical saw-cut exploratory openings at lower corner of window**



**Photo 2-24—Typical cored exploratory opening to confirm assembly materials and condition**



### Exterior or interior openings?

Exploratory openings can be made from the exterior or the interior of a building. Interior openings are made by removing a portion of the interior building finishes to gain access to the exterior wall sheathing and stud cavity. The advantage of an interior opening is that the integrity of the exterior cladding is not compromised.

Exterior openings are made by removing a portion of the cladding and sheathing to assess the condition of the wood components of the building envelope. There are two advantages to an exterior opening: less disruption to occupants and a view of the exterior layers so their condition can be documented.

If a cladding system cannot be acceptably repaired as a result of the exploratory opening, make exploratory openings from the interior. Seal interior openings airtight to prevent any mold within the wall cavity from contaminating the interior.

Deciding to cut an exploratory opening in an exterior wall is not to be taken lightly. Apart from esthetically damaging the building, an exploratory opening introduces another penetration that could lead to water leakage and subsequent deterioration of the wood-frame. Damage to sheathing paper should be minimized. Further removal of the cladding may be required to access undamaged sheathing paper and make permanent repairs at the exploratory opening.

Proper short-term sealing of exterior exploratory openings is crucial in a coastal climate to minimize impact on performance of the wall assembly. Techniques used to minimize impact include:

- Reuse of removed cladding together with sealant.
- Polyethylene sheets with caulking or tape at the perimeter.
- Pre-painted sheet metal with caulking at the perimeter.
- Foil-faced, self-adhering membrane to seal the exploratory opening with a caulking bead from the foil face of the membrane to the edge of the cladding. At the bottom of the exploratory opening, the membrane laps over the edge of the cladding to shed water effectively.
- Plywood patch with sealant at perimeter of plywood.

Whatever method is used, be sure that it will work for as long as it is in place. In most situations, reusing cladding or installing a plywood patch is likely to be appropriate and cost-effective.

### Location of exploratory openings

Consider the following factors, among others, when deciding where to place an exploratory opening:



- The moisture content of the sheathing.
- The appearance of the wood shavings removed from the holes drilled in the cladding for moisture content probing.
- Qualitative assessment of wood strength determined by the ease of penetration of the moisture meter probes.
- Symptoms and details from the visual review of the building.
- Information from occupant surveys.

Although the evaluator should base the number of exploratory openings on specifics of the building, between three and 10 is typical.

The typical exploratory opening in the cladding is 300 x 300 mm (12 x 12 in.) This will vary depending on the specifics of each building (see Photo 2-23). The 300 x 300 mm opening allows removal of portions of the sheathing to assess the condition of the wood-framed elements behind. It is recommended that portions of the sheathing be removed as part of the exploratory opening. It is also possible to use smaller, 75 mm (3-in.) diameter cores to verify probe results and confirm materials in the wall assembly (see Photo 2-24).

### Observations at exploratory opening

Measure moisture content of the wood-framed elements of the wall while conducting exploratory openings.

Wherever possible the type of wood decay and its extent into the wall assembly should be determined at each exploratory opening. There are many publications to help identify white and brown wood decay and how to distinguish mold, staining fungi, iron stain or other water marks. One is *Understanding Biodeterioration of Wood in Structures* by Forintek Canada Corporation—1998.

Probing suspect wood and using a pick test to determine the type of wood-fibre breakage readily detects wood decay at exploratory openings. Insert a knife blade about 10 mm (4/10-in.) deep at a shallow angle (around 30 degrees) at right angles to the grain direction (the long axis of the lumber) and attempt to lever up a splinter. If it takes the force typical of sound wood to insert the blade, and the wood is hard to lever up and splinters when it is, then it is sound. If the knife blade goes in easily, and the wood is easy to lever up and snaps across the grain like a carrot, and then the wood is decayed.

Show the location of exploratory openings on drawings of the building elevations. The condition assessment report should have photographs of relevant exploratory openings.

### 2.4.3 Window evaluation

Window testing can be done as part of a detailed condition assessment. It is done more often as a follow up investigation to confirm a suspected source of water penetration or to help decide whether to replace or refurbish windows. *In situ* testing verifies performance of the window unit and the window-to-wall interface. Appendix C is a detailed discussion of window evaluation.

### 2.4.4 Water testing

Water penetration testing of wall or window areas can often pinpoint specific leakage paths and details that may have caused an envelope failure. Water testing is typically conducted by mounting a spray rack on a wall's exterior and spraying for a set period to induce a pressure differential across the wall assembly. Water testing is usually used to find the point(s) of water ingress into or through a wall assembly.

Ineffective or inappropriate water testing can be expensive and further confuse the issue. Disputes arise about the severity of the test pressure differentials and the rate of application of the water—and, as a result, validity of the tests.

A typical water test should be performed using a spray rack conforming to the requirements of ASTM E1105. The differential pressure should range from 100 to 300 Pa (0.0145038 to 0.0435114 psi) with its upper limit set at the pressure dictated by the selection guide of the CAN/CSA-440 standard. Typically, the test should last 24 minutes. Do not run tests overnight without arranging to have the water shut off in case there is a leak.

Non-standard water testing, perhaps with a garden hose, can effectively isolate leaks or test specific joints within an assembly.

Start testing at the bottom of the test area and move gradually up the wall. This process helps to precisely and accurately locate the height of the ingress point.

Water testing does not always locate all sources of water penetration. Use your judgment in conjunction with testing to determine the appropriate rehabilitation strategy. When the water test is complete it is important to determine if water has entered the wall assemblies and if it has, ensure that it has an opportunity to dry.

### **2.4.5 Flood testing**

Test flooding on horizontal waterproofing surfaces, including roof, deck and balcony membranes, windowsills and flashing. It is recommended that the maximum water head created should be either 75 mm (3 in.), or 25 mm (1 in.) below the level of the doorsills—whichever is greater. Take care that the weight of the water does not exceed structural capacity.

Test until a leak develops or for four hours. Do overnight flood testing only if someone stays on site to remove drain plugs if there is a leak. Never leave a flood test unattended. Warn owners that there is a possibility of water penetration during testing and take precautions to minimize damage.

Leaks result either from membrane failure or from water overflowing the up-turn on the membrane. Testing must be able to distinguish between the two. For example, if damage or staining is most prevalent after snow, it is more likely that the leak is from a snow dam causing water to back up and overflow, than it is from membrane failure.

If flood testing produces a leak, evaluate the cost-effectiveness of repairs and replacement. Cost-effectiveness depends on the type of waterproofing membrane, usage circumstances, age of the membrane and expected service life.

## **2.5 Establishing scope of repairs or rehabilitation**

### **2.5.1 Interpreting results**

As well as reporting the condition of building envelope elements, it is critical that the assessment or investigation identify and report all moisture sources or mechanisms of deterioration. The report should also give a prognosis for the building envelope and outline recommendations for rehabilitation or repair. This process is illustrated schematically in Table 2-3—Establishing scope of rehabilitation.

It is important to quantify both the extent and severity of damage and to identify deterioration mechanisms—moisture source and the process leading to premature deterioration—since this is the only means of projecting performance.

In addition, rehabilitation must address both the symptoms of damage and the mechanisms of deterioration.

It is important to confirm the deterioration mechanisms on each building for three reasons:

1. There can be surprises in the type and nature of the moisture sources.
2. Each building is different in the way that it is located, sited, built, occupied and maintained and requires individual evaluation.
3. Combinations of mechanisms can be acting together. Addressing only one in rehabilitation means the others might resurface later individually.

Understanding the extent and severity of the deterioration and the mechanisms of deterioration gives the consultant confidence in the rehabilitation, maintenance and renewal recommendations. The following examples show how critical it is to know both the extent and mechanisms of deterioration:

**Example 1—Know the mechanism as well as extent of damage**

The exterior wall assembly of a walkway showed significant wood decay. The wall assembly was replaced with a new, more moisture-tolerant assembly and the decayed wood was replaced. It was assumed that water entered from the many saddle connections on the walkway and from possible failures in the waterproofing on the walkway surface. After rehabilitation the damage happened again because the dominant source of moisture—from unprotected stairwells which tied into the walkway structure—was not addressed in rehabilitation.

**Example 2—Multiple moisture sources**

It is critical to know the source of moisture if damage is discovered at the base of a wall assembly that is supported on top of a reinforced concrete garage roof slab.

Is water entering the wall assembly above-grade at poor details, such as windows, and saddles and migrating to the base of the wall where it cannot escape, causing damage and moving to the suite interior?

Or, is the water entering at the base of the wall through failed waterproofing on the parking garage roof slab? Is moisture present from both of these sources?

Clearly, the answer to these questions are significant in determining whether an improved wall assembly and details are required as well as replacement of deteriorated wood components, or whether rehabilitation of the failed waterproofing at-grade is all that is required.

**Example 3—Construction moisture**

A concealed barrier-seal wall assembly shows widespread, uniform decay of the wood components but is in a low-exposure situation. The source is moisture that was enclosed in the wall assembly in the original construction. Failing to identify this source may result in unnecessarily using new wall assemblies in addition to the replacement of decayed wood components.

In most cases there are several choices for balancing wetting and drying mechanisms and achieving durable performance. For example, the choice could be adding overhangs to reduce exposure combined with improving the existing assemblies, or simply building a new wall assembly that can accommodate the higher exposure.

Deciding on a recommendation is based on factors such as capital cost, extent and severity of existing structural damage and municipal approvals for changes to the building. The consideration of the various factors influencing the selection of alternative strategies is the subject of Chapter 3—Design.

Table 2-3—Establishing scope of rehabilitation

SYMPTOMS OF DAMAGE	MOISTURE SOURCES	CAUSES OF PERFORMANCE PROBLEMS	FACTORS AFFECTED SCOPE OF REPAIRS	CONCEPTUAL REPAIR ALTERNATIVES
<p>Staining on concrete below cladding</p> <p>Staining on cladding</p> <p>Staining at details (scuppers, saddles, window perimeter)</p> <p>Efflorescence</p> <p>Bulging in cladding</p> <p>Window frames deflected</p> <p>Cracking of finishes or cladding</p> <p>Mold on interior surfaces</p>	<p>Water penetration from exterior:</p> <ul style="list-style-type: none"> <li>• Rain</li> <li>• Flooding</li> <li>• Below Grade</li> </ul> <p>Condensation due to vapour diffusion</p> <p>Condensation due to air leakage</p> <p>Condensation due to high interior humidity resulting from occupant use and/or poor ventilation</p> <p>Condensation due to high interior humidity resulting from water leakage and subsequent evaporation</p> <p>Construction moisture</p>	<p>Exposure conditions</p> <p>Poor details</p> <p>Sensitive assemblies</p> <p>Poor ventilation</p> <p>Building form</p> <p>Occupant use</p> <p>Maintenance</p>	<p>Extent of damage</p> <p>Severity of damage</p> <p>Frequency of damage</p> <p>Type of damage</p> <p>Prognosis for future performance</p> <p>Remaining service life of existing components and materials</p>	<p>Reduce exposure</p> <p>Replace damaged components and materials</p> <p>Eliminate details</p> <p>Improve details</p> <p>Reconstruct with less moisture sensitive assemblies</p> <p>Improve resistance of current assemblies and details to moisture source</p>



### 2.5.2 Budget—costs estimates

In addition to describing required rehabilitation work, the evaluation report should include likely rehabilitation costs. At this stage the extent and severity of the problem is generally known and the rehabilitation concept and approaches identified. However, quantities are rough estimates. Exact assemblies and details are not developed and phasing and implementation approaches are not evaluated or selected.

Estimates should be based on historic information from previous similar projects, but should be considered accurate to the  $\pm 40$  per cent level. Estimates should include all project costs, not just construction costs.

These estimates are useful to alert owners to the magnitude of rehabilitation and allow decisions to be made about the next steps. The accuracy of these estimates is not usually appropriate for determining the value of special assessments, since the program is not yet fully defined. It is extremely difficult to estimate construction costs before design work starts. It is just as difficult to establish other project costs before the exact scope of work is known. Chapter 5 is a more detailed discussion of total costs.

It is recommended that owners provide project funds in two stages:

1. Initial funding covers professional fees for design and construction documentation to allow determination of more accurate construction costs based on detailed knowledge of the scope and nature of the rehabilitation work. Funds usually come from the owners contingency reserve fund and may or may not require a special assessment.
2. At the completion of the evaluation stage a special assessment can raise funds for construction and professional fees for tendering and construction. This approach results in a better-defined rehabilitation program, more accurate cost estimates and allows owners to make better-informed decisions.

### 2.6 Evaluation—consultant checklist

- ☐ Identify symptoms of performance problems
- ☐ Identify potentially problematic or higher-risk details
- ☐ Assess exposure conditions
- ☐ Identify appropriate follow-up activity as a result of initial assessment
- ☐ Determine expected service life for materials, components and assemblies
- ☐ Determine extent and severity of performance problems
- ☐ Determine cause(s) of performance problems
- ☐ Determine appropriate rehabilitation strategies
- ☐ Develop rehabilitation cost estimates considering all project costs
- ☐ Undertake initial assessment of implications of performance and proposed rehabilitation measures on other functions of the building based on its intended use and occupancy
- ☐ Take necessary mold precautions and advise owners of mold-related concerns



# Chapter 3—Design

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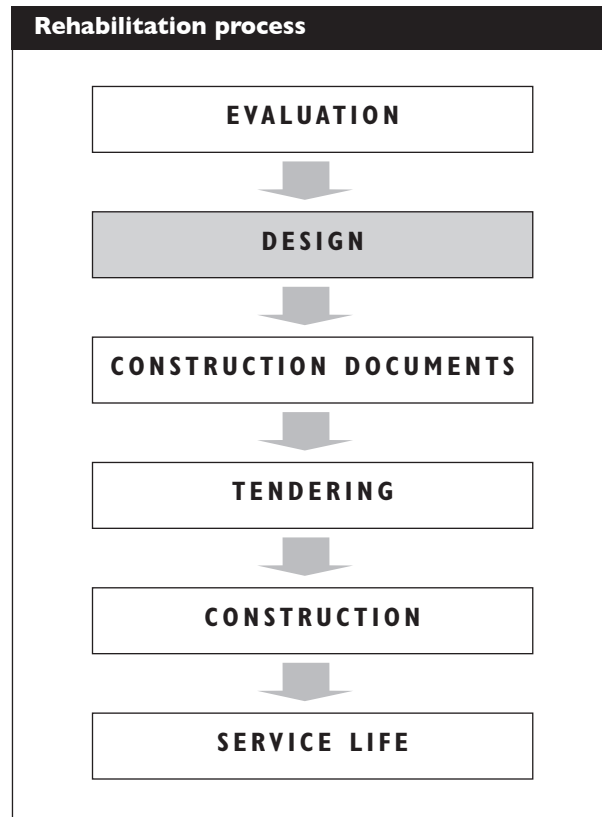
# Chapter 3—Design

## 3.1 Introduction

This chapter deals with the technical aspects of rehabilitation design and the administrative and contractual aspects of the pre-construction project stages. The main responsibilities of the consultant are to:

- Provide the owner with a consultant–owner agreement.
- Review the project program, scope of work and so on.
- Advise the owner about the need for specialist consultants, such as structural engineers, code consultants, quantity surveyors, mechanical and electrical engineers, building envelope professionals (BEP), architects, and so on.
- Advise the owners about the need for third party warranty coverage and arrange for owners to meet with warranty providers.
- Advise the owners about the requirement for a co-ordinating registered professional (CRP).
- Prepare design drawings and specifications to describe the character of the projects including, all major systems, materials and elements.
- Review and revise construction and project budgets as necessary.
- Review and advise the owner about other types of construction contracts.
- Review applicable statutes, codes, bylaws, regulations and so on.

Some technical and administrative issues are addressed on an ongoing basis and span both the design and construction document stages. A certain amount of detailed design may be undertaken during the construction document stage while some detailed building code issues may need to be addressed early in the design



stage. For clarity, topics related to municipal planning and development permits are dealt with in the design stage and building code issues are covered in Chapter 4—Construction documents.

The design stage in rehabilitation projects corresponds to the design development stage in typical architectural projects and the preliminary design-services stage in typical engineering contracts. Schematic design stages are generally not applicable to rehabilitation projects as the conceptual design decisions, building form, orientation, number of storeys and so on are already part of the existing building. However, a number of project start-up activities usually associated with schematic design must be addressed at this stage.

Structural design work for rehabilitation projects is split between the design stage and the construction stage. In the design stage, work can go ahead in areas—such as new support posts or guardrails—for which issues are known. In addition, many standard details, such as splices, can be developed and rehabilitation materials specified. Design decisions for areas such as decayed wood or deficiencies in original framing can only be made once the structure has been exposed in the construction stage. Structural design issues for both stages of the project are discussed in this chapter.

### 3.1.1 Project team

Larger, more complex rehabilitation projects require a team of consultants from different disciplines. Typically, owners deal directly with one prime consultant (usually also the Co-ordinating Registered Professional (CRP) as required by the applicable building code) who hires and co-ordinates the team members.

Ideally, the consultant who evaluated the building and produced the condition assessment or investigation report will continue throughout the pre-construction and construction stages. In many cases, it is desirable for continuity that the evaluation consultant directs the project as the prime consultant. If the consultant who conducted the original evaluation does not continue to be involved, the new consultant must review the previous work to be satisfied that the evaluation and its conclusions are appropriate. In some cases, this may mean more exploratory work or reconsidering some of the previous recommendations.

The owners must retain a CRP who is responsible for co-ordinating consultants in the design and construction stages. The CRP submits completed letters of assurance with the building permit

application. The AIBC and APEGBC developed standards for co-ordinating registered professionals. See the following in section 2.6, of the AIBC-APEGBC publication *Professional Design and Review of the B.C. Building Code*:

- Schedule A—Confirmation of commitment by owner and co-ordinating registered professional
- Schedule(s) B-1—Assurance of professional design and commitment for field review, for applicable disciplines
- Schedule(s) B-2—Summary of design and field review requirements, for applicable disciplines

In addition to the disciplines designated through the letters of assurance most municipalities require involvement by a BEP. The municipalities require a letter confirming that a BEP has been retained and another saying that the BEP has completed the job. The AIBC and APEGBC jointly publish *Guidelines for Professional Practice*. They are in Appendix E, page 34. Upon completion of the project, the project team must complete schedule Cs as set out in the B.C. BC.

### 3.1.2 Contracts

The two principal contracts in a typical rehabilitation project are the owner–consultant agreement and the construction contract. Whenever possible, use standard forms of agreement as the basis for contracts. Adjustments may be needed to reflect particular circumstances. Advise owners to seek legal advice about all contracts, particularly if changes to standard agreements are contemplated. It is important to remember that owners, typically strata councils, are unlikely to be familiar with construction projects and they may need additional time to ensure that they fully understand the design

and construction process. It is particularly important that the strata council appreciate its roles and responsibilities and the consultant's and contractor's role and responsibilities. In some cases, owners are unsure of the distinction between consultants and contractors. Clarifying these issues at this stage, particularly with respect to cost estimates, responsibility for performance, warranties and so on can save time and confusion later.

### **Owner–consultant agreement**

Before starting the pre-construction stages it is important to have a signed owner–consultant agreement. Ideally, it should be a CCAC 6, CCAC 7 or ACEC 31 contract. These contracts contemplate the consultant providing consulting services throughout the project.

### **Construction contract**

Although a construction contract will not be signed until later in the project, it is important to discuss other construction implementation options at this stage and to help owners select the most appropriate type of construction contract. Again, owners should be advised to seek legal advice before making this decision.

A number of alternative construction implementation approaches may be applied to rehabilitation projects. In addition to the common general contractor approach, construction management and design–build approaches may be used. Chapter 5—Tendering is a more detailed discussion of these alternatives.

At this stage outline the options for the owners and the advantages and disadvantages of each. The approach chosen will have an impact on activities in the construction documentation stage.

## **3.1.3 Project program and budget**

Standard consultant–owner agreements assign responsibility for providing project program and project budget to the owner. In rehabilitation projects the program is, to a certain extent, determined during the evaluation stage, although the scope and phasing of the work may not be determined until the design stage. Given the nature of rehabilitation projects it is unusual for the owner to provide a budget. Typically, the consultant will provide the strata with an initial estimate of likely construction cost, in many cases as part of the investigation–evaluation report.

It is important during the design stage to review both the evaluation stage estimate and the basis on which costs were calculated. This is particularly important if the consultant did not do the initial investigation of the building. In this case, it is also essential that the consultant review the evaluation report in detail and agree with recommendations made about the nature and extent of remedial work. If the consultant is not satisfied with any aspect of the evaluation, further investigation may be necessary. The owners should also be made aware that although standard consultant agreements (CCAC 6 and ACEC 31) require that the consultant prepare, review and update estimates of the cost of work they specifically state that the consultant does not guarantee the accuracy of estimates. Chapter 4—Construction documents has more detail about costs.

## **3.1.4 Municipal codes, regulations and processes**

Reviewing all applicable codes, bylaws, regulations and so on, is an essential activity in the design stage. There are two main types of municipal



regulations: zoning and planning bylaws and building bylaws or codes. Zoning typically deals with what is permitted in terms of building size, height, location on site, materials, colours and so on, and is regulated by the municipal planning department through the development permit process. The building code (or the building bylaw in the City of Vancouver) focuses on how buildings are built and addresses issues such as means of egress, fire safety, construction assemblies, protection from precipitation, and so on. Code issues are dealt with through the building permit process. In addition to the building code, many municipalities have additional requirements for building envelopes that are usually published as technical bulletins.

It is important that owners be made aware of the role of the municipality in a rehabilitation project, especially the need for building permits and the possibility of development permits—and the associated fees. Owners should also understand the role of the consultant with respect to letters of assurance and their responsibility as owners to retain a CRP.

Standard consultant–owner agreements assign responsibility for obtaining permits to the owner. This does not mean that the owner physically prepares and submits the application. The consultant typically applies on behalf of the owner, with the owners of the strata corporation identified as the applicant.

Permit requirements and fees for rehabilitation work vary significantly from municipality to municipality. Some calculate permit fees on the total value of the work, some base fees on the structural portion only. Some require amendments to the development permits for even relatively small changes; others approve fairly significant changes as part of the building permit application.

Design changes may have to be reviewed by a design panel, which can add months to the design stage. It is advisable to visit the municipality early in the design process to describe the proposed rehabilitation project and find out the procedures for obtaining the necessary permits. Confirm the outcome of these discussions in writing.

## 3.2 Factors influencing design

In addition to the esthetic and planning issues discussed later in this chapter and the building code issues discussed in Chapter 4, there are a number of other factors that influence design that the consultant has little capability of managing. The design therefore considers these factors as providing context for decisions rather than being variables that the owner can make decisions about. They include:

- Current condition of assemblies.
- Durability of existing construction.
- Exposure conditions.
- Building size, height, orientation and features.
- Existing assemblies, components and materials.

The following sections discuss the nature of each of these factors and the impact that each may have on the design process and decisions.

### 3.2.1 Current condition

The process and techniques for determining the current condition of building envelope assemblies are discussed in detail in Chapter 2—Evaluation. Knowledge of the current condition of the envelope is fundamental to determining the scope and extent of rehabilitation required. For example, additional design alternatives are available for consideration if the wood decay is not severe, or if it is localized.



Similarly, the presence of a health or safety issue dictates an immediate—and possibly temporary—response to rehabilitation.

### **3.2.2 Durability of existing construction**

Owner's expectations of future durability of existing construction also influence the design process. If deterioration is not widespread or systemic when evaluated, the question of whether it will deteriorate in the near future is as important as the extent of current damage. This part of the evaluation asks if the mechanisms that are acting to deteriorate parts of the building will begin to act on the undamaged part later; if other mechanisms are in place that will or could cause problems; or if the rate at which damage is occurring will escalate.

Part of this evaluation is judgment based on an examination of construction drawings or field conditions and extrapolating or deducing known problems with existing assemblies. With care and experience, failures from other projects with similar conditions can be used to extrapolate or deduce. This part of the evaluation is important because conclusions arising from it shape timing, nature and eventual costs. Furthermore, rehabilitation may be less expensive overall if more durable portions of the wall assemblies (low-exposure areas) can be left in place and incorporated in the rehabilitation program.

The level and appropriateness of past maintenance activities will have an impact on current condition, while future maintenance practices can be altered to have a positive impact on future durability.

An example of this assessment is the case of an undamaged face-seal wall assembly in a medium-exposure situation. In some cases the wall

assemblies, if well constructed, may continue to perform adequately for many years. However, at some point the extent and effectiveness of maintenance in achieving a perfect face-seal may become difficult to achieve. Applying coatings as part of maintenance will improve the face-seal characteristics of the wall assembly and may prolong its life. However, the coating also makes the wall assembly more sensitive to water that enters the assembly, potentially aggravating the moisture problems. The prognosis is that the face-seal walls may be maintained for the short-or medium-term, but over the long term, performance is likely to decline.

### **3.2.3 Exposure conditions**

The influence of exposure on building envelope assembly performance is significant and needs to be accommodated by appropriate design.

Wind and rain loads, temperatures and the number of sunshine hours varies across coastal British Columbia. Despite the local variation in rainfall and sunshine, there have been many building envelope failures in areas of relatively less rain and more sunshine, such as Victoria, Delta and Richmond. The high ratio of wetting-to-drying cycles and moderate year-round temperatures at all locations are the critical factors contributing to an environment suitable for decay of wood-framed buildings.

The influence of wind needs to be included, since the amount of rain that meets walls is influenced by the extent that it is driven horizontally. Straube (1998) assesses the amount of rain that is collected by a vertical surface by both measurement and statistical analysis of raindrop movement vectors. In general terms, his findings show that stronger winds and finer rain drops result in greater "drift" in the rain drops and as a result, more

rain being deposited on walls. Therefore, areas of lower rainfall may have as severe a wind-driven rain index as other coastal areas, given higher wind speeds and lighter rainfall in those locations.

Part 4 of the *User's Guide—NBC 1995 Structural Commentaries* contains information about the actions of wind on structures. The severity of wind-driven rain on buildings is a function of the local wind speed and in general is highest at the corners and parapets of a building without roof overhangs. The effect of combined rain and wind pressure can result in as much as 50 mm (1.9 in.) of standing water on the cladding elements (calculated for 15 m (49 ft.) buildings in Vancouver), not including the kinetic effects of raindrops hitting the building surfaces. It can be seen that water and wind-shedding elements need robust design to resist this loading. These forces might be more severe at the top corners of buildings given the aerodynamic effects at these locations.

While relative humidity statistics are not recorded for many coastal communities in B.C., it obviously affects the drying potential of wall assemblies. The drier the air, the more moisture that evaporation can remove.

There is limited opportunity for the north side of buildings and buildings sheltered by trees to be heated by the sun. The north side of a building receives direct sun only near sunrise and sunset at the height of summer. This reduces the drying potential due to the temperature and humidity gradients of ambient air. Buildings that have longer and more drying periods often have similar wetting patterns but lower rates of wood decay than similar buildings in the coastal zone's wetter areas.

Clearly, determining exposure involves considering both building design and environmental factors. Design factors range from building orientation to how the building and its components deflect water. Environmental factors include duration and intensity of rainfall and wind velocity and orientation. Together, these factors will determine how often and for how long the building walls will be wet. Evaluating exposure can be simplified by considering only the three most influential factors: climate, overhang and terrain.

Although the coastal climate zone contains various microclimates with different rainfall intensity and wind directions, it is reasonable in determining exposure categories to consider the entire zone a severe-wetting environment. Accordingly, the following does not consider climate to be a variable.

Overhang is usually created by the roof but may also be created by other features, such as awnings or extended floor assemblies. An overhang ratio can be defined as:

$$\text{Overhang ratio} = \frac{\text{Overhang width}}{\text{Wall height}}$$

Where *Wall height* is the height above the lowest-affected wood element (so it does not include concrete foundation wall height.) and *Overhang* is the horizontal distance between the outer surface of the cladding and the outer surface of the overhang

Terrain has a large influence on how much wind-driven rain will reach the walls of a building. This *Guide* uses four categories, which are defined in Figure 3-1—Exposure category nomograph.

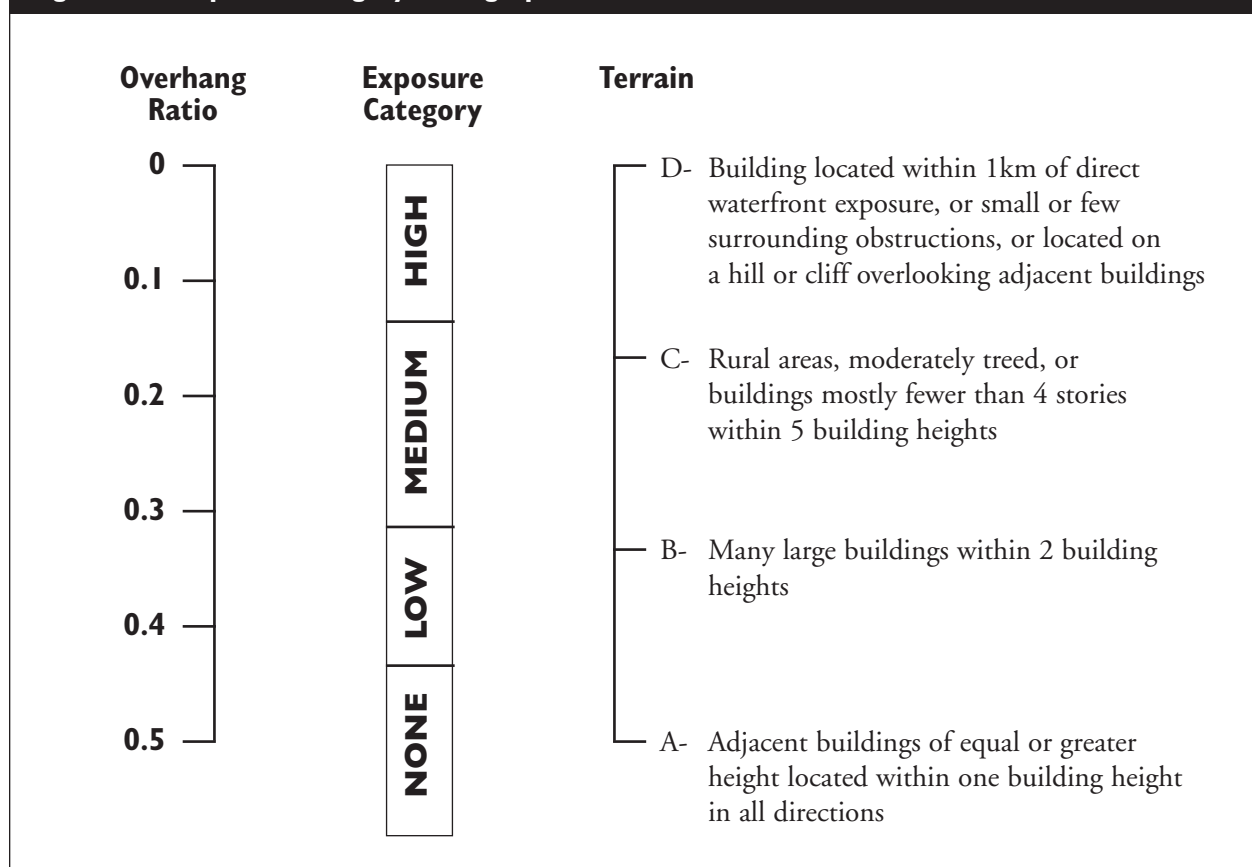
The nomograph in Figure 3-1 can be used to determine a general exposure category for different combinations of overhang ratios and terrain. Climate is assumed the coastal climate zone for all combinations of overhang and terrain.

For a new building, it is recommended that the selection of the wall assemblies be based on the highest exposure category for any location on the building. In rehabilitation design it is common to design wall areas for different exposure conditions on the same building in order to minimize the cost of rehabilitation. However, there is increased detailing complexity when

combining more than one strategy. For example, the transition between a face seal and a rainscreen assembly can be difficult. See discussion of this in Chapter 4—Construction documents.

Table 3-1, should be considered to assist in evaluating the potential performance of assemblies in controlling exterior moisture. Note that the table applies only to wall and window assemblies, as most horizontal envelope assemblies (roofs, decks, balconies and walkways) used in low-rise, wood-frame construction will utilize a face seal or barrier strategy (water shedding or waterproof membrane.)

**Figure 3-1—Exposure category nomograph**



**Table 3-1—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

The table compares general performance expectations of four exterior moisture control strategies for four exposure categories: high, medium, low and none. While these ranges are somewhat arbitrary and require an assessment by the designer they can be summarized as:

**High**—Wall is wet under normal service conditions and is subject to significant exposure to wind.

**Medium**—Wall is often wet under normal service conditions

**Low**—Wall is rarely wet under normal service conditions

**None**—Wall is not wet under normal service conditions

An example of a wall in exposure category *None* is a recessed ground floor level wall effectively protected from wetting by large overhangs.

The three performance expectation categories again are somewhat arbitrary in their definition but can be broadly summarized as:

**Good**—Wall assembly is likely to meet its expected performance criteria. There is low risk of failure occurring during the assembly's intended service life provided an appropriate maintenance program is followed.

**Fair**—Wall assembly may meet expected performance criteria although performance will be very dependent on quality of details, maintenance and local exposure conditions. There is a significant risk of failure within the expected service life of the assembly.

**Poor**—Wall assembly is not likely to meet the expected performance criteria. There is an unacceptable risk of failures occurring during the intended service life of the assembly.

The above discussion outlines performance expectations for general classes of exposure conditions. For existing buildings, examining the performance of the building envelope over the time it has been in service can better assess the actual response to particular exposure conditions. This will, in turn, help determine an appropriate rehabilitation strategy.

Photo 3-1 shows the impact of overhang on wall performance. In the area of wall protected by an overhang the wall sheathing (cladding has been removed) is undamaged. The area not protected by an overhang has begun to decay and is visibly stained. The poor transition detail between areas with roof overhang and those with no overhang has led to severe deterioration by focusing water runoff in a localized area.

In this case, it was the focusing of the water and saturation of the stucco that led to the problem rather than water penetrating past the stucco through holes at a joint.

--

**Photo 3-1—Impact of overhang on performance**



A range of wall and window assemblies suitable for the various exposure categories are described in detail in the *Best Practice Guide—Wood-Frame Envelopes in the Coastal Climate of British Columbia* and in "Assemblies" of this *Guide*.

### 3.2.4 Building form and features

The moderating influences of cornices, parapets, canopies and recesses on local rain deposit are complicated but substantial. In essence, any feature on a building that stills air in front of the building, or deflects the air around the building, has a beneficial effect on rain deposition.

Rain accumulates and then drains off buildings in paths that are defined by the building form and arrangement of building elements.

Penetration of water into the building occurs whenever a suitable hole or path is found by an accumulation of water and a driving force exists to move the water through the hole. Two fundamentals derive from this: first, accumulations of water anywhere on the surface of a building represent a potential leak and second, locations with holes must not get wet.

The configuration of building elements in relation to drainage of water is therefore an important design issue. Roof slopes, appropriate locations of drains and overhangs with drip edges that direct water off the building are important features. Where building design includes a façade without projections (overhangs) at each floor level, rainscreen technology allows control of rainwater such that water rarely contacts the primary moisture barriers within the wall assembly.

### 3.2.5 Existing assemblies, components and materials

Although existing building envelope assemblies, components and materials may not be deteriorated, they can still have an impact on the rehabilitation design. Examples of these considerations are:

#### Windows and doors

The evaluation of window and door performance and decisions regarding refurbishment versus replacement are discussed in detail later in this chapter. The decision whether to replace windows and doors as part of the rehabilitation program is not based solely on the condition and anticipated future performance of the window and door assemblies. Factors such as the cost-effectiveness of replacing these assemblies now rather than in the future when the work would

involve partial destruction of the adjacent wall assembly must also be considered. Further discussion of evaluation of windows can be found in "Assemblies" and in Appendix C.

### **At-grade waterproofing**

Since the flashing and wall moisture barrier should be lapped over the waterproofing of the at-grade assemblies, the advisability of replacing them as part of the rehabilitation program should be considered. It will be costly to replace and tie them into the wall properly in the future. If the membrane is nearing the end of its service life it may be more cost-effective to replace it when the wall is rehabilitated. In addition, the repeated cost of disruption to the landscaping should be also considered.

### **Roofing**

Similar to at-grade waterproofing, consideration should be given to replacement of the roofing at the time of any wall work. It can be cost-effective if the roof membrane is nearing the end of its useful life, since the transition detail at parapets would only need to be disassembled once. In addition, damage to the roofing will likely occur during the wall rehabilitation work, further reducing its life expectancy.

### **Quality of existing sealant**

Sealant will deteriorate over time, even in low-exposure areas or areas that are not having performance problems. Consider replacing sealant (possibly with higher quality sealant) at the same time as other rehabilitation work when it is cost effective and with the involvement of the consultant to specify appropriate joint design and installation. The quality of the installation is usually the important factor in the deterioration of sealant, not the material itself.

### **Exhaust vents and fireplace vents**

The quality of existing exhaust vents is often poor because there are no flanges for sealing with the wall assembly components, or the vent screens cannot be removed, or there is poor seal-to-duct work or no drainage. Consider replacing these items as part of rehabilitation.

## **3.3 Building science principles for rehabilitation**

The physics of building science do not differ from new construction to remedial construction nor do the climatic conditions to which the building is exposed. However, when remedial work is implemented it is often not possible to control or manage as many factors as can be controlled in new construction. For example, in new construction it is possible to define a distinct air barrier and to ensure the use of the same plane of airtightness throughout, while in remedial construction, the existing building may not have a well-defined air barrier.

The challenge in rehabilitation is to consider the existing conditions, building form and features and understand the mechanisms of deterioration so that appropriate rehabilitation measures can be implemented. In new construction a consultant can dictate the use of appropriate technology throughout, while in rehabilitation the consultant must assess how much of the existing technology can be left in place and still provide acceptable performance. Greater judgment is often required in rehabilitation than in new construction.

The *Survey of Envelope Failures in the Coastal Climate of British Columbia* documents that exterior water is the primary source of moisture leading to performance problems, rather than



interior sources or construction moisture. Furthermore the water gets into wall assemblies at details and assemblies fail because they are too sensitive—that is, they do not effectively drain or dry the moisture that enters the assembly. The appropriate design approach to resist water penetration from the exterior is selection of an appropriate wall assembly for the exposure conditions and proper design and construction of details.

*The Best Practice Guide—Wood-Frame Envelopes in the Coastal Climate of British Columbia* states that a durable building envelope "requires balancing the wetting mechanisms and drying mechanisms so that the moisture content is maintained within the tolerance level of the building materials. "This fundamental principle is as true for rehabilitation as it is for new construction. Consideration must be given to many factors in order to manage this balance effectively. The 4D-priorities for moisture management—deflection, drainage, drying and durability—also apply to rehabilitation.

It is important that property managers and strata councils understand why walls have failed and why different technology is required for rehabilitation. Developing this understanding will help them better communicate the technical issues to the other owners and better support the consultants and contractors as they implement the rehabilitation process.

### **3.3.1 Rain penetration control**

Most walls built since 1980 that have experienced no or low exposure (see "Exposure conditions") will not have deteriorated as a result of water penetration.

Walls in medium- or high-exposure conditions that have failed typically use either face-seal or concealed-barrier strategies. If Figure 3-1 were used to determine appropriate assemblies for given exposure conditions, the rehabilitation wall assemblies would use rainscreen or exterior insulation rainscreen strategies. An alternate approach to manage rainwater penetration—by altering the building form to reduce exposure conditions—is discussed later in this chapter. It may therefore be possible to combine modifications to building form to reduce exposure conditions with concealed barrier wall assemblies. It may also be possible to reduce exposure conditions and incorporate improvements to details in order to achieve an effective moisture balance.

Many existing building envelope situations are not clear-cut in terms of the remedial measures required. These situations include:

- Low-exposure face-seal walls that have experienced damage at many similar details. Although the extent of damage is localized, the removal of the cladding, repair of the decay and reinstatement of the cladding can only be done cost-effectively by removing all the cladding. In these situations, should the new wall assembly be of rainscreen design, and thus less sensitive, but slightly more costly than the previous wall assembly?
- Medium-exposure face sealed walls where only minimal deterioration has occurred due to a lack of problematic details. Should a new rainscreen wall assembly be provided as suggested in Figure 3-1 or should the deteriorated areas be repaired and diligently maintained?

- Medium-exposure conditions where moisture probes indicate high moisture content in many locations on the face seal-walls but decay has not started due to the short service life of the walls. Should the undamaged walls be remediated with rainscreen walls or should attempts be made to improve details, reduce exposure conditions and diligently maintain the face seal?

To make the best choice a large number of variables must be considered. This chapter describes these issues in the context of the development of an appropriate rehabilitation program.

Many wood-frame buildings that have experienced moisture problems are not the more difficult situations described above. Rather, they are medium- to high-exposure situations with either a face-seal or concealed-barrier water management system, combined with evidence of widespread systemic failures and decay. These situations generally dictate a comprehensive rehabilitation program. As concluded in the *Survey of Envelope Failures in the Coastal Climate of British Columbia*, water enters the wall assemblies at interface details because attempts to create and maintain a perfect seal at interfaces have not been successful. The wall assemblies were too sensitive to accommodate the quantity of moisture that was introduced to the wall. In simple terms, these systems failed because they were not suitable for the exposure conditions.

Two important changes in technology are suitable for rehabilitation in these clear-cut situations: the use of rainscreen wall assemblies and the use of improved details. Detailing issues are discussed in Chapter 4—Construction documents. The potential change in wall assemblies is discussed in more detail later in this chapter.

### 3.3.2 Controlling other moisture sources

The primary moisture source causing the problems is rain penetration; however other sources, including condensation due to air leakage or vapour diffusion, construction moisture and mechanical ventilation, must be considered in managing the moisture balance in the rehabilitation of the building envelope.

#### Air leakage control

In new construction it is possible to define a distinct air barrier and to ensure the use of the same plane of airtightness throughout. However, for remedial projects, there are a number of additional factors to consider when selecting a method of controlling air leakage.

#### What is the air barrier in the existing construction?

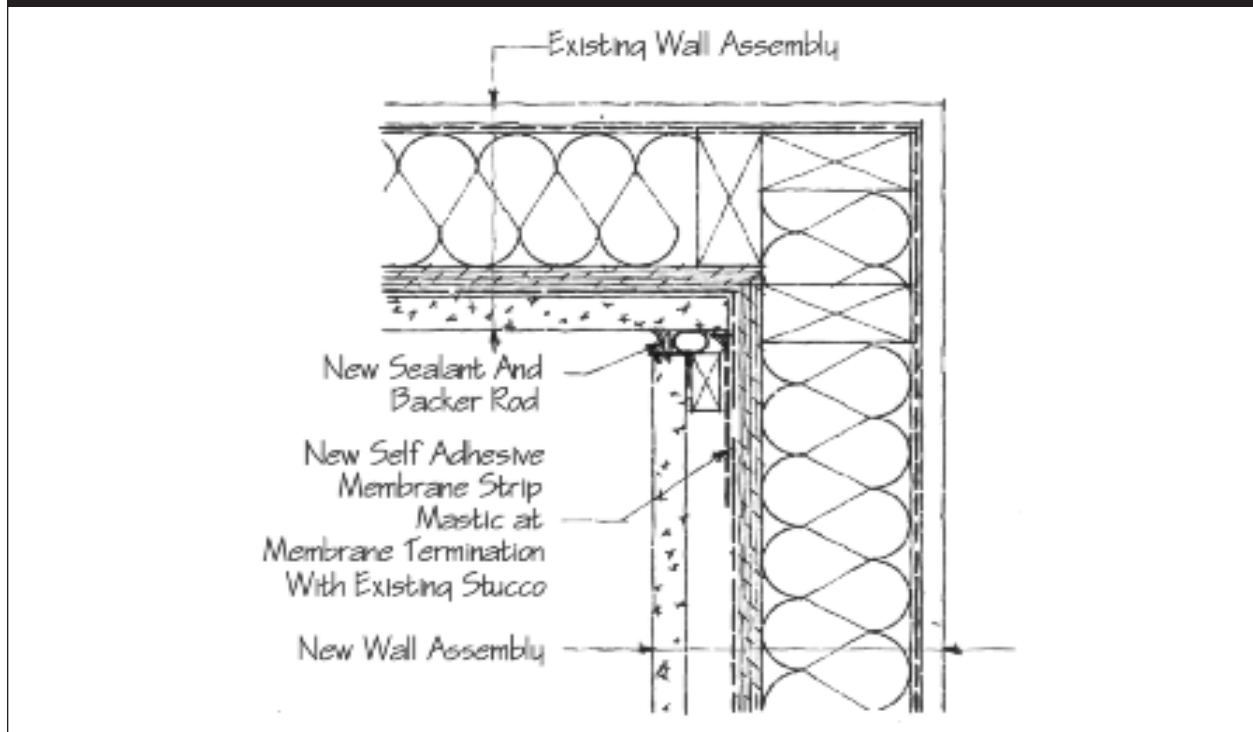
The air barrier is not usually identified in the design documents for most buildings that need remedial repairs. Therefore, the consultant for the remedial work must determine which of the wall assembly components is the most airtight and then detail the air barrier in the remedial repair to be sealed to this component. For example, it is probable that for most stucco clad buildings, the stucco is the most airtight component in the original wall assembly and that installation of a conventional rainscreen wall assembly without consideration for the air barrier will result in greater air leakage.

#### How can the air barrier in the new construction be effectively tied to the air barrier in the existing construction?

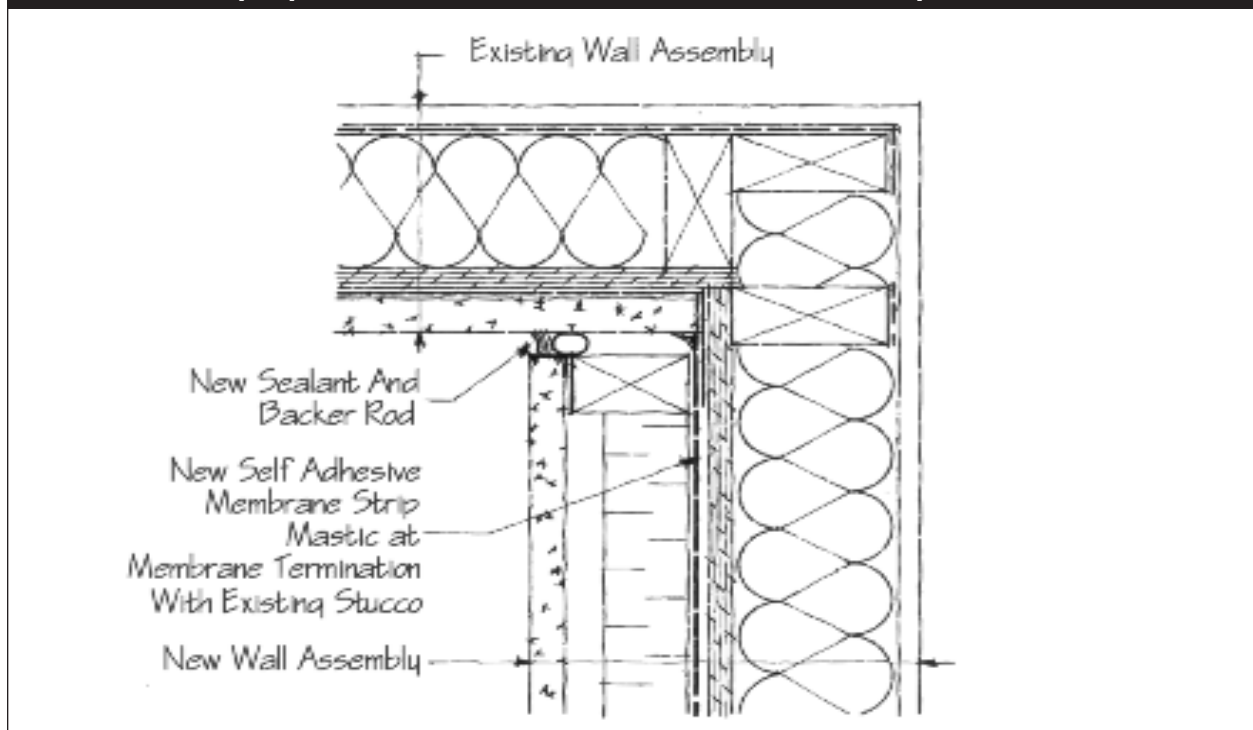
Once the most-airtight component in the building has been identified, the remedial wall assembly must be constructed so that the air barrier in the new wall assembly is sealed to the identified component. Examples of how this can be achieved for a face-sealed stucco clad wall assembly are illustrated in Figure 3-2 and Figure 3-3.



**Figure 3-2—Continuity of air barrier between new, strapped-cavity rainscreen wall assembly and existing face-seal assembly. These transitions should be made at low-exposure locations on the building if possible.**



**Figure 3-3—Continuity of air barrier between new dual insulation rainscreen wall assembly and existing face-seal assembly. If possible, these transitions should be made at low-exposure locations on the building.**



### Will adding an air barrier to one part adversely affect the remainder?

Air barriers have three primary purposes in a wall assembly. First, by reducing the inward flow of air they reduce the probability of water penetration. Second, by reducing the outward flow of interior air they reduce the probability of condensation forming in the wall assembly. Third, by reducing flow of air in either direction they reduce the building's energy requirements.

For most projects, the addition of an air barrier to part of the building envelope will not adversely affect the remaining areas. Reducing the inward and outward flow of air through part of the building will reduce the volume of air that penetrates the building envelope as a whole. The exception occurs when an improved air barrier is added to the complete structure except for a small area. Under this condition, there may be a localized increase in the air-leakage flow occurring at the area without an air barrier. This may or may not have consequences for moisture management performance—it will depend on whether condensation is likely to occur and where it occurs.

These general rules regarding air barrier implementation in remedial construction of three- and four-storey buildings can not be applied to high-rise structures that experience significant stack effect, or to buildings with mechanical pressurization.

Three methods of air-leakage control are discussed in the *Best Practice Guide—Wood–Frame Envelopes in the Coastal Climate of British Columbia*. They are:

- Sealed polyethylene approach.
- Airtight drywall approach.
- Exterior air barrier approach.

In the *Best Practice Guide—Wood–Frame Envelopes in the Coastal Climate of British Columbia* the exterior air barrier approach is illustrated with an adhered waterproof membrane acting as a vapour barrier, an air barrier and a moisture barrier. When this approach is adopted, there must be insulation on the exterior of the waterproof membrane to control condensation.

Another approach for the exterior air barrier approach is not discussed in detail in the *Best Practice Guide—Wood–Frame Envelopes in the Coastal Climate of British Columbia*. It is the use of a vapour-permeable air barrier on the exterior of the insulation. An example of this is applying housewrap on the exterior sheathing. The use of a vapour-permeable air barrier may be the only economical selection when the wall that is being repaired does not contain a well-defined air barrier and exposure conditions do not warrant the use of an exterior insulation rainscreen. The use of a vapour-permeable exterior air barrier may also be optimal when the level of deterioration in the existing wall assembly does not require removal of the plywood or disruption of the interior finishes.

The air barrier must be capable of resisting the wind loads for the design life of the cladding. When vapour-permeable sheathing papers are used on the interior of a cavity, the sheathing paper is supported only at the strapping locations. When installed this way, negative pressures—such as those created at parapet level, corners and so on—will pull the sheathing paper into the cavity, where it might tear. Applying additional strapping at locations of high differential pressure will increase the support provided to the air barrier; however, locations of high differential pressure are the locations most prone to water penetration and subsequently, the locations where an unobstructed cavity is most critical.

## Vapour diffusion control

In virtually all low-rise wood-frame buildings that are being rehabilitated, the vapour barrier is a layer of polyethylene located just outside the interior gypsum board in the wall assembly.

In situations where a rainscreen wall using a strapped cavity over a relatively vapour-permeable sheathing paper, such as housewrap or building paper, is created as part of rehabilitation, then the polyethylene can generally be left in place to continue functioning as the vapour barrier. This is also true if the wall assemblies are rehabilitated but a face-seal or concealed-barrier exterior moisture control strategy is maintained.

Remove the polyethylene sheet if using an exterior insulated rainscreen wall assembly with a vapour-impermeable membrane over the exterior sheathing. There is a discussion about the amount of insulation required on the exterior of the self-adhesive membrane later in this chapter.

## Construction moisture

Ensuring that the moisture content of the framing lumber and sheathing is below 19 per cent when the building is enclosed is good practice and is even required by code in some jurisdictions. This rule is equally applicable in rehabilitation construction. Very few problems related to differential shrinkage have occurred or been reported in rehabilitation work, most likely due to the existing structure's ability to accommodate small amounts of differential shrinkage and the better attention to details which accommodate some shrinkage.

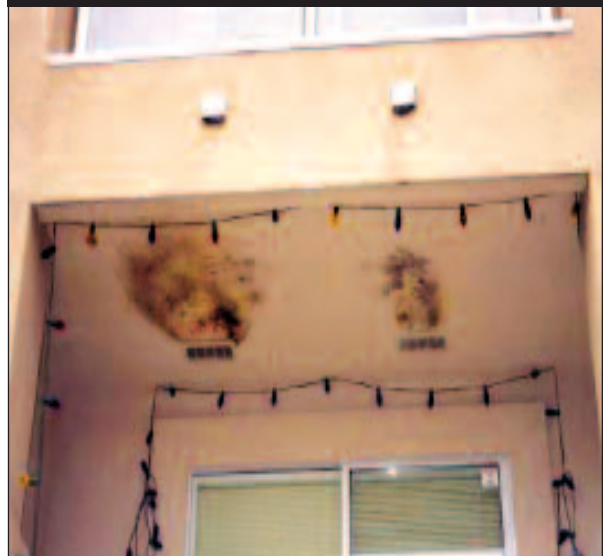
The use of self-adhesive membranes at interface details and, in some cases over entire wall areas, caused greater concern about excessive construction

moisture. The fact that self-adhesive membranes are vapour-impermeable means that construction moisture in the wall assembly cannot readily dry to the exterior at many of the of the interface details. In addition, if the moisture can not readily migrate to other parts of the wall where it can potentially be removed, then the conditions created are ideal for wood decay. The wood materials must be dried to a moisture content of 19 per cent or lower before closing in the wall assembly.

## Mechanical ventilation

The penetration of the envelope with exhaust ducts and fireplace vents has been linked both to rainwater ingress points but also to air leakage out of the duct and condensation related-damage in the surrounding framing. See Photo 3-2. Using improved details and better vent assemblies in rehabilitation should eliminate these problems.

**Photo 3-2—Poor sealing of vent assembly to duct boot and grills leads to moisture damage**



Mechanical ventilation of suites through bathroom and kitchen fans can be used to manage interior moisture sources. High humidity levels in suites can lead to condensation-related damage within wall assemblies or to condensation moisture at windows—or to both. This leads to mold or decay in adjacent wall assemblies. Using good quality fans wired to humidistats to manage interior moisture sources may be a feasible rehabilitation strategy. In some cases, it may be a low-cost way to justify keeping existing non-thermally broken windows rather than a window replacement program if other factors do not dictate window replacement.

### 3.4 Architecture–Zoning

In some cases, rehabilitation strategies and techniques alter or eliminate original architectural features, either replacing them with simpler features or introducing new elements that disregard the designer's original intent. These changes may not only affect the appearance of the building but performance in areas such as acoustics, fire safety and site drainage.

In addition, the focus of many consultants has traditionally been on improvement of the existing building configuration and they may have missed cost-effective opportunities to change the building form and resolve moisture problems. Examples of this include adding overhangs to walls to reduce exposure, adding roofs and enclosing walkway structures or adding glazed canopies over vulnerable areas.

The following are general comments about esthetics, zoning and planning arising from remedial work that goes beyond simple repair and improvement to existing assemblies and details. Chapter 4—Construction documents discusses municipal building codes and bylaws.

#### 3.4.1 Esthetic considerations

Often the most obvious result of rehabilitation work on a building is a change to its appearance. Any modification to a building's exterior, whether involving painting, change of cladding material, addition of flashing or more extensive work, such as addition of canopies, roof structures or balcony enclosures, can have a dramatic impact on the overall esthetics of the building. Esthetics are usually perceived in an individual and subjective manner and building designs, especially in the case of recent residential developments, cover a very wide stylistic range. For these reasons, it is difficult to evaluate potential visual impact of any of the remedial measures in general terms.

While other implications of remedial measures will be discussed individually below, this commentary on esthetics is limited to a general suggestion that care should be taken to select profiles, materials and colours which complement or enhance the original design. Revisions that do not respect the original design intent may have a detrimental effect on the building appearance and, ultimately, its resale value. It is important to make building owners aware of the esthetic impact of proposed changes. In some municipalities proposed design revisions may be referred to an advisory design panel, which will comment on proposed changes.

#### 3.4.2 Zoning considerations

Zoning regulations, through their control of development density, building massing and form, influence weather exposure and building performance. For example, building floor areas and setbacks are typically measured to the outside face of the exterior wall. This is a disincentive to better-performing wall assemblies, as their additional thickness has to be deducted from net floor area. In other instances, stepped massing

is often encouraged, which results in the creation of many fragmented roof and roof deck areas with vulnerable roof and wall junctions.

In recognition of the seriousness of the building envelope failure issue, Vancouver and other municipalities are considering changes to relevant portions of their zoning regulations. In the meantime, in Vancouver the director of planning can often relax existing setbacks, while the board of variance can approve FSR- (Floor-space ratio) related relaxations. In other municipalities variance processes may differ, with council approval often required. It is essential that plans for rehabilitation work that involve changes to a building's external parameters be reviewed with the local planning department for bylaw compliance. A simple check of the zoning bylaw may not be sufficient. Some jurisdictions, particularly Vancouver, rely on design guidelines and both published and unpublished administrative bulletins in addition to their zoning regulations.

The B.C. Ministry of Municipal Affairs and the Homeowner Protection Office (HPO) recently released *Land Use Planning and Weather Protected Buildings: A Best Choices Guide for Local Government*. It deals with many of the zoning and planning issues that may discourage good building envelope design practices. It is not yet clear how municipalities will incorporate recommendations from this document. As implementation becomes clearer parts of the following may require updating.

### 3.4.3 Addition of roofs and canopies

Increased shelter and rain protection (reduced exposure) of balconies, exterior walkways, doorways, entryways and windows can be provided by adding roofs or canopies. These can be made of a variety of materials, such as metal, glass, wood or even fabric.

**Photo 3-3—Adding canopies over patio doors and extending roof overhang over upper level arch windows to reduce exposure**



### Zoning bylaws

Zoning regulations regarding covered balconies, walkways and stairs vary between jurisdictions and are often subject to staff interpretation. For example, in certain districts of Vancouver a stepped building mass is permitted to provide a transition and light angles between adjacent buildings of different use or scale. To the planning department any cover over a roof deck, top floor balcony or walkway will have an impact on neighbouring buildings and will result in these areas being included as part of the building's floor area. Similarly, adding canopies or awnings to an existing building may be governed by zoning bylaws. In view-sensitive areas of the city, potential view-blockage can also be a major issue.

Any proposal to add a cover on an existing building should be reviewed directly with the municipal authority.



### 3.4.4 Enclosure of exterior space

Providing complete or partial enclosures to balconies, walkways and exterior stairs can be an effective method of reducing a building's exposure to water penetration. However, it can be costly and may have many serious technical, livability, zoning and building code implications.

**Photo 3-4**



**Photo 3-5—Enclosure of walkway to reduce exposure includes addition of roof over upper level and glazing in openings**



## Zoning

Municipal approaches to regulation of balcony enclosures vary greatly.

Policies, especially in Vancouver, can differ from zone to zone. Enclosed balconies are allowed or even encouraged in some areas and prohibited in others. Exceptions are often granted in locations with heavy traffic and noise. Check zoning regulations to confirm that enclosure of balconies does not create floor area more than the allowable maximum FSR and do not contravene building setback regulations. In Vancouver, detailed requirements for enclosure of balconies are contained in *Balcony Enclosure Guidelines* issued by the planning department.

Open walkways and exterior stairs are common in many recent projects, particularly in Vancouver. Review the original FSR calculation when planning enclosure or partial enclosure of exterior walkways and stairs. If they were excluded, the scope for their enclosure may be very limited without special approval from the municipality.

### 3.4.5 Additional protection of walls

Adding overhangs, projecting cornices or wider cap flashing can reduce weather exposure of exterior walls.

#### Zoning bylaw

Generally, most municipalities allow elements such as eaves, gutters, cornices and so on to project beyond the building face and into yards. Where building face is at or near a property line, it is usually not legal to extend any projection beyond the limit of the site. The exceptions include the installation of awnings over sidewalks in commercial zones and replacement of existing cornices on historic buildings. In special cases, Vancouver allows projections over street rights-of-way.

### 3.4.6 Reconstruction of exterior walls

Redetailing and reconstruction of exterior wall assemblies can include a drained and ventilated cavity as well as materials that are more durable. There is a variety of wall assembly options, ranging in type of material and total assembly thickness, in some cases adding up to 12.7 cm (5 in.) to the total wall dimension.

#### Zoning Bylaw

Many buildings constructed recently tend to maximize their perimeter by using minimum setbacks allowed by local zoning regulations. They also typically maximize their allowable floor area. In both instances the measurements are taken to the building face and any remedial work that results in a substantially thicker wall assembly could technically contravene zoning regulations. It is therefore necessary to secure planning permission before going ahead with remedial work. Some municipalities, in recognition of the gravity of the building envelope failure problem, are willing to relax their regulations to allow the necessary remedial work.

In Vancouver, the increase of building floor area beyond the allowable maximum requires board of variance approval. This should not be difficult to obtain with planning department support. The situation may be more difficult with walls at property lines. Many buildings are situated 20 to 50 mm from property lines, which may allow for remedial work. In other instances legal encroachment agreements may be required, a difficult and cumbersome procedure. Photo 3-6 and Photo 3-7 show a building that has been rehabilitated using rainscreen wall assemblies. In addition, some features of the building have been changed with the addition of new metal and glass guards and the elimination of the wood band at window and balcony perimeters.



**Photo 3-6—Previous walls and balconies**



**Photo 3-7—Rehabilitated building featuring rainscreen stucco clad walls, revised balcony guardrails, new windows and cross-cavity flashing at window head**



### 3.4.7 Landscaping modifications

Rehabilitation may require modifying site landscaping, paving and drainage to reduce ambient and deflected moisture to exterior walls. Modifications may also be needed to make access easier to concealed membranes over parking garages and other, similar locations. These modifications may involve removal of planters next to buildings and replacement of cast-in-place paving with unit pavers.

## 3.5 Structure

### 3.5.1 Building structure

The amount of structural damage is a factor in determining the extent of envelope reconstruction and therefore has an impact on the overall rehabilitation design.

For example, considering potential use of a strapped-cavity rainscreen wall assembly is much different for a building with significant structural damage than a similar building with damage that is not yet severe. In the first instance the structural damage dictates complete removal of the cladding and sheathing to address the structural deterioration. Thus, the incremental costs to put back a rainscreen wall assembly rather than a concealed-barrier wall assembly is low (see discussion of relative costs in Chapter 5—Tendering).

Alternatively, cladding may only need to be removed locally to address wood decay. In this scenario, incremental cost to remove all the cladding and replace it with a strapped-cavity rainscreen wall assembly is higher. Other factors, such as predicted future durability and in-service exposure conditions become more important in justifying the use of rainscreen wall assemblies.

### 3.5.2 Platform framing—general description

Platform framing is the usual method of wood-frame construction in coastal B. C. (see Figure 3-4). Stud walls are erected one storey at a time, followed by the construction of floors consisting of floor joists and floor sheathing. This creates a platform for construction of the next storey. The stud walls are prefabricated on the floor, elsewhere on-site, or off site and then lifted into place. Construction culminates in the installation of roof joists or trusses.

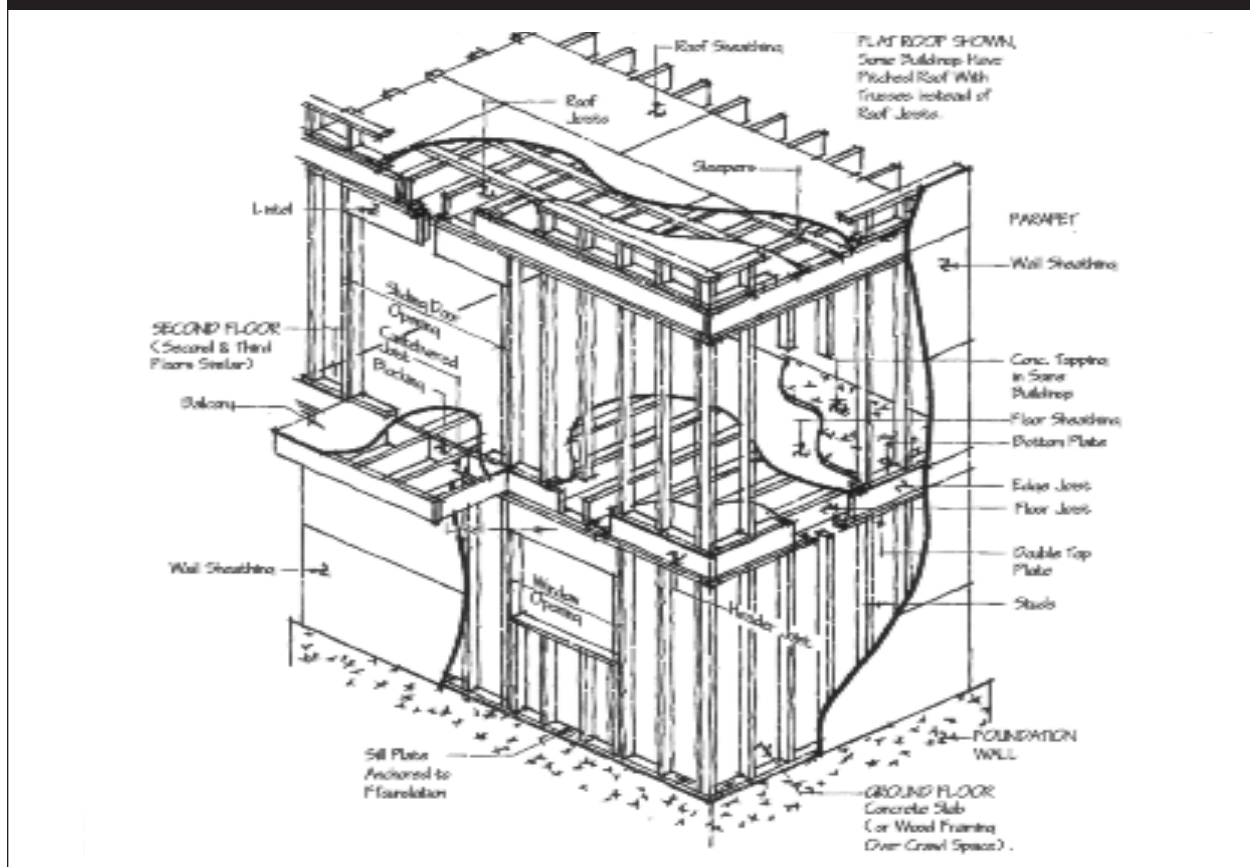
At the exterior walls of a multi-storey wood-frame building, the floors are essentially clamped between successive storeys with vertical loads being transferred from one storey to the next through the edge of the floor structure.

### 3.5.3 Loads

Consultants involved in rehabilitating wood-frame buildings should know the requirements of the *British Columbia Building Code 1998* (B.C. BC) for wood-frame design and construction.

The structure must be designed to support the loads prescribed by the B.C. BC. For residential buildings of three storeys or less and a building area not exceeding 600 m<sup>2</sup> (6,458.5 sq. ft.) Part 9 of the B.C. BC, "Housing and Small Buildings," applies. For larger residential buildings, Part 4, "Structural Design," applies. The B.C. BC defines building area as "the greatest horizontal area of a building above grade within the outside surface of exterior walls or within the outside

**Figure 3-4—Typical wood-frame structure components**



surface of exterior walls and the centre line of firewalls." Vancouver's *Building Bylaw 1999* (No. 8057) contains some unique provisions about Part 4.

For buildings designed under Part 4, the most common loads that must be considered in designing a wood-frame structure are:

- Dead loads, which consist of the weight of the structural member itself, the weight of all construction materials permanently supported by the member, the weight of non-load bearing partitions and the weight of permanent equipment.
- Live loads due to use and occupancy.
- Live loads due to snow, ice and rain.
- Live loads due to wind and earthquake.
- Horizontal loads on balcony guards.

With the exception of dead loads, Part 4 specifies minimum load values either directly or through formulas. The designer calculates dead loads.

For buildings designed under Part 9, the B.C. BC provides a simplified formula for calculating snow load and allows lower minimum live load values for bedrooms, balconies and attics other than those specified in Part 4. These provisions apply to wood-frame assemblies with clear spans not exceeding 12.20 m (40 ft.) and members spaced not more than 600 mm (24 in.) apart. Part 9 provides span tables. From the span tables, a designer can select lumber joists, rafters, lintels and beams, within certain limitations, without calculating dead loads as the tables account for typical dead loads. Larger dead loads than those accounted for must be addressed separately by the designer.

Part 9 does not require that live loads due to wind and earthquake be calculated, nor does it require a structural analysis and design of the lateral load resisting system. It is implied that

if specific Part 9 requirements for wall sheathing, bracing, sill anchor bolts, and so on, are followed the structure will be adequate to resist wind and earthquake loads. This is a result of structural redundancy in most typical, small, wood-frame residential buildings. The designer must recognize, however, that Part 9 does not deal adequately with buildings with non-typical features. These buildings require analysis and design in accordance with Part 4.

Part 9 and Part 4 also differ about horizontal loads on balcony guards. Part 4 specifies loads, but Part 9 specifies neither loads nor minimum member sizes. B.C. BC sentence 9.4.1.1.(1) covers such cases by requiring that structural members and their connections be designed in conformance with Part 4 if there are no specific requirements listed in Part 9. However, explanatory clause A-9.8.8 confuses the issue somewhat by stating that guards "may be accepted on the basis of experience or by structural design."

### 3.5.4 Function of framing members in resisting loads

Understanding the function of the members within the exterior walls is the key to successfully rehabilitating a wood-frame building (see Figure 3-4).

**Studs** carry vertical loads from the underside of a floor or roof down to the top of the floor below. Studs in exterior walls also act like beams, spanning floor-to-floor or floor-to-roof, carrying horizontal wind loads into the floor and roof diaphragms. Studs also provide support for the wall sheathing, allowing it to develop shear resistance in the plane of the wall to resist lateral loads produced by wind and earthquakes. Extra studs, or built-up studs, are required to provide extra bearing capacity beneath point loads from beams, lintels and so on.

**Wall plates** Top wall plates in load-bearing walls provide a bearing surface for roof and floor framing members, transferring vertical loads to the studs. Double top plates are generally used, in which case the studs need not line up with the roof and floor framing members and the plates act as a beam spanning between studs. Bottom wall plates provide a bearing surface for the studs, transferring the vertical loads to the floor framing or foundation wall. The top and bottom wall plates also transfer wind loads from the studs to the floor and roof diaphragms. The top and bottom plates also provide support for the edges of the wall sheathing and transfer shear forces from the floor and roof diaphragms to the wall sheathing.

**Lintels** over window and door openings transfer vertical loads from above the openings to the studs on each side of them. Lintels also carry horizontal wind loads to the adjacent studs and provide support for the edge of the wall sheathing above openings.

Wall sheathing, through shear wall action, contributes to the capacity of the structure as a whole to resist lateral loads due to wind and earthquake and serves as a backing for the exterior cladding. Wall sheathing, along with the interior drywall, also serves to brace studs and other compression members against lateral buckling. If wall sheathing is not required for fastening or backing of the exterior finish, the B.C. BC allows diagonal bracing to be used instead of sheathing to provide resistance to lateral loads for Part 9 buildings.

**Specially detailed shear walls** In some buildings, selected exterior walls may be designated as shear walls and be specially detailed to provide more resistance to lateral loads than typical exterior walls. Special detailing could include use of different or thicker sheathing materials, blocking of sheathing joints, chords, drag struts, additional nailing and hold-down anchors.

**Floor joists** Where an exterior wall is at right angles to the joist span, the joists bear partially on the top wall plate and a header joist is installed flush with the outside edge of the plate. Where an exterior wall is parallel to the joist span, the edge joist is installed flush with the outside edge of the top wall plate. In both cases, the edge of the floor joist assembly transfers vertical loads from the wall above to the wall below. The header and edge joists provide support for the edges of the floor sheathing and transfer shear forces from the floor diaphragm into the exterior walls. The header joists also provides lateral support to the floor joists. Where joists are cantilevered over the exterior wall, full-depth blocking is generally installed between joists in the wall to provide lateral support for these joists and to assist in transferring wall loads from above.

**Floor sheathing** In addition to supporting vertical loads, floor sheathing (through diaphragm action) distributes lateral loads due to wind and earthquake to the shear walls in the building.

**Fasteners**, including nails, staples and framing hardware, are required at all connections between framing members to transfer loads that cannot be transferred by direct bearing and to hold members in position on their supports. Adequate fastening of wall and floor sheathing to its supports is essential to achieve shear wall and diaphragm action. Other critical fasteners in the exterior walls include joist and beam hangers, roof truss hold-downs and sill-plate anchors.

### 3.5.5 Original materials

The framing materials most commonly encountered in existing multi-unit wood-frame buildings have not changed significantly over the past 25 years. Allowable design stresses



for dimension lumber have changed but standard sizes have not. Finger-joined studs have become more common.

Manufactured wood products, such as prefabricated wood I-joists, have come to be used as a substitute for solid sawn lumber in more recent years.

Where glued-laminated beams were used 25 years ago for unusually long or heavily loaded spans, other manufactured wood products, such as parallel-strand lumber and laminated-veneer lumber are now commonly available. These products have also become more common for lintels.

The most commonly used floor and wall sheathing materials over the past 25 years have been plywood and oriented strand board (OSB). The use of board sheathing (shiplap) has been limited in recent years, except—perhaps—in construction of small Part 9 buildings.

In the recent past, waferboard was also produced and used for wall and floor sheathing. The lay-up of wafers was random, resulting in about the same properties in both principal panel directions. Improved strength and stiffness properties were achieved when the lay-up of wafers was aligned and the industry has largely converted to produce only OSB.

## 3.6 Durability

### 3.6.1 Design for durability

Design for durability is at the heart of the recent crisis in condominium deterioration. It is also a recent addition to building codes. Until recently, durability issues were specifically excluded from building code requirements unless they had a direct life-safety consequence.

The 1998 *B.C. Building Code*, in section 5.1.4, specifically refers to the durability of materials in the building envelope assembly. It requires that the materials be "compatible" with adjoining materials and "resistant" to any mechanisms of decay that can reasonably be expected given the use of the material. The code further refers to the CSA S478 durability standard, which provides guidelines on service life and materials use. These requirements more clearly establish the consultant's responsibility for durable designs, although they do fall short in setting out specific durability performance expectations.

Other Part 5 references to durability relate to protection from various moisture sources, such as condensation, air leakage, precipitation and groundwater. Other examples of design for durability in Canadian codes are in CSA S413, which mandates specific durability measures for concrete parking structures. It was introduced in 1994 because of large-scale deterioration of concrete structures similar to recent experience with wood-frame residential buildings in B.C.

The use of stainless steel brick ties in the CSA A370 masonry connectors standard is an example of a component that has a high requirement for reliability in service, is difficult to inspect, maintain or repair and therefore requires high durability.

Table 3-2 gives typical moisture control functions, service life expectations (these vary depending on type of materials used) and design loads for components and materials within a strapped-cavity rainscreen wall assembly. These loads must be considered in the context of the service life expectations to arrive at durable designs.

**Table 3-2—Consideration of durability service life**

Zones	I	II	III	IV
Name	EXTERIOR CLADDING	CAVITY	PRIMARY OR SECONDARY STRUCTURE	INTERIOR WALLBOARD
Moisture control functions	Shield cavity from extremes of weather	Prevent rain and snow crossing, facilitate drying	Support gravity loads, seismic loads, wind loads, air barrier	Support finishes, vapour barrier
Secondary functions	Keep people out, resist impact, aesthetic	Control noise	Space to hold insulation, electrical and mechanical service corridor	Keep people in building, esthetic
Service life (years)	20–50	20–50	50–100	50–100
Ambient temperature–C	Minus 20–50	Minus 20–50	16–32	16–32
Moisture load (free water present)	Rain and snow, time of wetness 50 %	Water and frost, time of wetness 10–20 %	None, time of wetness 0 %	Spills, condensation, time of wetness < 5 %
Humidity load (% RH)	40–100	40–100	20– 80	20–100
Insects	Yes	Yes	Maybe	Maybe
Other effects	UV and heat aging, acid rain, alkalis, electro-chemical	Heat aging, sound transmission, inspection access		Cleaning

Mandating design for durability implies establishment of a defined service life for building envelope components. Achieving appropriate specifications for building envelope components therefore involves all of the usual Part 5 requirements for performance-in-service with the additional requirement that the function be preserved for a specific term. The consultant can identify design-service lives of materials, components and assemblies to the owner. The owner can then confirm the design-service lives before the consultant proceeds with the design. The selection of these periods is potentially

a problem for a consultant, since stating the design durability of an assembly, component or material may be interpreted as a warranty over which the designer does not have complete control. Local exposure conditions, the quality of construction, materials and maintenance all have an impact on meeting durability performance criteria. It is important that the owners understand that the consultant cannot guarantee service lives.

Table 3-3 summarizes suggested normal periods for design-service lives for residential buildings and most major components.

**Table 3-3—Suggested design-service lives**

<b>Building or component</b>	<b>Normal design life</b>
Residential building	50 to 99 years
Primary and most secondary structures	Same as the building
Cladding, window frame	More than 25 years
Window—insulated glass unit	More than 10 years
Roof membrane, deck membrane	More than 15 years
Balcony membrane	More than 10 years
Interior finishes	More than 5 years

These design lives are not specified in CSA S478. In the absence of specific performance criteria set out by authorities with jurisdiction they would be considered reasonable by most owners of wood-frame homes in B.C. Specific building materials are expected to last shorter or longer periods, depending on how easy they are to replace and ease of maintenance. At the end of these design-service lives it is likely that many components or assemblies will continue to provide acceptable service with no significant work required, while others may begin to require significant renewal or even replacement. However, it is not anticipated that cladding will fall off the building or water begin to penetrate the building the moment the design-service life ends. The aging of buildings is a gradual process with many factors at work. For this reason, maintenance and renewal plans need updating every few years to reflect actual performance of materials, components and assemblies.

It is also worth noting that replacement of cladding, windows and so on, is not always the result of assembly or component failure. They may be replaced because of changes in performance expectation, new technology or for esthetic reasons.

The following is a checklist of specific durability and service-life considerations:

- ☐ Expected service life of the primary structural system.
- ☐ Expected service life of the secondary structural system.
- ☐ Expected service life of cladding, such as stucco, vinyl, wood siding and metal flashing.
- ☐ Expected service life of all hidden components of the wall assembly outside the moisture barrier, such as ties, fasteners, wood strapping, sheathing papers and membrane flashing.
- ☐ Expected service life of roof shedding surface or roof and deck waterproof membranes, including penetration details.
- ☐ Expected service life of balcony membranes.
- ☐ Expected service life of the window and door frames.
- ☐ Expected service life of the doors and door hardware.
- ☐ Expected service life of operable vents in window assemblies.
- ☐ Expected service life of insulating glass units in windows and doors.
- ☐ Expected service life of wet and dry glazing seals in window assemblies.
- ☐ Expected service life of sub-grade drainage



and waterproofing.

- ❑ Material compatibilities and resistance to corrosion and other mechanisms of deterioration, given the nature, function and exposure of the materials.
- ❑ Is accessibility for all materials and components of the envelope consistent with the expected service lives and does it facilitate appropriate sequencing of renewal activities?
- ❑ Have appropriate design loads, performance and test criteria been specified for performance-based portions of material and component specification, for example, wind loads, airtightness and watertightness?
- ❑ What manufacturer and contractor guarantees and warranties are appropriate?

### 3.6.2 Precedent

Performance established by experience with traditional wall assemblies is not always adequate guidance for design decisions if there have been major changes to the environmental design parameters (for instance, exposure, temperature and humidity gradients.) In fact, inappropriate reliance on precedent has resulted in the many envelope failures in larger, more exposed buildings in recent years. For example, older stucco-clad buildings that performed well were quite different than the walls typical of leaky condominiums. These older walls may not have contained insulation or polyethylene, permitting a strong moisture drive out of the assembly. The stucco was applied over wood lath that created a cavity between the lath and the sheathing or sheathing paper. This facilitated drainage. In addition, many older buildings incorporate cornices or overhangs that reduce exposure conditions.

The successful performance of bricks and brick-veneer wall assemblies (rainscreen) in the coastal climate under medium exposure conditions is a good example of how precedent can provide confidence in wall assembly design. Experience with the use of rainscreen wall assemblies employing a variety of air barrier membrane, insulation, glazing and cladding systems is topping 30 years, which approaches design-service life expectations.

### 3.6.3 Temporary repairs

In some instances, a building needs temporary repairs before starting the main remedial work. These repairs are usually either emergency structural repairs or temporary tarping to prevent water ingress.

If the consultant identifies a life-safety concern or questions the structural adequacy of a building element, emergency structural repairs must be made immediately. A structural engineer should review the condition and design any temporary shoring required. A building permit is required before doing permanent repairs. A building permit is not needed for temporary shoring. See Photo 3-8.

Temporary tarping to prevent ingress of moisture is often required and can be carried out while financial assessments and contract documents are being prepared. See Photo 3-9.

Temporary repairs improve conditions for the occupants, and for the structure. Consultants should be cautious about other temporary repairs that may involve construction work covered by the building code and require a permit.

**Photo 3-8—Temporary shoring placed to support walkway structure**



**Photo 3-9—Temporary enclosure over top of stairwell and walkway to prevent water ingress and damage until permanent remedial work is undertaken**



The benefits of temporary repairs are often small if they do not address fundamental deficiencies in wall-assembly performance and provide only temporary relief or allow problems to continue. This is the case when cladding is removed and cannot be reinstalled without a building permit and the necessary documentation to obtain the permit.

Thus, the only reason for temporary repairs is for life-safety concerns and to reduce deterioration and occupant discomfort between discovery of a problem and permanent repairs.

It is strongly recommended that consultants be involved in determining the appropriateness of temporary repairs.

## 3.7 Assemblies

### 3.7.1 Walls

In low exposure conditions (possibly created by changes to the building form), various concealed barrier wall assemblies may be used, similar to ST-2 or HS-1 in *Best Practice Guide—Wood-Frame Envelopes in the Coastal Climate of British Columbia*. The essential aspect of these assemblies is that the moisture barrier must provide a secondary barrier to water ingress and allow drainage to occur. This may be possible with two layers of building paper or with one layer of housewrap and a cladding that provides a cavity between the cladding and the housewrap, such as vinyl.

It is very unlikely that an effective drainage cavity can be created with one layer of housewrap and cladding placed in direct and continuous contact with the housewrap, such as stucco or wood siding placed flat. Some newer housewrap products, by themselves or combined with building paper, may create the necessary drainage layer behind the cladding but each assembly must be examined closely with respect to drainage and moisture transfer into the wall assembly through the sheathing papers. For example, not all vinyl siding products provide adequate drainage paths (holes too small, holes only in the lowest of the board profiles.)

In most medium-exposure rehabilitation the appropriate choice for a new wall is a rainscreen wall assembly similar to ST-3, HS-3 or BV-1 in *Best Practice Guide—Wood-Frame Envelopes in the Coastal Climate of British Columbia*. These assemblies are now commonly used in new construction.

In some low- and medium-exposure conditions, specific combinations of exposure, wall assembly type and detailing may result in little or minimal damage, despite the fact that the assemblies and details are neither ideal nor recommended in *Best Practice Guide—Wood-Frame Envelopes in the Coastal Climate of British Columbia*. This can occur even after a considerable period in service. In these situations, a comprehensive rehabilitation program is not usually warranted. Rather, if there is a concern regarding future performance due to the inherent risky nature of the assembly or details, then specific preventive measures can reduce risk. Examples are improvements to specific details and diligently maintaining sealants. These measures, when combined with a periodic monitoring program, can be an acceptable way of reaching the intended service life of the wall assemblies and components.

## High exposure wall assemblies

In high-exposure situations, exterior insulation rainscreen wall assemblies similar to BV-2, ST-4, HS-3 in *Best Practice Guide—Wood-Frame Envelopes in the Coastal Climate of British Columbia*, provide greater resistance to water penetration than a conventional rainscreen for the following reasons:

- The insulation will add resistance to water penetration (insulation should be free-draining or closed-cell.)
- An adhered waterproof membrane air barrier will have better water resistance than a vapour-permeable sheathing paper.
- It is typically easier to obtain a continuous air barrier with an adhered waterproof membrane than other conventional approaches to achieving airtightness, such as sealed polyethylene, airtight drywall or vapour-permeable exterior air barrier.

Conventional construction in wood-frame buildings has been to install a polyethylene vapour barrier on the warm side of the insulation that is in the stud cavity. Typically, condensation within the wall assembly because of outward flow of interior vapour is not a problem with this assembly. However, condensation control becomes more complex when an exterior insulation rainscreen (vapour-impermeable exterior air) barrier is used. In this type of assembly, adequate insulation must be installed on the exterior of the air barrier to ensure that damaging quantities of condensation do not form within the assembly. A detailed discussion of this is in Appendix B.

It should be noted that some municipalities require the use of rainscreen wall assemblies regardless of exposure conditions.

### 3.7.2 Windows

"Exterior moisture penetration through and around windows is a significant contributor to moisture problems. Water penetrates through the window frame joints and through the interface details between windows and adjacent wall assemblies..."

Survey of Envelope Failures in the Coastal  
Climate of British Columbia

Windows have been significant contributors to building envelope performance problems in the Lower Mainland of B.C. The *Survey of Envelope Failures in the Coastal Climate of British Columbia* confirmed this, finding that about 25 per cent of wall problems were attributable to windows and their interface with other building envelope components. See Photo 3-10. The overall rehabilitation strategy must ensure that historic problems with windows are reduced to manageable, sustainable levels.

**Photo 3-10—Decay in wall assembly at lower corner of window**



When planning remedial work, consider refurbishing existing windows to provide acceptable performance, or replacing existing windows with windows of acceptable or even superior performance. The easy recommendation is replacement of windows that do not meet current standards for water penetration or thermal performance. However, to make a cost-effective choice an advanced understanding of windows that considers multiple performance issues and costs over the long term is required.

The high cost of window repair and replacement can easily justify a detailed study of the window rehabilitation strategy, particularly for larger buildings. Appendix C outlines the many considerations in developing this aspect of a rehabilitation program. As well, the enclosed CD-ROM contains a three-dimensional presentation of a wall rehabilitation at a window location.

### 3.7.3 Decks

Decks over living space are often incorporated into wood-frame buildings as a design feature (the enclosed CD-ROM contains a three-dimensional presentation of a balcony to wall junction). The following should be considered if rehabilitation of decks is required:

- One of the primary functions of decks is to act as a roof for the space below. However, decks are more difficult to waterproof than roofs because they are exposed to regular pedestrian traffic.
- Unless decks over living spaces are constructed with insulation above the waterproof membrane, the space below the membrane must be vented. If the space below the membrane is vented, the vents must be uniformly distributed around the deck to allow cross ventilation. Vents are prone to water penetration and are difficult to detail around the decks.



- The air barrier in the wall assembly must tie-in to the air barrier in the deck assembly.
- Scupper drains are a major source of water leakage with vinyl and built-up roof assemblies. It is recommended that scupper drains be replaced wherever possible with clamped membrane deck drains. Scupper drains should be fully enclosed and have fully welded flanges. Vinyl-coated scuppers should be used for vinyl deck membranes.
- Depending on the extent of the rehabilitation and considering the above criteria, the use of an inverted deck assembly (insulation placed outside the waterproof membrane) may be the most cost-effective measure. Inverted deck assemblies have the following advantages:
  - Venting of the space below the membrane is not required if adequate insulation is installed above the membrane.
  - The membrane is protected from pedestrian damage.
  - The air barrier is clearly defined. If an exterior insulation rainscreen assembly is used on the wall, the adhered waterproof membrane can be adhered to the deck membrane, assuming material compatibility.
- If a vented deck assembly is to be converted to an inverted deck assembly it may be necessary to raise the height of doorsills and other penetrations through the wall assembly. In addition, with the requirement for ballast over the insulation, the dead load increases, possibly triggering the need for upgrading the structure. Therefore, the decision to invert a deck assembly may be cost-prohibitive unless remedial work is also being conducted on the wall assembly and damage has occurred to the existing deck sheathing and framing.

### 3.7.4 Specific assembly issues

There are usually many technical issues to resolve in both design-development and construction-documentation stages. It is not always possible to assign a particular issue to a specific stage. Many issues identified in the design stage are resolved in preparing construction documentation. The following checklist lists issues to consider at design stage and address either during design or construction-documentation stages:

#### Walls

- ☐ Do changes in wall assemblies accommodate exit width requirements?
- ☐ Do changes in wall assemblies restrict door or operable windows?
- ☐ Are there areas of wall not being rehabilitated that will require an interface detail?
- ☐ Do cross-cavity flashings have adequate slope (2:1 in *Best Practice Guide—Wood-Frame Envelopes in the Coastal Climate of British Columbia*) to provide drainage?
- ☐ Does occupancy of the building create interior conditions that affect wall design? Are there high humidity areas? Should improved ventilation be investigated?
- ☐ Are expected service lives of all materials and components in the wall assembly consistent with overall expectations?
- ☐ Is assembly appropriately layered so long service life components do not have to be destroyed to access short service life components? For instance, is component assembly layered so it is not necessary to destroy and 20-year component to reach a 10-year component?
- ☐ Does removal of cladding have an impact on airtightness of wall assemblies? If so, how will adequate levels of airtightness be achieved in rehabilitation design?

- ☐ Do rehabilitated wall assemblies make modifications to balcony, deck or walkway railings necessary?
- ☐ Are modifications to existing plumbing, electrical and sprinklers required because of the rehabilitated wall assembly? If so, are appropriate consultants who can address these issues on the project team?
- ☐ Do walls accommodate anticipated movement in the cladding and building frame?

### Roofs

- ☐ Can roofs be adequately protected during construction or should replacement be considered along with other work?
- ☐ Is remaining life span of the existing roof sufficient to leave it in place or would replacement as part of current rehabilitation program be cost-effective?
- ☐ Does the interface of roof with rehabilitated wall assemblies and skylights facilitate later roof replacement?
- ☐ Are all existing roofs and rehabilitated roof assemblies adequately sloped and drained?

### Balconies and decks

- ☐ Do modifications to balcony assemblies reduce railing height below code-required minimum?
- ☐ Do existing railings meet structural requirements in current building codes?
- ☐ Is existing balcony substrate adequately sloped or is new framing and sheathing required to achieve slope?
- ☐ Can balconies be modified to increase ventilation through the soffits?
- ☐ Does interface of balcony (existing or rehabilitated) with rehabilitated wall assemblies and skylights facilitate later balcony membrane replacement?
- ☐ How is air barrier continuity maintained

through balconies and decks at interface with main building walls and any upstand wall assemblies?

- ☐ How are decks and balconies to be drained? Is additional plumbing needed to facilitate drainage?
- ☐ Does the door threshold height restrict ability to slope surfaces to drainage locations?
- ☐ Do upper level balcony doors require canopies or other protection to reduce exposure conditions?

### Windows and doors

- ☐ What performance levels do current windows meet?
- ☐ If not replacing the windows, what refurbishment and maintenance work is required?
- ☐ Does head flashing restrict operation of operable windows or doors?
- ☐ Does an overhang to reduce exposure protect all doors?
- ☐ What is the expected life span of the window frame and insulating glass units? Even if not a problem now, should replacement be considered given the much lower installation costs?
- ☐ If windows are not replaced does the cladding and wall assembly design facilitate relatively efficient replacement of windows in the future?

### At-grade assemblies

- ☐ If the landscaping and base-of-wall areas are to be disrupted as part of the rehabilitation program, should the interface between the at-grade parking garage roof slab and the exterior walls be improved?
- ☐ Are there other areas where disruption to the landscaping may make it cost-effective to replace or repair at-grade-waterproofing assemblies?

### Walkways and exterior stairwells

- ☐ Do roofs protect all exterior stairwells?
- ☐ Are exterior stairwells constructed so that treads do not interface with walls and create a difficult waterproofing detail?
- ☐ Is the front of the elevator core protected from exposure to rain?
- ☐ Can walkway assemblies be provided with improved ventilation to increase drying potential?

### **Mechanical ventilation**

- ☐ Is existing mechanical ventilation (bathroom and kitchen exhaust fans) functioning adequately?

## **3.8 Rehabilitation program**

### **3.8.1 Program development**

As with any new construction project, rehabilitation design starts with a definition of program requirements. This is not as complex for rehabilitation as it is for new construction, since many basic parameters are established for use and occupancy, the site and layout of the space. Two design stages, schematic design and design development, are typically applied to new construction projects. The basic schematic design decisions about building orientation, form and layout are not applicable to rehabilitation projects as they are pre-existing conditions and all design work is essentially of a design-development nature. Many owners may tend to view this stage too simplistically: for them, it may seem as simple as: *We want the building to stop leaking!*

The rehabilitation program definition must include consideration of all the factors previously described in this chapter. Consideration of these factors together may lead to several alternative approaches for the rehabilitation design. Each alternative will involve different levels of initial construction cost, renewal and maintenance costs: may or may not involve a change in the appearance of the building and introduces more or less risk with respect to future performance.

The effective analysis and presentation of these alternatives is fundamental to the owner's ability to make informed rehabilitation choices. Table 3-4 is a summary of many of the considerations for selecting alternate repair strategies.

Although there must be certain minimum levels of performance in the rehabilitation program the consultant must realize that the owner must decide among alternatives. The owner must decide how to balance risk, capital cost, durability, maintenance and renewal expenditures, appearance, cash flow and many other factors. The consultant must provide advice in all these areas and clearly identify each issue in presenting information.

Design of the building envelope for effective performance involves a certain amount of risk management. Risk of performance failure is inherent in all construction activity. This is particularly so in rehabilitation work, where existing buildings may have features that contribute to the risk of failure and that cannot be changed. Owners should be made aware of this and understand the levels of risk associated with alternative design solutions. Greater certainty comes at greater expense, usually in both design and construction costs.



The warranty provider will also have an interest in design decision-making since the provider will want to evaluate risk of future failure. Therefore, it is important to include the warranty provider in the design process and that the consultant effectively explain the various alternatives and associated performance risks to the warranty provider.

### **3.8.2 Phasing of rehabilitation**

There is usually more than one possibility for phasing the rehabilitation program. On one hand, it may be possible to phase work starting with the most-damaged areas or those with the highest risk of future damage. This has the advantage of spreading the cash flow requirements over several years. On the other hand, owners may decide to do the work as one continuous project. This has the advantage of quick completion, minimizing the length of disruption to the occupants, as well as the lowest construction costs due to the optimization of start-up costs. It also provides the quickest opportunity for the building to lose the stigma of being a leaky condo.

In some situations, it may be possible to phase work over longer periods. For example, a building with one high-exposure face with extensive damage from moisture ingress might not show deterioration in other lower-exposure elevations with the same assemblies and details. The slower deterioration rate of the lower-exposure elevations may mean that extensive rehabilitation can be deferred for five to 10 years. Some monitoring of the wall performance over the five-to-10 year period is warranted. A life-cycle cost analysis of deferred work should consider that costs are not only deferred but owners are receiving the benefit of useful service provided by the envelope assemblies over the deferment period.

The decision about how to phase rehabilitation work is the owner's, but it must be made with the consultant's advice about the implications of the various scenarios. Primary factors that consultants and owners must consider and the consultant's input for them are described below.

#### **Construction costs**

The implications of phasing work have an impact on construction costs since there are additional start-up costs for each phase. In addition, there is a learning-curve cost for each phase because the new workers are new to the building and the project.. The consultant should help the owner to quantify the additional start-up and learning-curve costs.

#### **Risk of further damage**

Phasing rehabilitation work means that areas of the building that are not repaired will continue to deteriorate. The consultant should assess and quantify the probable impact on costs of this deterioration. It may also be necessary to monitor the rate of deterioration so a decision can be made about an implementation schedule.

#### **Disruption to occupants**

Different phasing scenarios mean different time frames and disruption to occupants. While there may not be hard costs associated with this disruption, the consultant should outline probable impacts of various rehabilitation scenarios on occupants. These impacts include noise, access, use of space (balconies in particular), dust and potential increase in airborne irritants.

Table 3-4—Alternate repair strategies

Possible repair strategy	Impact on performance						Zoning/development permit implications			Building Code implications			Effectiveness
	Reduce exposure	Repair damage	Eliminate details	Improve existing details	Less-sensitive assembly	Improve existing assembly	None	Minimal	Significant	None	Minimal	Significant	
Replace sealant				✓			✓			✓			Use in low-exposure situation where minimal damage has occurred, or in combination with other measures that reduce exposure conditions.
Add coating						✓	✓			✓			Use in mass wall assemblies. May also provide short-term relief from active leakage in face seal assemblies, but also reduces the ability for the wall to dry over the long-term leading to elevated moisture content if details still allow moisture ingress.
Add overhangs	✓							✓				✓	Use in situations where minimal damage has occurred and addition of overhangs (lower exposure) will have significant positive impact on performance of assemblies and details. Use in combination with improvements to existing assemblies and details.
Add canopy	✓							✓			✓		Use in reducing exposure conditions locally when existing windows and doors are to be left in place and/or details cannot be improved.
Add roof	✓								✓			✓	Use in situations where considerable area in plan could benefit from reduction in exposure conditions (upper level balcony, exposed walkway.) Can eliminate need for improvement to assemblies and details.
Enclose space	✓									✓		✓	Use in situations where building form facilitates the enclosure of space to reduce exposure conditions (walkways.)

Table 3-4—Alternate repair strategies														
Possible repair strategy	Impact on performance						Zoning/development permit implications			Building Code implications			Effectiveness	
	Reduce	Repair damage	Eliminate details	Improve existing details	Less-sensitive assembly	Improve existing assembly	None	Minimal	Significant	None	Minimal	Significant		
Remove, waterproof window opening; reinstall windows		✓		✓			✓			✓			Appropriate where basic window performance is acceptable but perimeter detailing is suspect or contributing to leakage into adjacent wall assembly. May also be appropriate to defer expense of replacing poorer performing window replacement to the future.	
Reconstruct saddle details		✓		✓			✓			✓			Use to improve detail where damage has occurred locally if in low-exposure conditions and in combination with improvements to wall assembly for higher exposure conditions.	
New rainscreen wall assemblies					✓			✓				✓	Appropriate when damage is systemic due to many problematic details or inadequate existing wall assembly. Different rainscreen assemblies should be considered depending on exposure conditions.	
New windows					✓			✓			✓		Use when existing windows do not meet performance expectations and cannot be effectively refurbished for given exposure conditions.	
Use metal and glass guards rather than upstand walls		✓	✓					✓			✓		Use when existing guardrails and associated attachment details are deteriorated or structurally inadequate. May be more cost-effective in other situations rather than adapting existing guardrails to meet new wall assembly or balcony configuration.	

### Cash flow

Each phasing scenario dictates a different cash-flow plan. The consultant should help the owners develop a realistic cash-flow plan based on anticipated construction cost and other project costs, such as consulting fees and permit fees.

### Property value

Assessing the impact of implementation rehabilitation scenarios on property values is not within the expertise of consultants and should not be attempted. Owners should ask a qualified real estate assessment professional to assess the impact on property value.

### 3.8.3 Cost analysis of alternatives

Cost is one area that owners must consider when evaluating alternatives. The consultant should compare costs for the reasonable alternatives and present the comparison to the owners.

Rehabilitation cost estimates that are part of the design stage are based on more detailed development of the proposed assemblies, more accurate area takeoffs and much more thought about phasing work and construction implementation than is done at the evaluation stage. These construction cost estimates should be prepared with the assistance of a quantity surveyor or a contractor familiar with remedial work. These budget estimates can usually be considered accurate to  $\pm 25$  per cent. Chapter 5—Tendering is a more detailed discussion of rehabilitation costs.

The estimates can be used for overall project planning purposes, obtaining approval for special assessment (project estimate plus 25 per cent

owner contingency) and for rehabilitation funding programs such as the HPO Reconstruction Loan Program.

The costs to be evaluated should include initial construction costs for rehabilitation, and anticipated renewal and maintenance costs over a set time. The time selected is somewhat arbitrary but could reasonably be at least as much as the life expectancy of the cladding and less than the life expectancy of the structure—30 to 50 years is appropriate.

Given the stable and low rates of inflation, the cost of borrowing and guaranteed investment rate of returns over the past few years, and the unknown and highly variable impact on property value of rehabilitation, it is usually acceptable to ignore these factors and focus only on the capital costs. The rate of deterioration should be factored into the anticipated rehabilitation costs for all alternatives that involve deferring work. This rate will vary and has to be assessed building-by-building.

In many cases the "do nothing" alternative is not feasible. However, even if not a feasible alternative, it should be considered and presented to the owners in the context of describing the consequences of doing nothing and to help make the case for the more realistic alternatives.

Table 3-5 is a case study for a building requiring extensive rehabilitation. Along with the costs associated with alternatives, the case study gives other risks and factors. Although the format and level of detail may vary, the basic information and approach used in this case study should be used for all rehabilitation projects.

Exel table here

Table 3-5—Cost analysis of alternatives

### 3.8.4 Deliverables

During the design stage the consultant should develop and prepare documents that fully describe the extent of rehabilitation, assemblies to be used in rehabilitation and changes to building form and appearance. Essentially, these documents are used for program review by the owners and establish the basis for preparing working drawings and specifications for the construction documents stage. They may also be required for an application for a development permit or revision to an existing permit.

The deliverables vary for this stage depending on project specifics. Preliminary drawings, details, reports and graphical presentations may all be required to some degree. Once agreement has been reached with the owner regarding the rehabilitation program, a design brief should be prepared that documents design decisions and outlines the rehabilitation program.

### 3.9 Design stage—consultant checklist

- ☐ Sign consultant–owner agreement
- ☐ Determine the need for additional specialist consultants and advise owners
- ☐ Advise owners about the need for third-party warranty
- ☐ Present and review proposed rehabilitation program with warranty provider
- ☐ Review design and construction process with owners
- ☐ Review project and construction budgets with owners
- ☐ Review municipal permit process with owners
- ☐ Review project scope
- ☐ Review construction contract types
- ☐ Review of applicable codes, bylaws and regulations
- ☐ Review alternative design approaches
- ☐ Develop design documents to show nature and scope of work





# Chapter 4—Construction documents

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# Chapter 4—Construction documents

## 4.1 Introduction

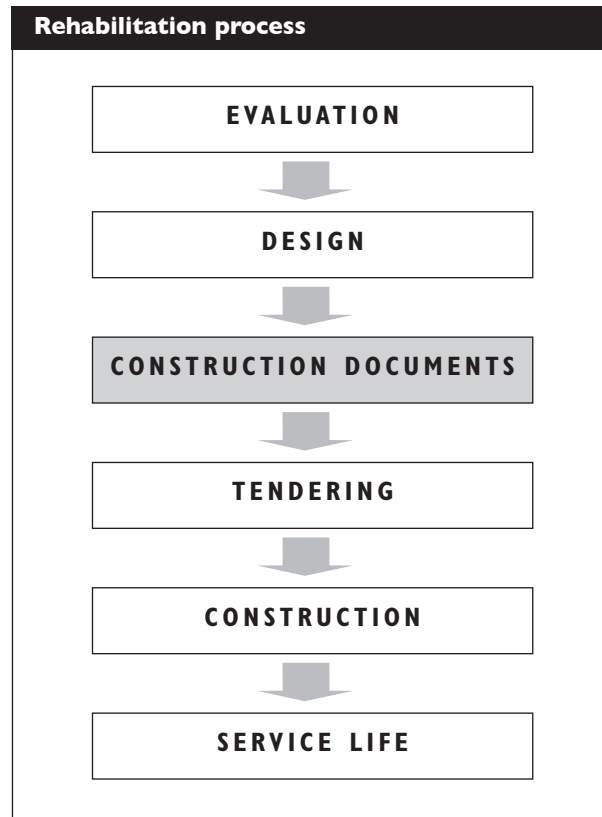
Based on design-development documents and construction cost estimate approved by the owner, the consultant can proceed to prepare the construction documents. These drawings and specifications are the detailed construction requirements. They are part of the bid package for contractors and a necessary part of the building permit application. The main responsibilities and activities of the consultant in the construction documents stage are:

- Co-ordinating project.
- Preparing drawings and specifications describing project in detail.
- Reviewing and revising construction and project budgets as necessary.
- Assisting owner in obtaining municipal approvals and permits (Development permit, if applicable, and building permit.)
- Providing letters of assurance to accompany building permit application.
- Continuing to review applicable statutes, codes, bylaws, regulations and so forth.

All construction work, including remedial work, must comply with the *B.C. Building Code* or the City of Vancouver *Building Bylaw*.

The *B.C. Building Code* 1998 (1.1.2.1. 1) states that the Code applies to any one or more of the following:

- a) the design and construction of a new building,
- b) the occupancy of any building,
- c) the change in occupancy of any building,
- d) an alteration of any building,
- e) an addition to any building,



- f) the demolition of any building
- g) the reconstruction of any building that has been damaged by fire, earthquake or other cause
- h) the correction of an unsafe condition in or about any building. ..

Some municipalities do not require building permits for minor repairs, although compliance with the Code is required. As requirements differ from municipality to municipality, consultants should check with the local building or permits and licenses department. The City of Vancouver, for example, requires a building permit for all remedial work projects, regardless of size.

## 4.2 Building Code

This section summarizes some of the more significant Code issues. Other Code sections may also apply. It is the consultant's responsibility to verify that all relevant Code requirements have been considered. In particular, there are differences between the requirements for small buildings (Part 9 of the *Code*) and large buildings (Parts 3, 4, 5 and possibly others). The consultant must confirm which parts of the Code apply. Some jurisdictions require the application of Part 5 of the code even for some smaller buildings.

### 4.2.1 Applicable building codes

This *Guide* refers to the 1998 *British Columbia Building Code* (B.C. BC). All areas of B.C. outside the City of Vancouver have adopted the B.C. BC. The current version of the Vancouver *Building Bylaw* (VBBL) No.8057—1999 is based on the 1995 *National Building Code* and the 1998 B.C. BC, with some unique provisions. It is essential to consult the Vancouver Permit and Licences Department for any projects in Vancouver.

### 4.2.2 Addition of roofs and canopies

The materials and the type of construction allowed for canopies, roofs, awnings and so on, are governed by building code regulations dealing with the spread of fire at the exterior building face and between buildings. The governing articles are 3.2, 3.6, 9.10. and 14.13, among others (3.2. 3.20.)

#### **B.C. BC 3.2.3.6. combustible projections (B.C. BC 9.10.14.13. similar)**

"Except for a buildings containing 1 or 2 dwelling units only, combustible projections on the exterior of a wall that could expose an adjacent building

to fire spread and are more than 1m above ground level, including balconies, platforms, canopies, eave projections and stairs, shall not be permitted within:

- a) 1.2 m of a property line or the centreline of a public way, or
- b) 2.4 m of a combustible projection on another building on the same property."

In most circumstances, awnings, canopies and roofs can be added without compromising the integrity of the adjacent wall or roof assembly. If the separation between the new structure and the existing assemblies is breached for any reason, there is an increased risk of fire spreading between the inside and outside portions of the roof or attic space. This is discussed in B.C. BC Articles 3.2.3.15. and 9.10.12.5. "Protection of soffits."

#### **B.C. BC 3.2.3.15. protection of soffits (9.10.12.5 similar)**

- 1) Except as permitted by Sentences (3) and (4), where there is a common attic or roof space above more than 2 suites of residential occupancy or above more than 2 patients' sleeping rooms and the common attic or roof space projects beyond the exterior wall of the building, the soffit and any opening in the soffit or other surface of the projection located within 2500 mm of a window or door opening, shall be protected by
  - a) noncombustible material
    - i) not less than 0.38 mm thick and
    - ii) having a melting point not below 650°C,
  - b) plywood not less than 11 mm thick,
  - c) strandboard or waferboard not less than 12.5 mm thick, or
  - d) lumber not less than 11 mm thick
- 2) The soffit protection required by Sentence (1) shall extend the full width of the opening and to not less than 1 200 mm on either

side of it and shall apply to all openings through the soffit within this limit.

- 3) If an eave overhang is completely separated from the remainder of the attic or roof space by fire stopping, the requirements of Sentence (1) do not apply.
- 4) The protection required by Sentence (1) for projections is permitted to be omitted if
  - a) the fire compartments behind the window and door openings are sprinklered in accordance with Article 3.2.5.13. and
  - b) all rooms, including closets and bathrooms, having openings in the wall beneath the soffit are sprinklered, notwithstanding exceptions permitted in the standards referenced in Article 3.2.5.13. for the installation of automatic sprinkler systems.

It is important to note that VBBL section 1A.9.1 "Projection Over Streets" deals with projections of building elements over city property. Requirements for awning and canopy construction are listed in article 1A.9.7 of the VBBL.

### Structural

Roofs and canopies can be supported by their own independent structure, that is, beams and columns, or attached to adjacent walls, or a combination of both. The solution depends on factors such as roof/canopy projection, weight and type of support in the structure below or in the wall.

### Mechanical

Directing and controlling water runoff from the roof or canopy is an important consideration. Ideally, a continuous gutter and a downpipe should be provided, with a connection to the storm drainage system.

## 4.2.3 Enclosure of exterior spaces

Building code requirements for enclosing balconies can be extensive. The provincial code and the VBBL make no direct reference to balcony enclosures, but suite fire separations, spatial separation between buildings, travel distance within suites and other aspects must be considered when enclosing balconies or exterior walkways.

Different, but equally complex building code points need addressing for enclosure of exterior walkways and stairs. Exterior passageways in buildings are regulated mainly by articles 3.4. 4.3 of B.C. BC. Many provisions dealing with fire separations, fire exposure protection of exits, and so on, are relaxed for exterior passageways. Enclosure or partial enclosure of walkways would bring these provisions into force. It is imperative to study all building code implications when considering enclosure of balconies or exterior walkways in remedial work.

### B.C. BC 3.4. 4.3. exterior passageway exceptions

The requirements in sentences 3.4. 4.1.(1) and 3.2. 3.12.(1) and (3) do not apply to an exterior exit passageway provided

- (a) at least 50 per cent of the exterior side is open to the outdoors and
- (b) an exit stair is provided at each end of the passageway.

### Light and ventilation

In many instances, rooms adjacent to balconies or walkways rely on their exposure for light and ventilation. Other ways of ventilating these rooms need to be considered. Bathroom,

kitchen and laundry vents and direct-vent fireplaces sometimes discharge into these areas as well. In these cases, duct extensions or another duct-routing may be required.

### Other technical issues

Full enclosure of balconies can present other technical challenges, as balcony floor and curb wall assemblies begin to perform the roles of roofs and exterior walls. For example, the ventilation of the balcony floor can be lost when the balcony below becomes fully enclosed. At the same time, the lack of insulation and vapour barrier in the assembly, combined with the additional heat and humidity introduced into the enclosure can result in significant condensation within the floor of the balcony above.

### 4.2.4 Additional protection of walls

Projections such as soffits and cornices are governed mainly by B.C. BC articles 3.2. 3.15, 9.10.12.5. The articles seek to prevent the spread of fire within the projecting element or into the roof or attic space, by precluding soffit vents when more than two residential suites share common attic or roof space. In areas where limiting distance is a factor, articles 3.2. 3.6. and 9.10.14.13. of B.C. BC apply. For specific Code wording see "Addition of roofs and canopies". In Vancouver, if proposed cornices and soffits project over city property, VBBL section 1A.9.6 "Cornices and Ornamentation" applies.

### Structural

A structural engineer should review the attachment method of any additional building projection, taking into account the element's size, weight and the likelihood of it having to support ladders or people.

### 4.2.5 Reconstruction of balconies

Reconstruction of balconies and walkways often involves installing inverted membranes and new traffic surfaces, such as loose-laid concrete pavers. This may alter the height of the guardrail relative to the balcony surface and require raising the existing railing or installing a new one. Heights of guards at balconies, walkways, stairs and landings are regulated by B.C. BC sentences 3.3.1.17.(1), 3.4.6.5.(2), (3) and (4) and Article 9.8.8.2.

#### B.C. BC 3.3.1.17. guards

- 1) Except for the front edges of stages and loading docks, a guard not less than 1070 mm high shall be provided
  - a) around each roof to which access is provided for other than maintenance,
  - b) at openings into smoke shafts referred to in Subsection 3.2.6. that are less than 1070 mm above the floor and
  - c) at each raised floor, mezzanine, balcony, gallery, interior or exterior vehicular ramp and at other locations where the difference in level is more than 600 mm.

#### B.C. BC 3.4.6.5. guards

- 2) Except as required by Sentence (4), the height of guards for exit stairs shall be not less than 920 mm measured vertically to the top of the guard from a line drawn through the outside edges of the stair nosings and 1070 mm around landings.
- 3) The height of guards for exit ramps and their landings shall be not less than 1070 mm measured vertically to the top of the guard from the ramp surface.
- 4) The height of guards for exterior stairs and landings more than 10 m above adjacent ground level shall be not less than 1500 mm



measured vertically to the top of the guard from a line drawn through the outside edges of the stair nosings.

**B.C. BC 9.8.8.2. height of guards (See Appendix A, page 34)**

- 1) Except as provided in Sentences (2) to (4), all guards, including those for balconies, shall be not less than 1 070 mm high.
- 2) Guards for porches, decks, landings and balconies are permitted to be a minimum of 900 mm high where
  - a) the walking surface of the porch, deck, landing or balcony served by the guard is not more than 1 800 mm above the finished ground levels and
  - b) the porch, deck, landing or balcony serves not more than one dwelling unit.
- 3) Except as provided in Sentence (4), guards for stairs shall be not less than 900 mm high measured vertically from a line drawn through the outside edges of the stair nosings and 1 070 mm high at landings.

Raising of balcony or walkway surfaces may also allow climbing of guardrails, contrary to sentences 3.3.1.17.(3), 3.4.6.5.(7) and article 9.8.8.5. of the Code.

**B.C. BC 3.3.1.17 (3.4.6.5.(7) similar)**

- 3) Unless it can be shown that the location and size of openings do not present a hazard, a guard shall be designed so that no member, attachment or opening located between 140 mm and 900 mm above the level protected by the guard will facilitate climbing.

**B.C. BC 9.8.8.5. design to prevent climbing (See Appendix A, page 1.)**

- 1) Guards required by Article 9.8.8.1. and serving buildings of residential occupancy shall be designed so that no member, attachment or opening located between 100 mm and 900 mm above the floor or walking surface protected by the guard will facilitate climbing.

**Structural**

Any new or modified guardrail and its method of attachment will also require a structural design review and certification to ensure compliance with article 4.1.10.1 of the B.C. BC.

**Mechanical**

It is common for balconies and exterior walkways to lack any form of drainage beyond a scupper or a drip-edge. Where possible, consider down pipes connected to a drain, scupper or a continuous gutter along the balcony edge and to the building's storm drainage system

**4.2.6 Replacement of windows**

Where windows are being replaced for better performance, it may be necessary to revise the window design to comply with current provisions of the *Building Code*. Windows are regulated in many respects by the *B.C. Building Code*, including ventilation, thermal properties, wind-loading, type of glazing, emergency egress, fire protection, safety and so on. It is recommended that all Code requirements relating to window design be reviewed before replacing windows. Some of the most critical provisions are articles 9.7.1.3, 9.7.1.6 and section 9.10.

### B.C. BC 9.7.1.3. bedroom windows

- 1) Except where a bedroom door provides access directly to the exterior, each bedroom shall have at least 1 outside window openable from the inside without the use of tools or special knowledge.
- 2) Windows referred to in Sentence (1) shall provide unobstructed openings with areas not less than  $0.35 \text{ m}^2$  and with no dimension less than 380 mm. (See article 9.7.1.4. and Appendix A).

### B.C. BC 9.7.1.6. height of windowsills above floors or ground (See Appendix A).

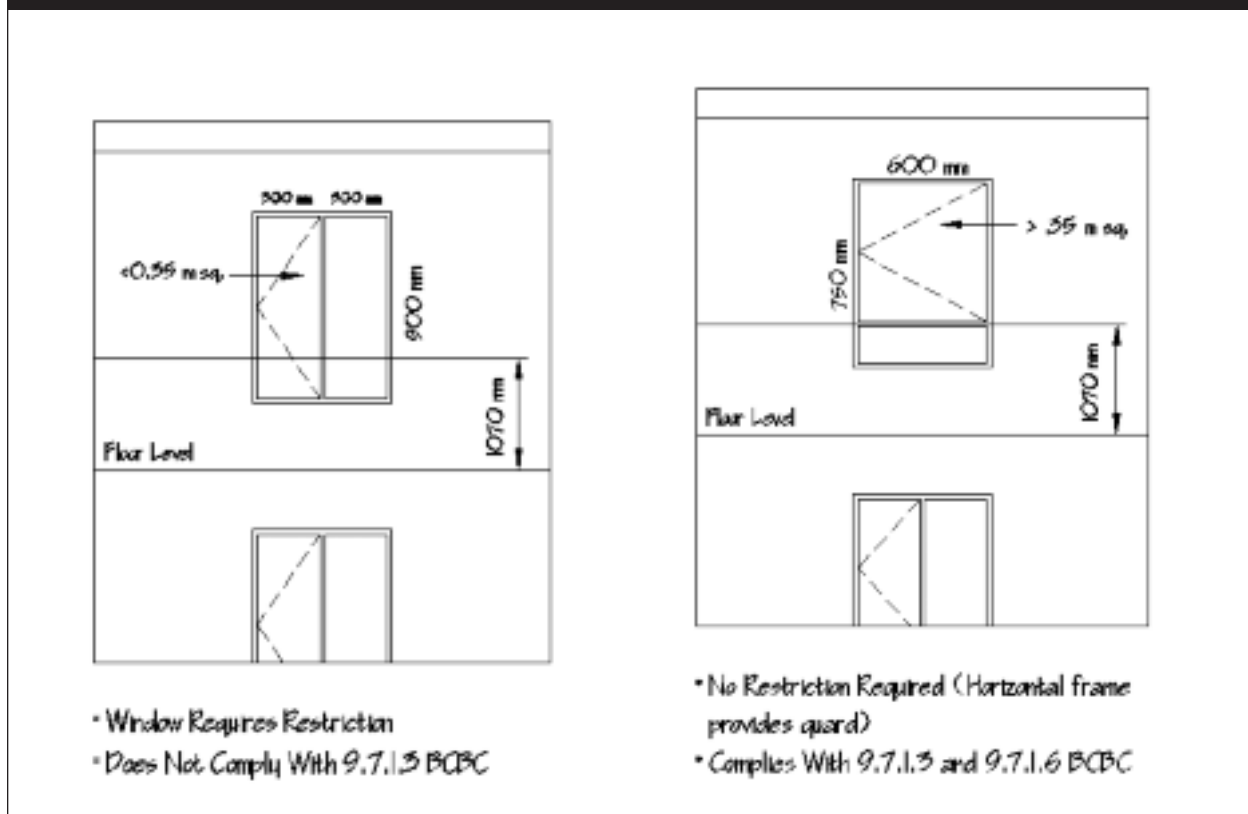
- 1) Except as provided in Sentence (2), openable windows in buildings of residential occupancy shall be protected by

- (a) a guard, in accordance with Section 9.8., or
- (b) a mechanism capable of controlling the free swinging or sliding of the openable part of the window so as to limit any clear unobstructed opening to not more than 100 mm measured either vertically or horizontally where the other dimension is greater than 380 mm.

Figure 4-1 illustrates application of the requirements of 9.7.1.3 and 9.7.1.6 1.

Other articles are exceptions to some of these requirements and the intent of article 9.7.1.6 does not appear to apply for larger buildings (Part 3). However, it is recommended that the requirements of VBBL sentence 3.3.1.18.(7) be followed in all other jurisdictions.

**Figure 4-1—Restriction and size requirements for operable windows**



### VBBL 3.3.1.18.(7)

Openable windows, or parts thereof, less than 1000 mm above an interior floor level, which is more than 600 mm above the floor or ground level on the other side of the window, shall be protected by

- (a) a guard, in conformance with Article 3.3.1.17., or
- (b) a mechanism capable of controlling the free swinging or sliding of the openable part of the window so as to limit any clear unobstructed opening to not more than 100 mm measured either vertically or horizontally where the horizontal dimension of the window is greater than 380 mm.

### Effect on heating loads

Removal and re-installation or replacement of existing windows is often necessary. Improved performance and thermal qualities of currently manufactured windows should be taken into account when deciding whether to repair and re-install existing windows or replace them. The cost of new windows can be at least partially offset by long-term savings in heating costs.

### 4.2.7 Improved ventilation of building cavities

B.C. BC articles 3.2.2.11 and 3.2.2.12, among others, govern construction of balconies and exterior walkways. For balconies, the requirements for the type of construction apply but not for fire resistance. It is generally easy to increase ventilation to most balcony soffits by, for example, the addition of a perforated soffit finish material. For exterior passageways that provide access to exits the fire-resistance rating requirements apply and walkways are required

to be fire separations with the same fire-resistance rating as mezzanines. Better ventilation is more difficult to provide for exposed walkway structures and requires careful attention by design professionals. Spatial separation requirements at adjacent properties or buildings impose additional fire-resistance requirements for both balconies and walkways.

### B.C. BC 3.2.2.11 exterior balconies

- 1) An exterior balcony shall be constructed in accordance with the type of construction required by Articles 3.2.2.20. to 3.2.2.83., as applicable to the occupancy classification of the building.

### B.C. BC 3.2.2.12 exterior passageways

- 1) An elevated exterior passageway used as part of a means of egress shall conform to the requirements of Articles 3.2.2.20. to 3.2.2.83 for mezzanines.

## 4.2.8 Reconstruction of exterior walls

### Building code

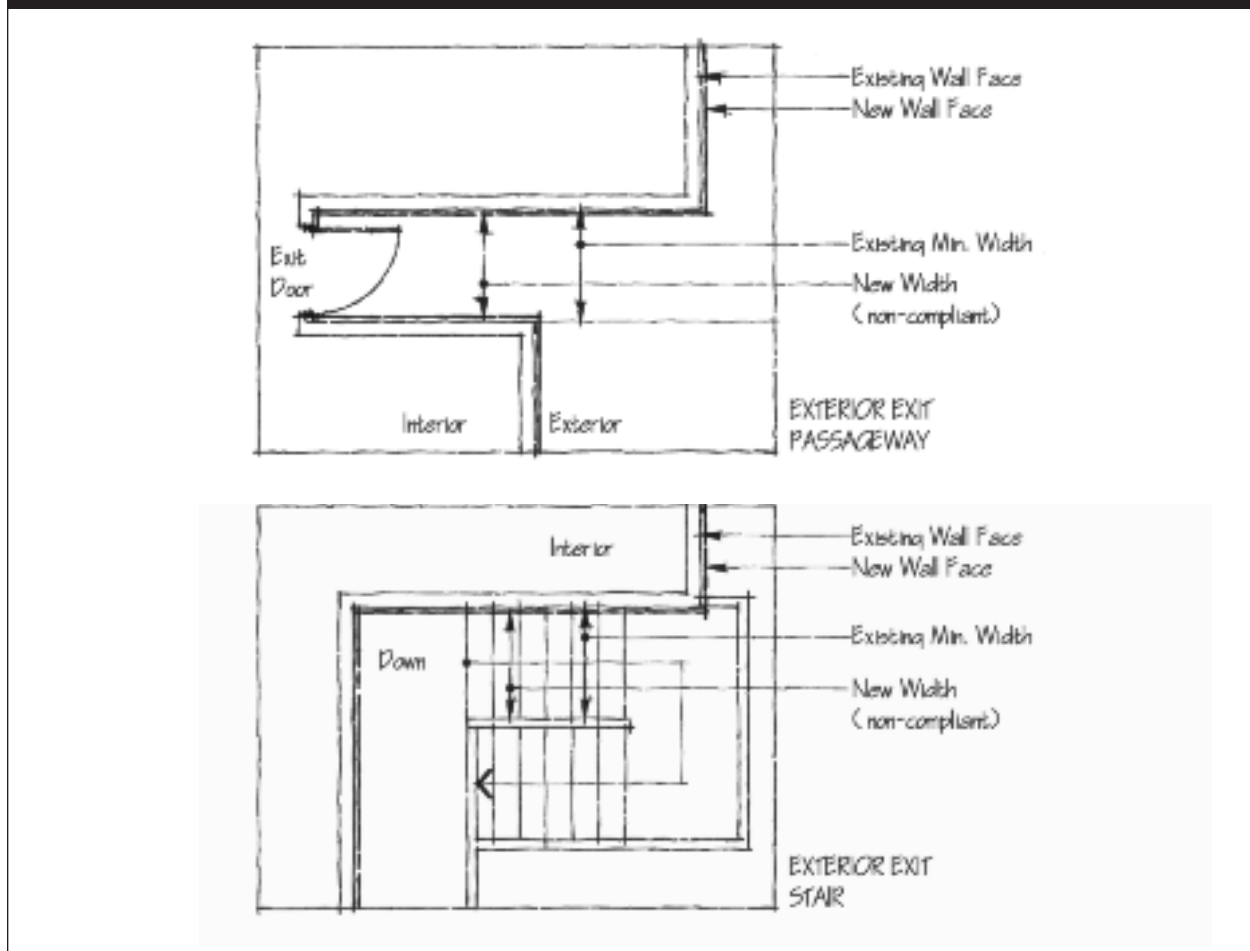
Exterior walls of buildings are designed to meet a number of requirements. Besides providing environmental separation, they typically form part of a building's structure and are subject to *Building Code* requirements with respect to the level of fire exposure protection in areas of adjacency to property lines, other buildings and other parts of the same building. In addition, in some locations, exterior walls must meet sound-transmission criteria.

Exterior wall construction is primarily regulated by B.C. BC section 3.2.3, "Spatial Separation and Exposure Protection." This sets out the maximum amount of unprotected opening

(windows and doors) area in a wall and stipulates the type of construction and cladding material required, depending on the wall's distance from the property line or another building. These requirements must be met in any reconstruction work. In addition, if there is a significant increase in wall thickness, a spatial separation calculation may be required, to confirm that more stringent requirements are not triggered through the reduction of the limiting distance. Section 3.2.2 defines the type of construction and fire-resistance ratings.

In some cases, means of egress, such as exterior stairs or exterior passageways, may be bordered on one or two sides by a building's exterior wall. Where these exits are at or near the minimum allowable width, the increase in the thickness of the wall may not comply with Code requirements. (See Figure 4-2.) The City of Vancouver's mandated use of rainscreen wall assemblies in all situations can create a conflict. It is difficult to resolve these two issues in strict compliance with VBBL and B.C. BC requirements. In these instances, the consultant will have to develop and discuss alternate strategies or compromises to meet the intent of the B.C. BC and VBBL.

**Figure 4-2—Conflict between exit width requirements and need for rainscreen wall assembly**



## **Insect control**

Openings allowing drainage and drying of rainscreen cavities also create the potential for the ingress of wood-destroying insects. Care should be taken to include effective screens at these locations to minimize this risk.

## **4.2.9 Changes in Code design loads**

### **Live loads for Part 4 buildings**

**Residential areas:** The specified live load for sleeping and living quarters remained at 1.9 kPa (40 psf) from NBC 1970 to NBC 1995. This generally includes upper floor corridors.

**Exits and fire escapes, corridors, lobbies and aisles over 1,200 mm (48 in.) wide:** The specified live load remained at 4.8 kPa (100 psf) from NBC 1970 to NBC 1995. This excludes most upper floor corridors.

**Balcony floor live load:** The specified live load for exterior balconies remained at 4.8 kPa (100 psf) from NBC 1970 to NBC 1995.

**Guard live load:** The guards most commonly encountered in building envelope remedial work are railings on balconies of individual residential units and railings on exterior exit walkways. The following is a synopsis of the live loads specified in the NBC for such guards:

**NBC 1970:** 2.19 kN/m (150 lb./ft) applied horizontally at the top of the guard and 1.46 kN/m (100 lb./ft) applied vertically at the top of the guard, acting separately.

**NBC 1975 and 1977:** For exterior balconies of individual residential units, 0.59 kN/m (40 lb./ft) and a concentrated load of 0.89 kN

(200 lb.), concurrently, applied horizontally at the top of the guard and 1.46 kN/m (100 lb./ft) applied vertically at the top of the guard. For exits, the horizontal load is 2.19 kN/m (150 lb./ft) with the same vertical load.

**NBC 1980, 1985 and 1990:** For exterior balconies of individual residential units, 0.6 kN/m and a concentrated load of 0.9 kN (200 lb.), concurrently, applied horizontally at the top of the guard and 1.5 kN/m applied vertically at the top of the guard. For exits, the horizontal load is 1.5 kN/m with the same vertical load.

**NBC 1995:** For exterior balconies of individual residential units and exits, 0.75 kN/m or a concentrated load of 1 kN applied at any point applied horizontally, whichever governs and 1.5 kN/m applied vertically at the top of the guard, acting separately.

Thus, the specified vertical load on the top of guards remained essentially constant while the horizontal load on the top of guards was reduced for common size balconies and exits. The NBC also specifies concentrated horizontal loads for individual elements within a guard, including solid panels and pickets, that designers should be aware of.

**Earthquake loads:** Earthquake design requirements in the NBC became more stringent from NBC 1970 to NBC 1995. Also during that time, calculated lateral forces increased for typical wood-frame residential buildings as concrete floor toppings and four-storey building height became commonplace. This resulted in a need to analyse these buildings in detail. Interior drywall partitions have long been considered by designers as contributing to the seismic load-resisting system in these buildings.

Thinking changed in 1994 with the Northridge earthquake and drywall shear walls were prohibited by some regulatory authorities. Now, many designers completely ignore drywall partitions in their lateral design and rely entirely on plywood shear walls. Often the exterior of a wood-frame residential building offers few, if any, walls with sufficient width and continuity to be useful as shear walls. This dictates that interior corridor walls and specific party walls between suites be designated as plywood shear walls.

#### **Live loads for Part 9 buildings**

**Residential areas:** The specified live load for bedrooms remained at 1.4 kPa (30 psf) from NBC 1970 to NBC 1995. The specified load for other areas remained at 1.9 kPa (40 psf), which generally includes upper floor corridors.

#### **Exits and fire escapes, corridors, lobbies and aisles over 1,200 mm (47.2 in.) wide:**

The specified live load remained at 4.8 kPa (100 psf) from NBC 1970 to NBC 1995. This excludes most upper floor corridors.

**Balcony floor live load:** The specified live load for exterior balconies was 4.8 kPa (100 psf) from NBC 1970 to NBC 1977. In NBC 1980 it was changed 1.9 kPa (40 psf) or the design roof snow load, whichever is greater, for balconies not used as passageways. The requirements remained the same in NBC 1995.

**Guard live load:** Live loads on guards were not specified in Part 9 from NBC 1970 to NBC 1995. Instead of specific requirements in Part 9, the NBC requires that structural members and their connections be designed in conformance with Part 4. A summary of the Part 4 requirements was discussed above.

**Earthquake loads:** From NBC 1970 to NBC 1980, Part 9 specified that buildings with structural systems of wood-frame construction need not be designed for the earthquake loads specified in Part 4. From NBC 1985 to NBC 1995, Part 9 specified that where structural members and their connections conform to the requirements of Part 9 (for member sizes, and so on) the structural design requirements are deemed to have been met.

#### **4.2.10 Duty to upgrade to current Code requirements**

The major structural issues facing designers responsible for rehabilitation of wood-frame buildings is whether the building is governed by Part 4 or Part 9 of the B.C. BC and, for Part 4 buildings, whether it complies with current NBC earthquake design requirements. Specified floor live loads for Part 4 buildings remained constant between NBC 1970 and NBC 1995. For Part 9 buildings, specified floor live loads remained constant or were reduced. Specified loads on guards have undergone several changes in the same period but those specified in NBC 1995 are less stringent for most guards than in the preceding editions.

Part 9 buildings can generally be distinguished by their height and building area as discussed in section 1 of B.C. BC.

The B.C. BC does not require designers to upgrade to meet current earthquake design requirements. Article 1.1.2.1 states:

"This Code applies to any one or more of the following;"



And the list includes  
"the correction of an unsafe condition in or about any building."

And  
"the installation, replacement, or alteration of materials or equipment regulated by the Code."

Article 1.1.2.3 states  
"Where a building is altered, rehabilitated, renovated or repaired, or there is a change in occupancy, the level of life-safety and building performance shall not be decreased below a level that already exists."

Therefore, the B.C. BC requires that building components worked on during a restoration program be upgraded to meet current Code requirements but does not require upgrading of the building as a whole, such as for earthquake design.

Structural components such as balconies, guards and exterior walls should not be simply replaced in kind without structural review. Designers have a responsibility to ensure that the structural requirements of the current B.C. BC for those components are met, regardless of whether they met the Code in force at the time of original construction.

Although designers are not required to upgrade the earthquake design of a Part 4 building during a restoration project, they should inform building owners that the design may not meet the current Code. This gives the owners the opportunity to have an evaluation carried out by a professional engineer with a view to possibly including some seismic upgrading measures in the restoration program.

Although there are no specific earthquake design requirements for Part 9 buildings, designers should tell building owners if they see any indications that the building may be deficient. Refer to B.C. BC section A-9.4 for examples.

#### **4.2.11 Duty to address structural deficiencies in original construction**

Consultants performing remedial work on an existing building have a responsibility to address framing deficiencies in the original construction that are uncovered during the work. Non-complying or substandard framing should be brought into accordance with B.C. BC Part 9 as a minimum requirement. Examples include missing extra studs or blocking beneath point loads, missing framing hardware, such as sill anchor bolts or joist hangers, and lack of adequate bearing for beams or joists at supports.

### **4.3 Details, components and materials**

#### **4.3.1 Cross-cavity flashing**

In new wood-frame construction, control joints are typically installed horizontally at the floor lines to accommodate relative movement between the cladding and the building frame as the frame moves downward. This downward movement is a combination of wood shrinkage and frame "seating" or "settlement." In new construction, the cross-cavity flashing at the floor lines is typically designed so that it will accommodate the downward movement. In remedial projects there is typically less frame movement because not all frame members are replaced. Those that are replaced should have a moisture content of less than 19 per cent.

The *Best Practice Guide—Wood-Frame Envelopes in the Coastal Climate of British Columbia* recommends that all wood products be kiln-dried.

If minimal frame movement is anticipated, the location of the cross-cavity flashing should be selected to simplify construction and detailing. For example, it may be possible to combine the cross-cavity flashing and the window head flashing. Combining the cross-cavity flashing and the window head flashing will reduce cost and simplify construction because there is no duplication of flashing and there are fewer end dams to install the cladding around. Combining flashing should also reduce the quantity of water penetrating past the primary cladding because there is a reduction in the number of details. See Figure 4-6 and Figure 4-7.

The consultant may also elect not to require a cross-cavity flashing for each floor level. Installing cross-cavity flashing at only select locations is feasible provided frame movement can still be adequately accommodated and the cavity is maintained unobstructed throughout. For example, this approach would be feasible for a brick-clad, low-rise building where the brick is supported at the base of the wood-frame.

Reducing the number of cross-cavity flashing locations will reduce the compartmentalization of the cavity. In a high-exposure situation, where pressure moderation of the rainscreen walls is desirable, a reduction in compartmentalization could increase the pressure differential across the exterior cladding. This increases the potential for water penetration of the cladding.

However, for most wood-frame buildings, the need for vertical compartmentalization of the cavity is limited: compartmentalization at the outside corners is sufficient for most buildings.

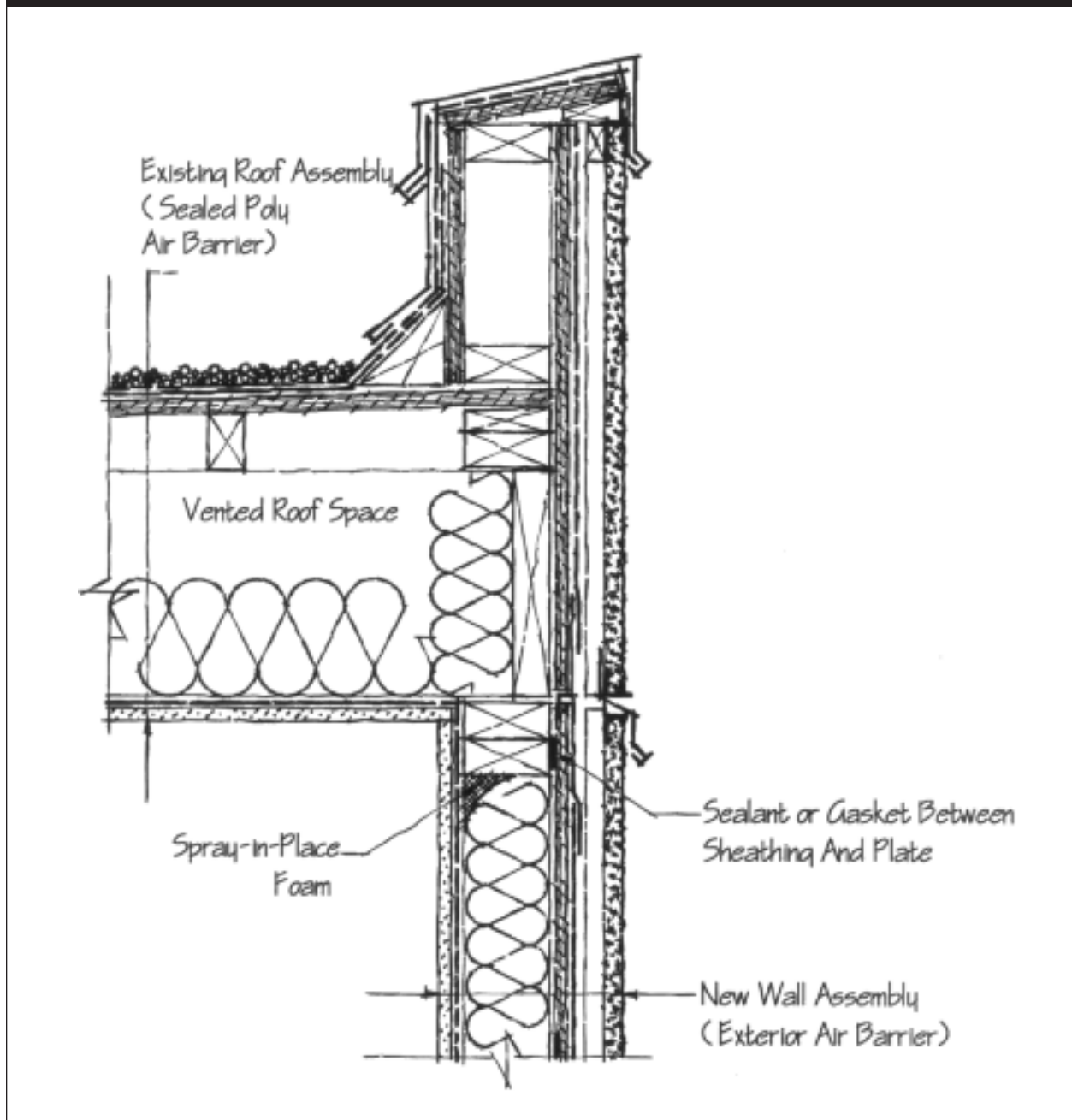
In addition to cost savings, reducing the number of cross-cavity locations may also maintain the current appearance of the building.

### 4.3.2 Transitions between wall types

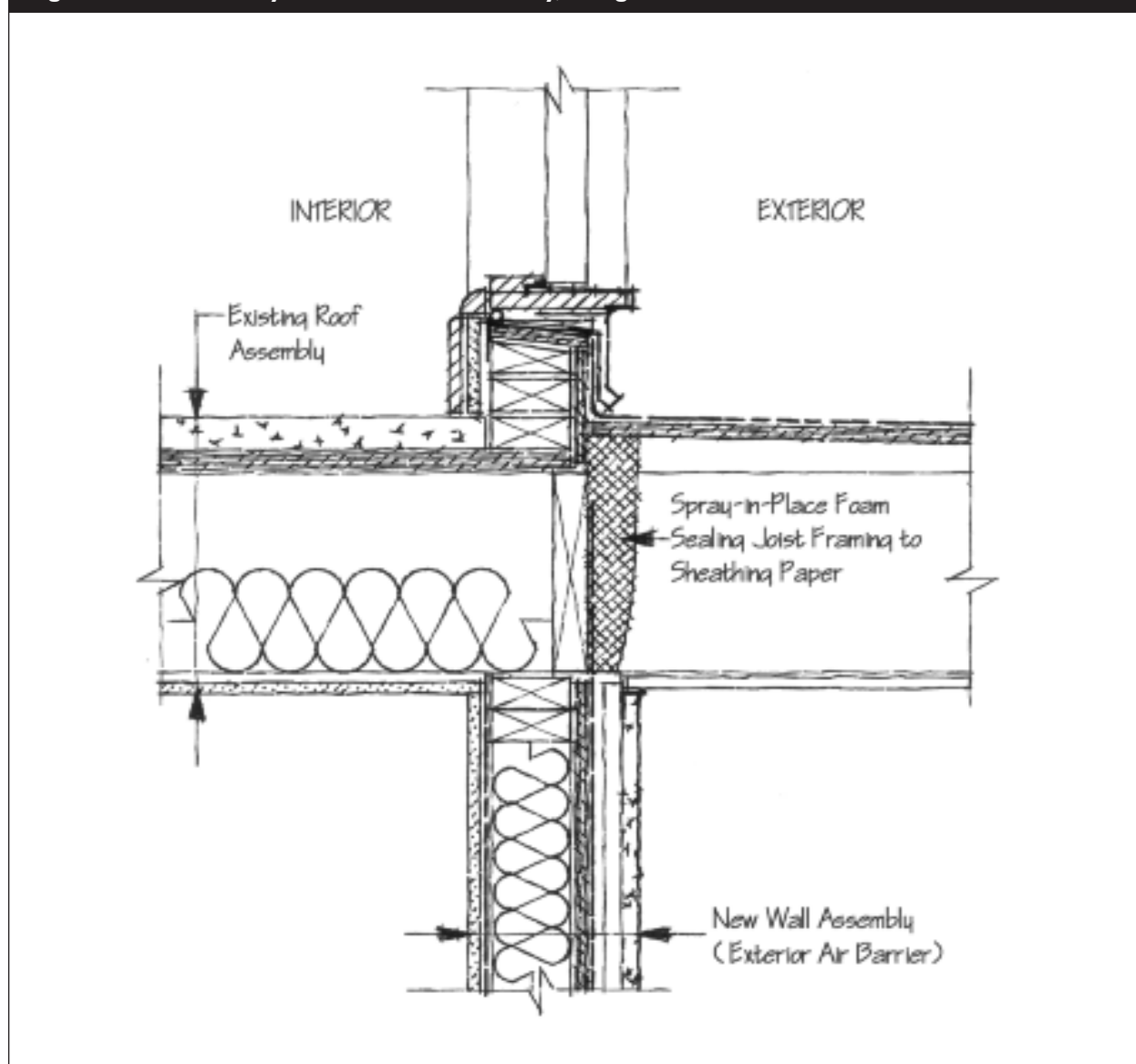
One of the important factors to consider is the extent, or the area, to which the remedial wall assembly will be applied—where the new wall assembly should start and stop. Do not select the area solely on the condition of the existing wall. Transitions between the remedial wall assembly and the existing wall assembly are protected (low exposure) from rain penetration because tie-ins are prone to leakage. The new wall assembly should extend vertically to the underside of a protecting overhang, or to the top of the building.

When designing details for transitions between wall types, the air barrier must be continuous. For most existing face-sealed assemblies, the cladding is the most airtight component of the wall assembly, while for most existing concealed-barrier assemblies, the sheathing paper is the most-airtight component. See Figure 3-2 and Figure 3-3.

Figure 4-4 is a detail for tie-in of an exterior air barrier to a sealed polyethylene air barrier at roof level. Continuity of the air barrier is most critical at the roof level because this is the portion of the building with the greatest differential pressure across the building envelope (wind pressure and stack effect.)

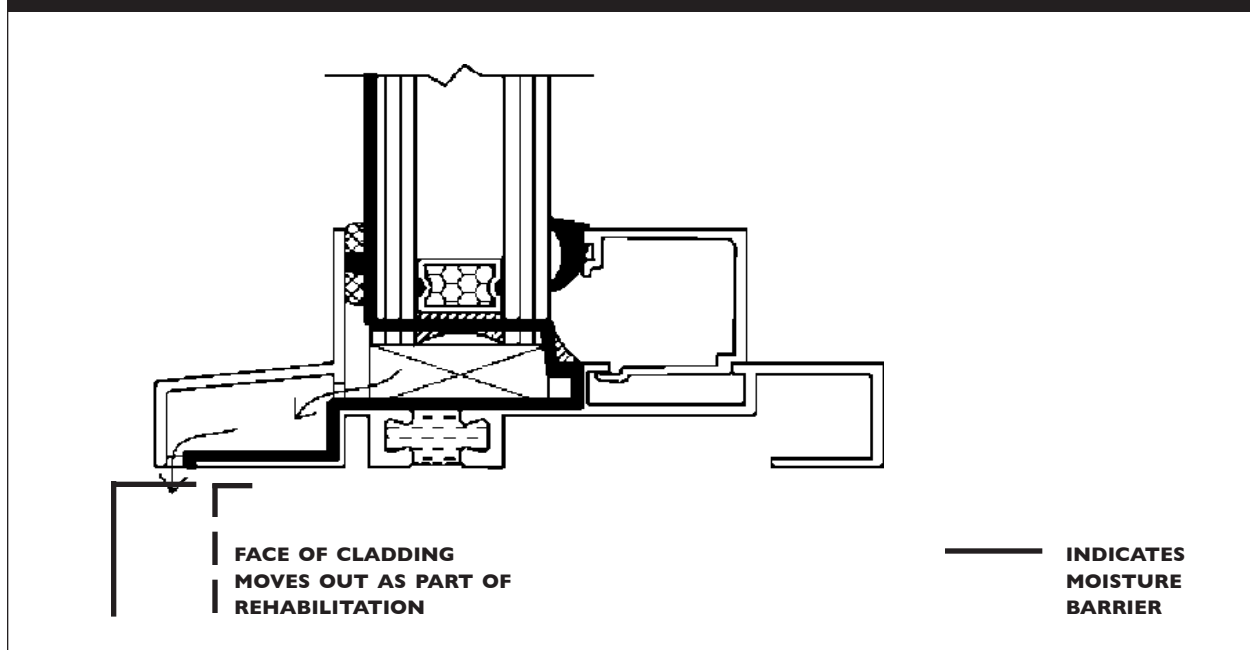
**Figure 4-3—Roof-wall air barrier continuity**

Projections through the main airtightness plane can create problems in a remedial project that does not require removal of the projections. Figure 4-4 is a detail for air-barrier continuity between cantilevered joists supporting an exterior balcony. The use of spray-in-place polyurethane foam allows for continuity of the air barrier around the complex framing configuration associated with a cantilevered balcony.

**Figure 4-4—Continuity of air barrier at balcony, using urethane foam**

### 4.3.3 Windows

Once a final window rehabilitation strategy is set, window installation details must be developed. It is good practice to assume that windows will leak and to provide a continuous moisture barrier under windows to carry moisture out of the wall assembly. It is also important to provide continuity of the air barrier from the wall assembly into the windows. It is critical that the interface between the wall assembly and the windows allow free drainage of the window weepholes. As illustrated in Figure 4-5, some windows have weepholes in the underside of the sill extrusion and these weepholes can easily be blocked when the thickness of the wall assembly is increased. The enclosed CD-ROM contains a three-dimensional presentation of a wall rehabilitation at a window location.

**Figure 4-5—Potential for blocked weepholes when cladding face is moved outward**

### 4.3.4 Extent of wood removal

Visible evidence of decay is the last stage in wood decay. The fungus that caused the decay will have continued to spread along and across the wood member. It is critical to remove not only wood that appears decayed within a member, but a further 600 mm (24 in.) past the visible decay along the length of the member. Using this "rot-plus-600" guideline, if part of a member's cross-section is visibly decayed, the entire cross-section should be removed. The cut end of the member, or edges of sheathing, being left in place should be field-treated with a preservative.

Although decay fungus most readily follows the wood grain, it will also spread between adjacent pieces of wood. The "rot-plus-600" guideline is not intended to be applied laterally from one piece of wood to the next. Members adjacent to decayed wood should be visually examined and, if no decay or obvious signs of fungal infection are found, left in place and field-treated with a preservative.

Sound portions of partly deteriorated members that have been removed from the building can be salvaged, field-preservative treated and re-used elsewhere in the building.

After applying these guidelines, some remaining wood will likely still be infected with decay fungus. The question becomes: "How active is it?" To decrease the likelihood of the decay progressing, all wet framing exposed during the repair program should be allowed to dry to a moisture content of 19 per cent or less before being enclosed. This is consistent with the VBBL requirement that the moisture content of lumber be not more than 19 per cent at the time of installation. While drying the wood will stop the decay process, it will not necessarily kill the fungus. It can remain dormant in the dry wood and reactivate if the wood is wetted again.

If there is doubt about dryness of the post-repair environment, wood left in place should be field-treated with a preservative.

The main purpose of field-applied preservatives is to contain fungus and insects within infected wood to prevent their transfer to uninfected wood. They do not render the wood free of infection and they do not restore the structural capacity. They should be used only in conjunction with decay removal and drying of the framing, not as a substitute.

The “rot-plus-600” guideline can be extremely onerous when applied to the ends of joists as it may mean removing past the point of bearing, making complex splicing and removal of interior finishes necessary.

Under particularly difficult circumstances, cut out the decayed wood along with adjacent wood that is obviously water-marked. Test the remaining dry, unmarked wood within 600 mm (24 in.) of the decay for strength using a Pilodyn wood tester or other, similar technology, accompanied by examination of the remaining cut end for signs of decay. The use of such technology requires a great deal of experience and judgment. Unfortunately, there are few practitioners in B.C.

The decision not to cut out the full 600 mm (24 in.) distance should only be made by a professional engineer or guidance of a consultant familiar with wood decay. Liberally applying a preservative and drying the framing will help minimize regrowth of any residual fungi.

Wall and floor sheathing should be cut out along the centreline of studs and joists or cut alongside studs and joists if new nailers are installed (see Figure 4-6). Cuts in floor sheathing parallel to the span will require the addition of blocking between joists if the original sheathing had tongue and groove edges or was blocked along unsupported edges. Similarly, with wall sheathing, unsupported edges should be blocked if they were originally constructed in this way.

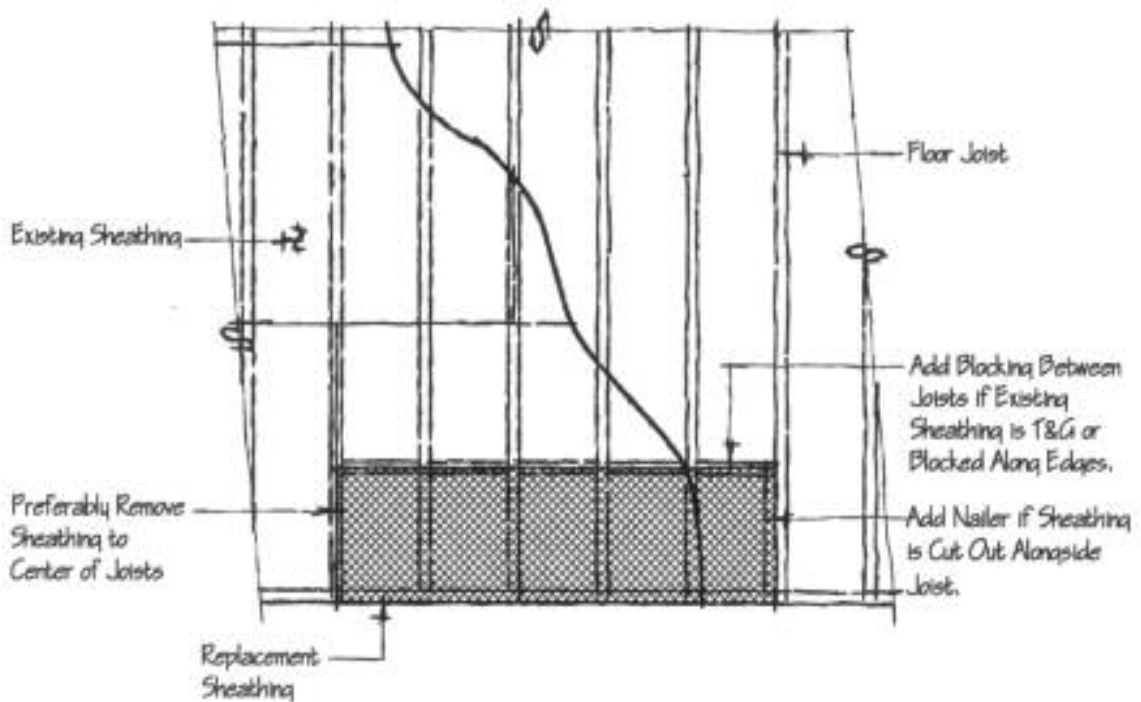
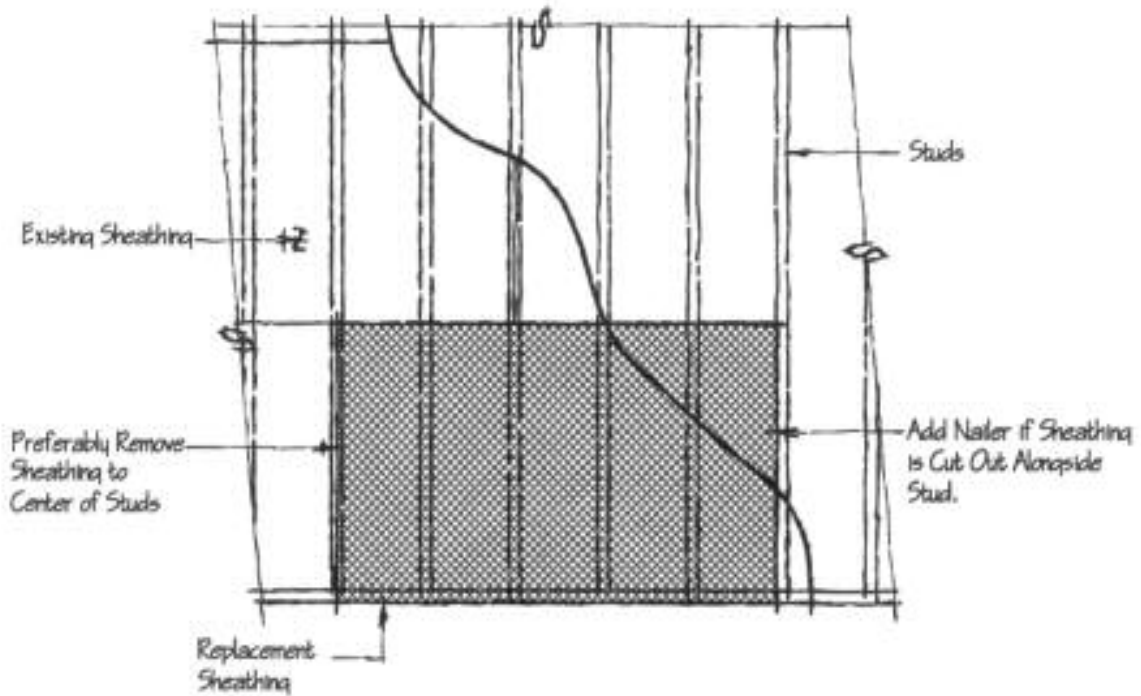
Piecemeal patching of wall and floor sheathing without adequate blocking and nailing may lower the capacity of the wall or floor as a shear wall or diaphragm.

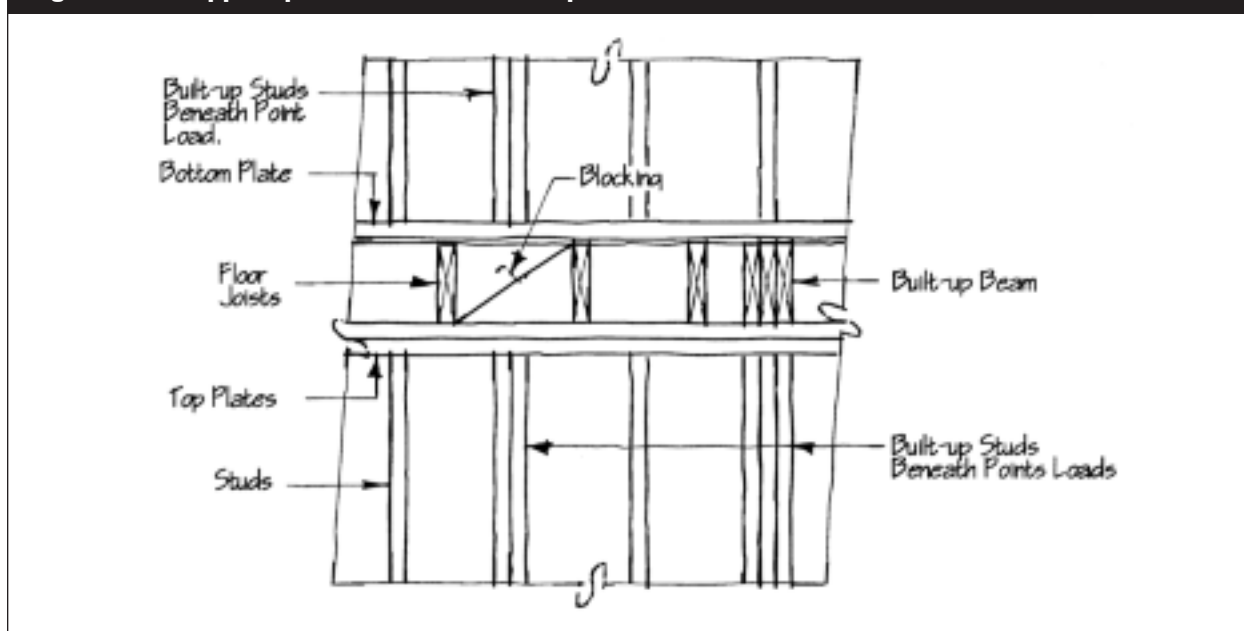
Indications that an exterior wall is a designated shear wall include heavy nailing of the sheathing, blocking of unsupported sheathing edges and hold-down anchors at the ends of walls. Such walls require special attention.

It often costs less, because of labour and material costs, to replace partially decayed studs than to splice them. If replacing them, the sound portion of existing studs can be left in place alongside the new studs to minimize the damage to interior finishes caused by removal. If splicing, following the “rot-plus-600” guideline will remove enough material to install an appropriate splice. Built-up studs should be either spliced or removed and replaced so they provide support in the same location beneath the point loads. Take care to locate studs so that splices in the top wall plates are adequately supported (see Figure 4-7).



Figure 4-6—Replacement of sheathing in walls and floors



**Figure 4-7—Support provided beneath load points**

Joist splices are generally complex and costly. However, full-length joist replacement requires extensive removal and replacement of ceiling finishes. If splicing, following the “rot-plus-600 mm” guideline will remove enough material to install an appropriate splice.

A professional engineer should design splices resulting from partial removal of a structural framing member.

While it may be expedient to use standard splice details that fully restore the structural capacity of members, it is not always necessary. A splice must be capable of restoring the structural capacity of the member so it can resist its design loads. If the design loads do not produce maximum-allowable stresses at the point of the splice, then the splice need not restore the full structural capacity of the member. Bending, shear and, for vertical members, axial forces have to be considered in the design of splices. The stiffness of the member at the splice location, if less than the original member, also has to be considered for control of deflection.

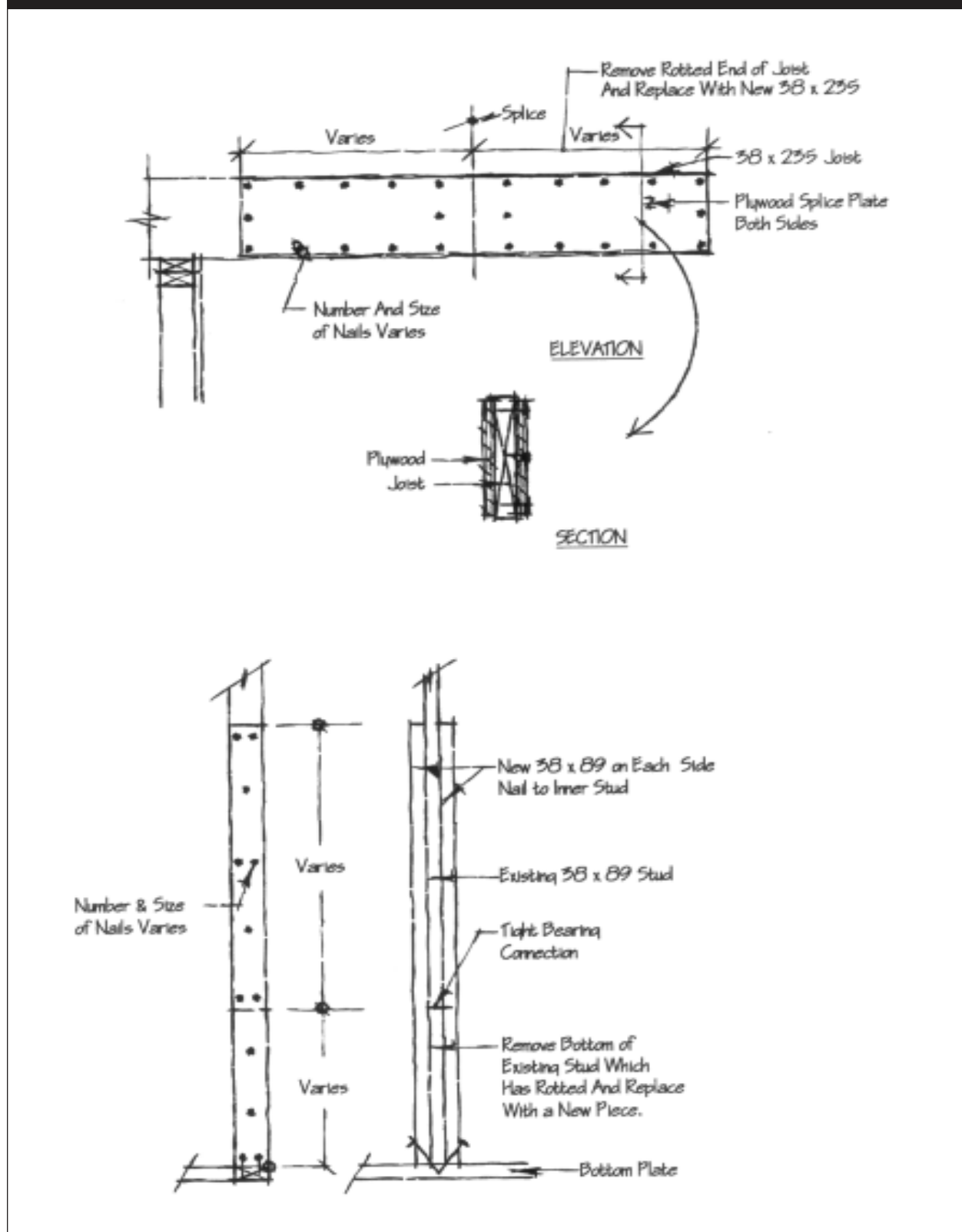
Examples of stud and cantilevered joist splice details are in Figure 4-8.

Header and edge joists, provided they are not functioning as part of a lintel assembly, can be cut out at any point along their length because they are fully supported by the wall plate. Similarly, bottom wall plates need no special splicing considerations. Double-top wall plates in load-bearing walls should be cut out so that joints are staggered at least one stud space, as set out by B.C. BC. sentence 9.23.11.4.(1).

Appearance will generally dictate that isolated posts and exposed dropped beams be replaced rather than spliced. Similarly, lintels generally cannot be spliced economically within the confines of an exterior wall.

Partial removal and splicing of manufactured wood products, such as prefabricated wood I-joists, glued-laminated beams, parallel-strand lumber and laminated-veneer lumber requires case-by-case engineering analysis.

Figure 4-8—Splicing of wood framing



### 4.3.5 New sheathing and framing

All new wood products must comply with the rule of not more than 19 per cent moisture content at the time they are closed in. Take care to protect wood products from exposure to precipitation. Ensure they are not stored in run-off areas or where puddles might form.

**Dimension lumber** should be replaced with new dimension lumber having the same, or better, strength properties than the removed lumber. The most-critical properties depend on the loading of the member involved. For joists, bending strength or stiffness will generally govern the design. For lintels, longitudinal shear strength generally governs, but bending strength and stiffness become more important as spans increase. For studs and posts, compression strength parallel to grain will govern the selection. For wall plates, compression perpendicular to grain will govern. Graded finger-jointed studs are considered equivalent in strength to sawn studs of the same grade. All replacement framing materials should be in accordance with B.C. BC Part 9 as a minimum requirement.

Pressure-preservative treated lumber has lower strength properties than untreated lumber if it has been incised. This has to be considered before using it as a replacement.

Replacing dimension lumber with material of the same species and equal, or better, grade will generally—but not always—be sufficient. Exceptions occur in older buildings because of changes in the specified strengths of dimension lumber (or allowable stresses in working stress design) that have taken place in CAN3-O86.1, *Engineering Design In Wood (Limit States Design)* and its working stress design equivalent,

CAN3-O86. Most notably, the allowable bending stress for common framing sizes in species group D. Fir-L was downgraded significantly from the 1972 edition to the 1984 edition. For example, in the 1972 edition, the allowable bending stress for No. 2 grade D. Fir-L joists was 37 per cent higher than No. 2 grade Hem-Fir. In the 1984 edition, the allowable bending stress for No. 2 grade D. Fir-L joists was 15 per cent lower than No. 2 grade Hem-Fir. In the current, 1994 edition, No. 2 grade D. Fir-L is rated nine per cent lower.

These changes are the result of a large, industry-wide, in-grade strength test program on full-sized material. Before this, the allowable stresses were derived from knowledge of the mean strength of clear wood of each of the species included in each lumber marketing group. Reductions in stress from clear-wood properties were based on maximum-sized defects permitted in each grade. Therefore, in an older building, replacing D. Fir-L joists with D. Fir-L joists may not be equivalent. Upgrading to Hem-Fir may be required. Bear in mind that neither the strength of the trees nor the lumber may have changed—only the industry's knowledge about actual strength of production material and the resulting allowable unit stresses.

Another significant change between the 1972 and 1984 editions of CAN3-O86 was the difference in allowable bending stress between No. 1 and No. 2 grade lumber in the common framing sizes. In the 1972 edition, No. 1 grade lumber was assigned higher allowable bending stresses than No. 2 grade. In the 1984 edition, the allowable bending stresses for No. 1 grade were lowered to be the same as No. 2 grade. In the current 1994 edition, not only are the allowable bending stresses the same for No. 1 and No. 2 grade lumber in the common framing sizes, but all other allowable stresses are as well.

Therefore, in significantly older buildings, replacing No. 1 grade with No. 1 grade may not be equivalent. Upgrading to Select Structural grade may be required. Again, the above changes are the result of the in-grade test program on production material which found that there was no statistical difference between the strength of No. 1 grade material and No. 2 grade material. Some of the characteristics permitted for each grade, on which visual grading is based, do not have sufficient strength reducing effects to justify marketing No. 1 grade material as a separate structural grade. No. 1 grade continues to be identified as such for other applications.

Based on the above, a structural engineer should be consulted in all but the most straightforward of cases, that is, replacing dimension lumber in a newer building with material of the same species and equal or better grade.

**Wall and floor sheathing** should be replaced with new sheathing having strength properties equal to, or better than, the removed material. In general, board sheathing should not be used to replace panel sheathing and only O-2 grade OSB should be used if replacing plywood sheathing with OSB, unless thicknesses are adjusted and reviewed by a structural engineer.

**Manufactured wood products**, such as prefabricated wood I-joists, glued-laminated beams, parallel-strand lumber and laminated-veneer lumber, should be replaced with identical materials unless reviewed by a structural engineer and found to be appropriate.

#### 4.3.6 Preservative treatment

Replacement lumber and sheathing should be pressure-preservative treated wherever it is inaccessible in the finished construction and

outside the moisture barrier. Refer to the *Best Practice Guide—Wood-Frame Envelopes in the Coastal Climate of British Columbia* and CSA O80 Series-97 for recommended preservative treatments for various service environments, as well as wood species and grades. In addition to the recommendations in the *Best Practice Guide—Wood-Frame Envelopes in the Coastal Climate of British Columbia*, it is recommended—and increasingly common—to specify Kiln Dried After Treatment (KDAT) products. It is also recommended that preservative pre-treated products be identified with a mark showing proof of third-party assurance inspection.

Field-treat all untreated areas of pressure-preservative treated wood that are exposed from cutting and boring. There are essentially two readily available field preservatives suitable for use in wet service conditions: copper naphthenate and zinc naphthenate. Only copper naphthenate should be used, as it is roughly twice as effective. Borate-based preservatives should not be used outside the moisture barrier in wet service conditions, as water will leach the borates out of the wood over time.

Also consider using preservative-treated sheathing on exterior walls that are deemed to be important as shear walls, or if it is doubtful that the moisture leading to the degradation has been eliminated. In those cases, replacement sheathing and lumber should be pressure-preservative treated and existing sheathing and lumber that is left in place should be field-treated with a preservative. A borate-based preservative is suitable, since improvements to deflection, drainage and drying capability of the walls should have reduced the moisture load below the threshold for leaching.

Another way of field-treating wood members is boron rods or paste. The soluble rod or paste is inserted into holes drilled in the wood. Borates

diffuse into the wood when sufficient moisture is present. Boron rods are best-suited to treat isolated, larger framing members in damp conditions protected from exterior moisture sources, such as those inside the moisture barrier or in low-exposure conditions.

People working with preservatives and preservative-treated wood must be familiar with the product's safe-handling practices.

### 4.3.7 Fasteners

Unit capacity and spacing or number of replacement fasteners should be equal to, or better than, the existing fasteners. As a minimum, all replacement fasteners should meet B.C. BC Part 9 requirements.

Take care to ensure that load paths for vertical and lateral loads are restored to original or better condition through proper fastening. Restricted access must not be allowed to preclude this from being done.

Use corrosion-resistant fasteners for the same applications given in "Preservative treatment". Nails used in applications outside the moisture barrier should be stainless steel or hot-dip galvanized. Electro-galvanized nails should not be used outside the moisture barrier as they have thinner zinc coating and offer less corrosion resistance.

Inside the moisture barrier, common nails are adequate except where preservative treated lumber or sheathing is used as a precaution against incidental moisture or residual fungi. Use hot-dip galvanized or stainless steel fasteners.

Nail guns using stainless steel, electroplated galvanized and hot-dipped galvanized nails are available.

## 4.4 Construction documents

"Construction documents" are all written and graphic documents prepared by the consultant (and sub-consultants) to communicate the design and construction of the project. Within this broad grouping other subsets of documents may be identified.

**Contract documents** are identified in the contract and consist of the legal agreement between the owner and contractor and all construction documents except the bidding documents.

**Bidding documents** are provided to the contractors for the purposes of preparing bids. During the tendering period, additional information may be added in the form of addenda.

**Addenda** and later changes during the construction stage also become part of the contract documents. Table 4-1 sets out the structure of the various construction document subsets

Standard construction contracts assign an order of precedence to contract documents in case of conflicting requirements. Typically, specifications are given priority over schedules and drawings; schedules have priority over drawings. For this reason it is important to clearly distinguish between drawings, schedules and specifications, to understand the information to be provided by each and to avoid repetition. Drawings should include neither specification notes nor refer to proprietary products.



**Table 4-1—Summary of construction documents**

Document	Document set		
	Construction documents	Bidding documents	Contract documents
Bidding requirements (See Chapter 5)	✓	✓	✓
The agreement	✓	✓	✓
Definitions	✓	✓	✓
General conditions of the contract	✓	✓	✓
Supplementary conditions of the contract	✓	✓	✓
General requirements (Division 1)	✓	✓	✓
Technical specifications (Divisions 2-16)	✓	✓	✓
Drawings	✓	✓	✓
Addenda	✓	✓	✓
Contract modifications	✓	✓	✓

#### 4.4.1 Drawings

Drawings provide graphical information and identify the size, location and arrangement of various building assemblies, components and materials. Although drawings are used as part of the building permit submission, their primary function is contract documents to provide information to enable the contractor to perform the work. Many municipalities issue documents setting out the information to provide on permit application drawings. Materials and components should be identified with generic terms. Provide detailed information in the accompanying technical specifications.

Drawings should not attempt to define means of construction or assign subtrade responsibility for portions of the work.

The drawings should document previous design decisions. Making fundamental design decisions (as opposed to detailing decisions) during the preparation of the drawings can be inefficient and have an impact on construction costs.

However, it may be necessary to revisit some design decisions made during the design stage to deal with issues that arise during production of the drawings.

Although each project is unique, the basic information provided does not change significantly. The drawings must provide sufficient information to identify and locate all materials, components and assemblies and to indicate the extent of the work. The following drawings and information should be provided:

## General arrangement drawings

Site plan, floor plans, building elevations and sections. The purpose is to indicate the overall scope of the work, to identify interfaces between remedial work and existing elements to remain unchanged, to identify the locations of assemblies and components and to reference detail drawings.

## Detail drawings

Show the detailed location of materials and components and their relationship to adjoining assemblies. Show dimensions of all materials assemblies and components. Actual profiles of existing components such as windows should be drawn, rather than relying on generic indications. Existing and new construction should be clearly identified and distinguished.

All drawings should be to scale. The appropriate scale for detail drawings will vary depending on the level of detail to be conveyed. However, critical interfaces such as window perimeter details should be drawn at 1:2 or 1:1 scale.

All drawings should have a title block giving:

- Project title and address.
- Drawing number and revision.
- Date of drawing issue and dates of revisions.
- Consultant(s) name and address with space for a seal.
- Name of designer, draftsman and reviewer.

Use standard symbols, abbreviations and drawing conventions on all drawings.

## 4.4.2 General requirements

The preparation of general requirements should use the standard three-part specification format (general, products, execution) that is the basis for the National Master Specification and which is used for the technical specifications. General requirements are the organizational structure for the specifications. They deal with three broad areas:

1. Administrative requirements.
2. Procedural requirements.
3. Temporary construction facilities.

Construction Specifications Canada (CSC), a construction trade organization, provides various guide documents that may be used to prepare specific, division 1 requirements. CSC TEK-AID Division 1 provides a *pro-forma* format for a series of master specification sections.

Division 1 (see 01001—General requirements, page 34 and 01011—Scope of work, page 34) sets out overall project requirements that are not specific to particular assemblies, components or materials.

### 01001—General requirements

Table 4-2, is a sample of issues that should be addressed within the general requirements section of the project specifications.

**Table 4-2—Sample of general requirements issues**

Summary of work	General
Related sections	Project co-ordination
Cutting and patching	Inspection
Execution	Project meetings
Submissions	Administrative
Shop drawings and product data	Samples
Record drawings	Schedules
Schedules required.	Format of construction progress schedule
Submission	Quality control
Inspection	Municipal inspection
Construction facilities and temporary controls	Safety
Installation—removal	Site trailer
Hoarding	Weather enclosures
Dust-tight screens	Interior unit protection
Site storage—loading	Sanitary facilities
Water supply	Temporary power
Temporary telephone	Equipment—tool—materials storage
Project cleanliness	Standards of conduct
Emergency contact	Material and equipment
Product and material quality	Storage, handling and protection
Manufacturer's instructions	Workmanship
Concealment	Project closeout
Final cleaning	Systems demonstration
Documents	Inspection—takeover procedures

### 01011—Scope of work

Because rehabilitation projects involves working at an existing building, this section is often included to help define the extent and nature of work, in addition to sequencing, access or other occupant issues that are not otherwise in the technical portion of the specifications.

### 4.4.3 Technical specifications (divisions 2 to 16)

Technical specifications complement the drawings and provide details about the quality of materials and components, compliance with standards, workmanship and approved suppliers of particular materials and components.

Preparation of technical specifications should use the standard CSC three-part section format (general, products, execution) that is the basis for the National Master Specification and is used almost exclusively for new building construction.

The technical portion of the specification package needs to be developed for each unique project. However, there are commercially available master specification packages that provide good starting points for the development of specifications. Other guideline documents such as the *Best Practice Guide—Wood-Frame Envelopes in the Coastal Climate of British Columbia* can provide the information needed to prepare technical specifications.

### 4.5 Construction documents stage—consultant checklist

- ☐ Review project and construction cost estimates with owners
- ☐ Develop construction documents (drawings and specifications) to illustrate nature and scope of work
- ☐ Review municipal permit process with owners
- ☐ Assist owners in obtaining permits
- ☐ Advise on bidding documents and obtain instructions
- ☐ Continue to review applicable codes, bylaws and regulations

# Chapter 5—Tendering

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# Chapter 5—Tendering

## 5.1 Introduction

This chapter deals with tendering and contractor selection and discusses other construction implementation scenarios. The consultant's main tendering activities are:

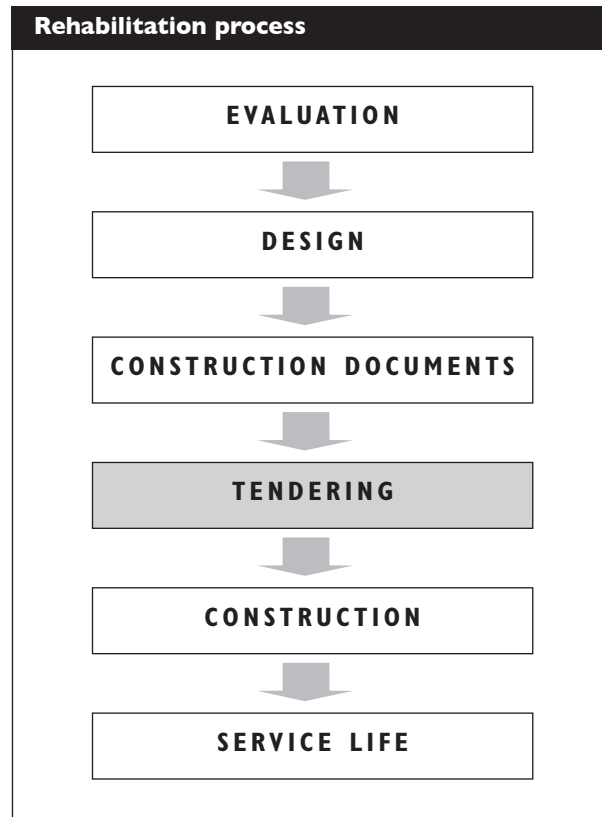
- Assembling bid documents.
- Assisting and advising the owner in obtaining bids or negotiating proposals.
- Assisting and advising the owner in preparing contract(s) for construction.
- Assisting and advising the owner in awarding contract(s) for construction.

## 5.2 Implementation approaches

Three basic approaches have evolved for delivery of construction projects.

**The first** is the "traditional" approach. It involves hiring a consultant to investigate the problem and establish the basic rehabilitation need and scope. As a second step, a consultant team undertakes the design and produces construction documents (drawings and specifications) that are tendered to general contractors. The general contractor then contracts independently with trade contractors for specific components of the work. Advice and input from contractor may or may not be sought during the investigation and design stages.

**The second** is the "construction-managed" approach. In its most fully developed form, once the consultant's condition assessment or investigation confirms a problem, the owner retains a manager to guide the process and provide input about costs and other construction issues throughout rehabilitation. The construction management role is a part of the overall management responsibilities and involves tendering of the work directly to trade contractors and subsequently managing construction activities on site.



In one of the two basic construction-managed forms, there is a consultant or team of consultants, a construction manager (usually a general contractor or a construction management firm) and trade contractors who contract with the construction manager.

The second form is a consultant or consultant team, a construction manager (who could be the consultant, a general contractor, or a construction management firm) and trade contractors. They contract directly with the owners. In some instances, the consultant may be capable of providing construction management services as an extension of the basic design and administration services. In this case the need for a separate construction manager is eliminated. In either case, overall project management is provided by the consultant or a separate project-construction management firm.

The **third approach** is "design–build." It is essentially a turnkey approach to project delivery. A contractor and consultant team provides the project delivery on a unified basis with a design–build contract between the owner and contractor and a separate contract between contractor and consultant. This approach offers the advantage of only one point of contact and responsibility for the owner.

Selecting an approach for a project should be based on a number of factors, including:

- Experience and abilities of the consultant.
- Size of the project.
- Nature of the rehabilitation work.
- Number of trades involved in the project.
- Availability of qualified and experienced trade and general contractors.
- Ease of quality assurance with each approach.
- Relative costs of the approaches.
- Other specific needs of the owner.

In each approach, the contractors' role is to adhere to the construction documents, as much as possible, for a stipulated price and within a reasonable schedule. Unfortunately, because of the nature of rehabilitation, neither consultants nor contractors can accurately determine the

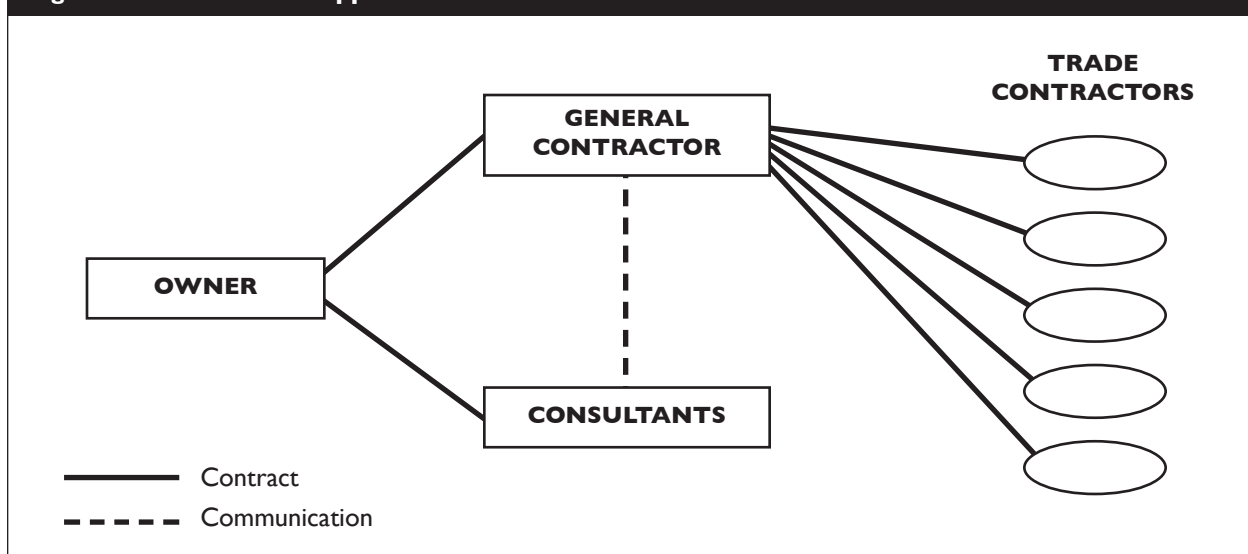
extent, severity and cost of wood decay (rot) repair at the time of tendering. The amount of rot can only be determined after stripping the exterior walls and exposing the structure. Then, the work needed to repair the rot can be verified and the cost and schedule adjusted.

There are a variety of agreement forms. The most common is the *CCDC-2 (1994) Stipulated Price Contract*. This standard agreement is the basis of discussion in Chapter 6—Construction. *CCDC-20—Guide to the Use of CCDC-2 (1994)* and *CCDC-24—Guide to Model Forms and Support Documents* are useful reference tools for consultants.

### 5.2.1 Traditional approach

The traditional approach is, by far, the most common model for rehabilitation projects. It requires the involvement of the owner, consultants and a general contractor in roles that are widely understood and recognized. This approach's advantage is that it provides a single point of responsibility and can generally be implemented with the least involvement of the owners. Figure 5-1, shows the relationship between the owner, consultants and a general contractor.

**Figure 5-1—Traditional approach**



The owner typically retains a consultant to assess the problem, undertake the design and prepare construction documents so that construction work can be tendered to general contractors. They, in turn, contract with trade contractors of their choice for portions of the work. Upon completion of the tendering process the successful general contractor signs a contract with the owner to carry out the remedial work in accordance with the contract documents prepared by the consultant. This contract is defined by CCDC-2. While the consultant is not party to the contract between the owner and the contractor, the contract does refer to a consultant and specify a role in the process. This is discussed in Chapter 6—Construction.

Since owner groups faced with a significant rehabilitation project generally do not have sophisticated construction expertise, the consultant has an essential role. The consultant administers the contract between the owner and the contractor, assesses whether the work is being done in general conformity with the contract and impartially interprets the requirements of the documents. Owners typically rely heavily upon the consultant to provide advice and insight into an often complex and difficult process.

Owner groups generally prefer the traditional approach because they are familiar with the concepts and they perceive that the contractor is assuming the risk for construction-related issues. This perception is not entirely accurate in rehabilitation projects as the single greatest risk is the cost of rot repair. This risk stays with the owner until the owner and contractor agree, with the consultant's assistance, on the fair value of the rot repair and a reasonable adjustment to the construction schedule. Naturally, the owner is at some disadvantage in this process. The owner is committed to a contractor and the true impact of the rot repair is difficult to determine even with the help of an experienced

consultant. For this reason, owners should rely heavily on the contractor's reputation in making a selection.

CCDC-2 can function effectively as a self-contained form of agreement. It is, however, common to amend the agreement's terms and conditions to customize application of the contract to meet specific conditions.

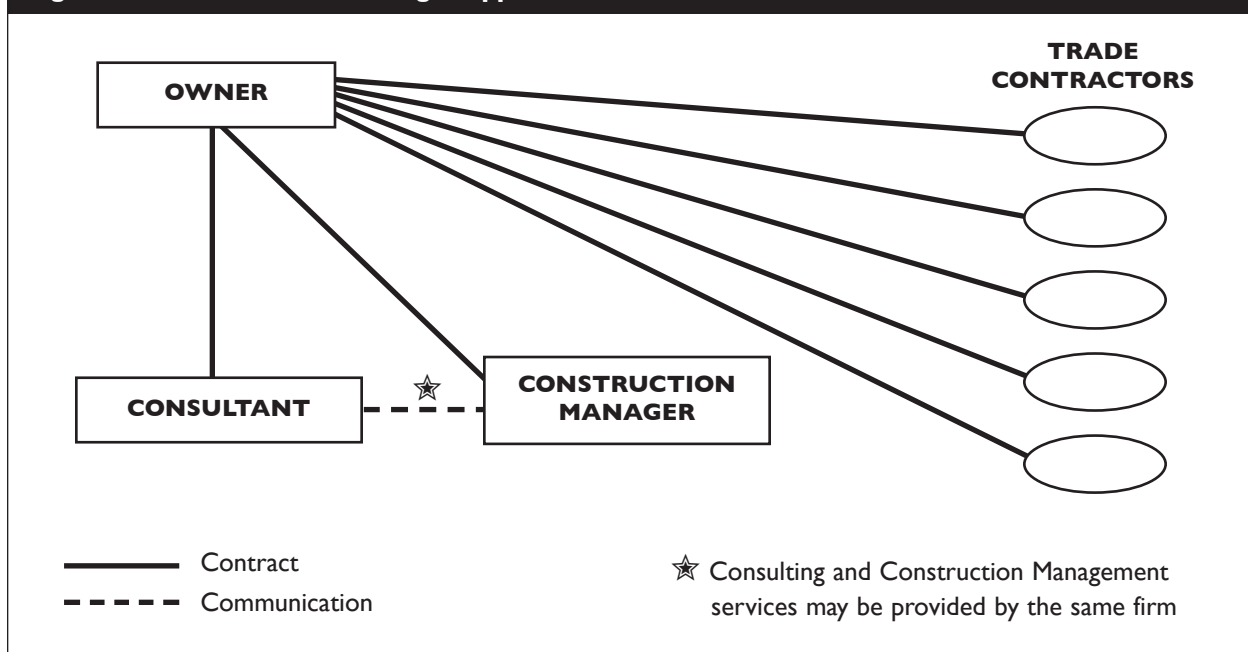
### **5.2.2 Construction-managed delivery**

At this time, construction-managed delivery is sometimes not presented to owners as a possibility. This reluctance may be due to unfamiliarity with the approach and difficulty in explaining its more complicated contractual relationships to the owners. However, for some projects this alternative offers advantages and should be presented to the owners.

The owner typically retains a consultant for many of the same investigation, design and field review services as the traditional approach. The owner also retains the services of a construction manager as an agent for co-ordination and management of construction. Together, the consultant and the construction manager act on behalf of the owner as the construction management team. The work is tendered to select trade contractors who actually do the construction. The trade contractors who perform the work can provide warranties and bonding.

Construction-management services can be provided by specialty project management firms or by a suitably experienced general contractor. Figure 5-2 shows the relationship.

As a variation, the owner may retain a consultant who is qualified to offer construction management services in addition to design and field review services. There is no need for an independent construction manager and the owners only have to deal with one entity.

**Figure 5-2—Construction-managed approach**

Rehabilitation projects for multi-unit residential buildings present some unique difficulties. The owners are not familiar with the construction process and require significant education and guidance throughout the project for it to succeed. As the owner's agent, the construction manager looks after most education and guidance of the owners and occupants, bringing in trade contractors and consultants when information is needed about specific issues.

Also unique is occupancy of the building during construction. Sensitivity to this can often be the difference in the perception of a successful project by owners and occupants. The construction-managed approach offers more direct control over scheduling and site management and can effectively accommodate the difficulties of working in an occupied building.

In many cases the building is being restored because of poor original design or construction practices. For this reason, owners know about

the past mistakes and do not want similar mistakes. They want good consultants and good contractors. The traditional approach gives owners only limited control over the selection of the trade contractors, phasing and timing. The construction-managed approach can tender to individual trade contractors to better control the quality of the trades and still obtain competitive pricing.

An important aspect of the construction-managed approach is the ability to have construction expertise early in the design stage so there can be appropriate cost evaluation of alternate approaches. The ongoing involvement of the construction manager provides direct input to the design on construction issues as well as opportunities for cost savings before the work is tendered.

The common forms of agreement for construction-managed approach are CCA-5 for the construction manager and a modified CCDC-2 for trade contractors.

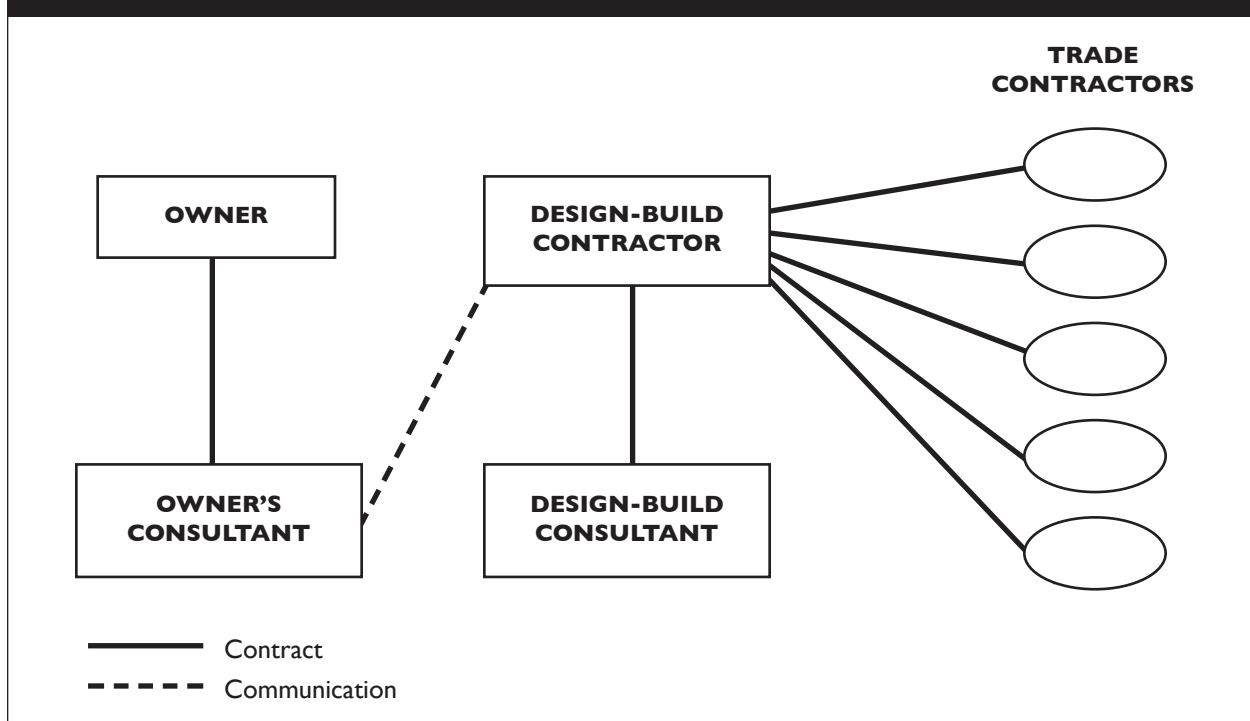
### 5.2.3 Design–build delivery

Design–build delivery is not common in rehabilitation projects. The owner retains a "design–builder" for the design and construction of the rehabilitation project under one contract. The design–builder is typically a contractor who has retained a consultant directly to provide the necessary services. Unlike either the traditional or construction-managed approaches, the contractor—not the owner—pays the consultant. The contractor contracts with trade contractors as required. Figure 5-3 shows the relationship and indicates that the owner might want to hire a consultant independent of the design–builder's consultant to review issues.

While the design–build approach benefits the owner by having one point of contact, it takes control of the process away from the owner almost completely and it becomes more difficult to demonstrate accountability. The design–build approach is not likely to be favoured or recommended. It may be necessary for the consultant to arrange project-specific professional liability insurance in the design–build scenario.

A common form of this agreement is CCDC-14, *Design-Build Stipulated Price Contract*.

**Figure 5-3—Design–build approach**



## 5.3 Front-end documents

In addition to the general requirements and technical portion of the construction document package discussed in Chapter 4—Construction documents, sections need to be added to tender work to contractors. These sections are normally included as "Division 0" and referred to as the "front end" of the specification book. The National Master Specification defines these sections as:

0100—Bid Solicitation  
 0200—Instructions to Bidders  
 0300—Information Available to Bidders  
     (0330 is Existing Conditions)  
 0400—Bid Forms and Supplements  
     (0410 is Bid Forms)  
 0500—Form of Agreement  
 0600—Bonds and Certificates

0700—General Conditions  
     (not used if 0500 refers to CCDC-2 or similar)  
 0800—Supplementary General Conditions  
 0900—Addenda and Modifications  
     (record documents for on site)

Some specific aspects of sections 0200, 0410 and 0800 are discussed below.

Although the consultant prepares the front-end documents, they will eventually be part of the contract between owner and contractor. The owner's lawyer should review them to ensure that the owner's interests are appropriately represented.

### 0200—Instructions to bidders

Instructions to Bidders describes the bidding process. Table 5-1 shows what instructions to bidders might include for a rehabilitation project.

**Table 5-1—Instructions to bidders**

Invitation	Time and location of bid submission
Procedures for opening bids	Intent
Description of project intent, time frame, nature of site and occupants, intent to phase work, etc.	Bid documents
Definition of terms	Availability and responsibility to examine documents
Substitutions of products	Assessment of the work
Examination of site	Bidders briefing meeting
Qualifications	Bid submission
Bid qualification requirements	Bid submission requirements
Bid Enclosures—requirements	List and details of enclosures required with bids
Bid Price	Describes what the bid price is to include and not include; labour, material, taxes, contingencies and adjustments
Offer acceptance-rejection	Evaluation criteria
Duration of offer	Acceptance and rejection of offers
Contract with unit owners	Restrictions concerning services provided to unit owners in addition to strata corporation
Contract	Describe commitment to enter into an agreement with the owner



## **0410—Bid forms**

The bid form is the offer made by the contractor to enter an agreement with the owner for the price that the owners provide in the bid form. The bid form is also an opportunity for contractors to confirm that they have received and are familiar with all the bid documents and have enclosed all of the necessary submissions with their bids. Any unit-pricing information required is also provided in the bid form.

## **00800—Supplementary General Conditions**

Standard forms of agreement between owner and contractor, such as CCDC-2, are templates and are the backbone of the agreement. The supplementary general conditions provide more specific terms than the base form of agreement. These supplementary conditions are very owner-and project-specific. The owner's lawyer should review all aspects of these changes to ensure that there are no conflicts with the base form and to ensure that all appropriate changes have been made.

## **5.4 Process**

### **5.4.1 Tendering**

Throughout the *Guide* there are references to the term "tender." Generally, issuing a tender is an offer by the owner to the invited bidders. Submitting a bid is acceptance of the offer made by the owner (assuming the bid complies with the bid documents prepared by the consultant for the owner). In fact, it creates a free-standing tender contract. One of the terms

of this first contract is that the bidder selected by the owner is obliged to enter into a second contract (the construction contract) in which CCDC-2 or similar form of agreement is the basic document. The tendering process is the process by which the offers (contractor bids) are solicited, submitted, reviewed and a contractor selected.

Since tendering is the process by which offers are made and accepted, it has very definite legal consequences and all participants have a number of explicit and implied responsibilities. Owners should be aware that the tender process is not to be taken lightly and must be conducted under the direction of professionals familiar with the process. They should always seek advice or direction from their lawyer about tender issues.

### **5.4.2 Tender stage clarifications**

It is advisable for all rehabilitation projects to require mandatory attendance by contractors bidding on the project at a pre-tender meeting at the site. It is not possible to describe all existing conditions and restrictions associated with the site in contract documents. The site visit makes contractors fully aware of these issues and helps to avoid misunderstandings and possible requests for extras after contract award.

Document and distribute any clarifications made at the site meeting to all bidders. Similarly, any questions posed to the consultant during the tender period should be in writing with clarifications in writing to all bidders as addenda.

### 5.4.3 Selecting a contractor

The owner's consultant is generally the best resource for identifying contractors to ask to submit a tender. Contractors must be pre-qualified on their ability to perform the work. The contractor should be selected by competitive tender from a short list of three to five is assembled.

While it is customary to have contractors compete for work in a competitive process price is not the only factor to consider. Value is much more important than the lowest price.

Owners and consultants can establish a list of invited bidders through a pre-qualification process. As a starting point, ask contractors to submit a fully executed CCDC-11. It is a valuable source of basic information about the contractor's history. Try to talk to the owners' representative for the contractor's most recent projects—do not rely solely on the list of selected contractor references given on the CCDC-11. The following are factors to consider in pre-qualification:

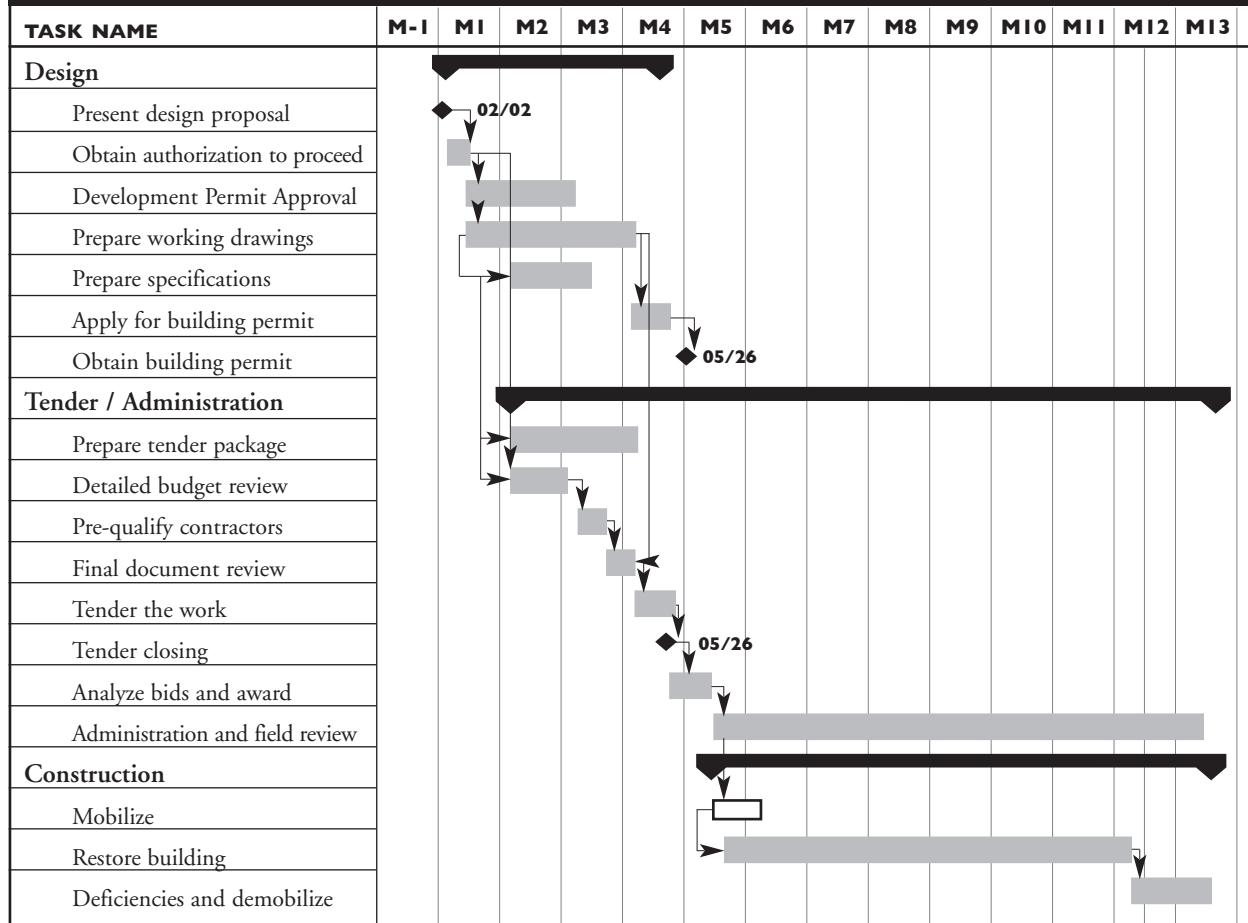
- The contractor's ability to effectively manage the work.
- The contractor's ability to co-operate and work with the consultant.
- The contractor's reputation for completing work on time and on budget.
- The contractor's reputation for pricing extras and changes fairly and reasonably.
- The contractor's proven expertise in construction and rehabilitation construction.
- The financial strength and capability of the contractor

Owners and consultants are cautioned that all factors to be considered in selecting a contractor in a formal tendering process must be fully disclosed in the tender documents. The body of law regarding the tender process favours the low bidder unless other criteria and the basis for evaluation on those criteria is clearly set out in the tender documents. In the absence of clearly set out criteria, the low bidder may sue if not awarded the contract. Typical selection criteria include:

- The price.
- The schedule.
- The strength of the specific superintendent to be assigned to the project.
- The contractor's specified hourly rates, unit rates, alternate prices or separate prices.
- The contractor's presentation of cost-saving proposals.
- Inclusion of all documents asked for in the tender offer, such as bonds, proof of suitable insurance coverage and proof of good standing with the Worker's Compensation Board.

### 5.4.4 Construction schedule

The time needed for construction work is only a portion of the time needed for the entire rehabilitation process. Once the owners decide to go ahead with repairs, the process starts. Owners must be aware that the time frame must include time to prepare drawings and specifications, obtain permits, pre-qualify contractors, tender the work, complete a contract with the contractor and for the contractor to mobilize. Figure 5-4 is a generic schedule for a typical rehabilitation project with an anticipated construction value of \$1 million.

**Figure 5-4—Typical rehabilitation schedule**

### 5.4.5 Permits

The work defined by the tender documents is the construction project. It is subject to municipal building permit requirements. Owners are required to submit a proper building permit application and pay building permit fees levied by the municipality. Preparing permit documents and applying for the permit is best done by the owner's consultant and should be included as part of the consultant's scope of services. The time required to obtain a building permit varies and can be as long as six weeks. The process

may be more complicated and take longer if the project changes the building's appearance and, consequently, requires a development permit amendment. Different municipalities handle approval of development permits issues differently. Some require formal amendment to the original development permit. Others handle approval through the building permit application. In Figure 5-4 the time to obtain a building or development permit is shown as *Obtain building permit*. Determine specific municipal requirements early in the process. They can be very time consuming.

Apply for the building permit as soon as practical in the design process—usually when the work is tendered. The timing for receipt of the permit must be considered in making final arrangements with the contractor as work cannot start until the permit is received. Consultants should verify if building permit fees are required and include the cost of the building permit in the overall project budget.

The contractor is best suited to obtain trade permits for incidental plumbing or electrical work and to arrange for associated municipal inspections. The cost, effort and time needed to obtain trade permits are usually not significant. However, the responsibility for obtaining them should be clearly set out in the tender documents.

#### **5.4.6 Owner involvement**

Owners can help by choosing an individual or small group to liaise with the owners and the contractor on issues such as:

- Unit access.
- Providing notice to owners.
- Providing approvals for small issues.
- Communicating requests for more significant decisions to the strata council.
- Co-ordinating site access and areas for materials.
- Assisting in communicating with the remaining owners and occupants as work progresses.

Consider areas for parking, storage, trailers and portable toilets before job tendering so that additional street occupancy permits and temporary construction are added to the tendered cost of work.

Landscaping may be destroyed. If it is left up to the contractors, a contingency for complete removal and replacement will likely be added to the work at marked-up rates. Most multi-unit

residences have a business relationship with a landscaper and can arrange for removal and replacement of landscaping, separate from the rehabilitation contract.

Fully understand the terms and conditions of payment. Make sure that whoever issues payments for the owners is aware of the approvals procedure and the requirements for timely payment. Compliance with the contracted terms of payment helps maintain a good relationship between the owner and contractor.

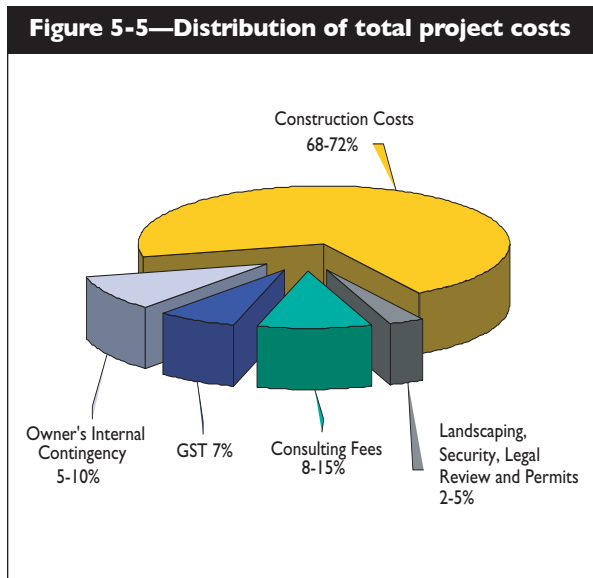
## **5.5 Costs**

### **5.5.1 Realistic project budgets**

In many ways, cost overruns or failure to meet project milestones are more often a result of unrealistic expectations and inadequate budgets than unanticipated conditions. It is essential to create realistic project budgets that accurately reflect probable costs. When preparing a rehabilitation budget it is pointless to be unrealistically optimistic and understate probable costs—this can result in owners committing themselves to a project that they are unable to pay for. It is equally irresponsible to be overly conservative and inflate budget numbers—this can result in owners delaying or not proceeding with necessary repairs. To create a realistic budget, include:

- Consultant fees.
- Legal review fees.
- Goods and Services Tax (GST).
- An owner's contingency fund for unforeseen or unexpected problems.
- Construction costs, including an appropriate wood-decay contingency fund.
- Building permits.
- Third party warranty coverage.
- Other costs that may not strictly be part of the rehabilitation project, such as landscape repair, additional property management work, additional security, and so on.

Figure 5-5 shows cost distribution for a typical project budget with anticipated construction costs of \$1 million. The costs do not include consultant fees during the evaluation stage and assume a traditional project delivery model.



The costs associated with providing a third party warranty must be included in the project budget. These costs may increase the total cost by:

- Increasing construction costs because the warranty providers prefer low risk solutions.
- Adding three to 10 per cent of construction costs if the owners pay the warranty fees.
- Adding to the consultant's and contractor's hidden costs for additional administrative and indemnity provisions they might have in their agreements with the warranty providers.

The owner and the contractor(s) should plan for various contingencies in the project. The contractor(s) should include contingency in their bid(s) for unforeseen or perceived risk items. The owners should have an overall contingency for unforeseen project costs.

The construction budget should also carry a contingency for wood decay and structural repairs and other possible costs. However, the nature and extent of this work is difficult to determine and fixed price bids can not be obtained.

It is important to note that wood decay and structural contingencies are not necessarily going to be spent completely—amounts not spent are the property of the owner. In some instances, contingencies for structural repair are identified before tendering and when the contract is awarded, some of these contingencies are "borrowed" to make up for a higher-than-anticipated tender price. This borrowing from a structural repair contingency fund at the time of contract award can result in project budget problems as work proceeds if sufficient funds are not available to complete the work.

Many construction costs can be well defined and estimated once the program is confirmed. However, until the building framing is exposed it is not possible to provide accurate estimates of the costs associated with structural damage. For this reason, budget estimates typically carry large construction contingencies and cannot be refined to nearly the level of accuracy possible in new construction.

The stated accuracy of the project cost estimates in Table 5-2 include construction contingencies but typically do not include the owner's contingency. The owner's contingency should cover the high side of the shown accuracy range. Therefore, suggested owner contingency figures at the condition assessment stage should be 40 per cent, at the design report stage 20 per cent and the tender stage five to 10 per cent.

Table 5-2 describes milestones at which project budgets should be determined and re-evaluated and gives the purpose(s) and level of accuracy for each estimate.

**Table 5-2—Project budgets****Condition assessment or investigative report**

At this stage the extent and severity of the problem is generally known and conceptual level rehabilitation approaches have been identified. However, quantities are rough estimates. Exact assemblies and details have not been developed, nor have various phasing and implementation approaches been evaluated or selected. Estimates should be based on historic information from previous similar projects, but should be considered accurate to the  $\pm 40$  per cent level. Estimates should include all project costs, not just construction costs.

These estimates are useful in alerting the owners to the overall magnitude of the rehabilitation project and allow decisions to be made about proceeding to the next steps in design of the rehabilitation.

The accuracy of these estimates is not usually appropriate for determining the value of special assessments, since the program is not yet fully defined.

**Design stage**

The project cost estimates that are part of the design stage are based on more-detailed development of the proposed assemblies, more-accurate area takeoffs and much more detail about phasing of the work and construction implementation. These construction cost estimates should be prepared with the assistance of a quantity surveyor or a contractor familiar with remedial work.

Once decisions have been made based on the alternatives the project budget estimates can usually be considered accurate to  $\pm 20$  per cent.

These estimates can be used for overall project planning purposes, obtaining approval for special assessment (project estimate + 20 per cent owner contingency) and for rehabilitation funding programs such as the HPO's reconstruction loan program.

**Pre-tender**

Near the completion of the construction document stage the project estimate should be refined based on the complete documents. It will be necessary to pay contractors or a quantity surveyor for their assistance at this stage and this cost should be included in the project budget. The contractor's budgeting review will also likely result in more general comments and questions about the design documents, in addition to possibly identifying cost-saving opportunities and assisting in developing a preliminary construction schedule and cash flow plan.

The construction cost estimate provided by contractors at this stage should be combined with other project costs to arrive at an overall project estimate which should be accurate to the  $\pm 5$ –10 per cent. Tendering should not proceed without this estimate being completed and the owners ensuring that there is appropriate funding. The detailed breakdown of this estimate will also form the basis for the evaluation of the bids. Note that the owner's overall project budget should be between five and 10 per cent of the project construction estimate.

**Construction**

The construction budget is based on the accepted bid(s) plus all construction and owner contingencies. The budget should be monitored every month with the contractors progress draws. By reviewing the budget monthly, there should be no big surprises and as the work is completed the certainty associated with the final project costs increases. The accuracy of the overall project budget estimate gradually improves from  $\pm 5$ –10 per cent.

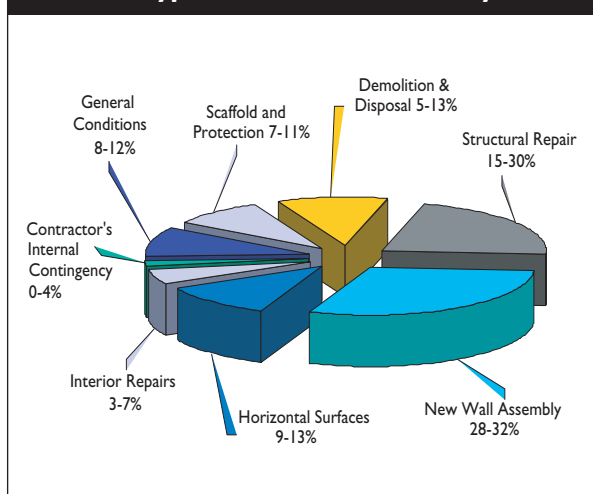


It is important to note that neither the consultant nor the owner have control over many of the factors that affect construction costs. The cost of labour, materials, equipment, the contractor's method for determining bid prices, market conditions—thus competitiveness of the bids or negotiating conditions—are all beyond the consultant's control. For these reasons, the consultant cannot guarantee the accuracy of construction cost estimates.

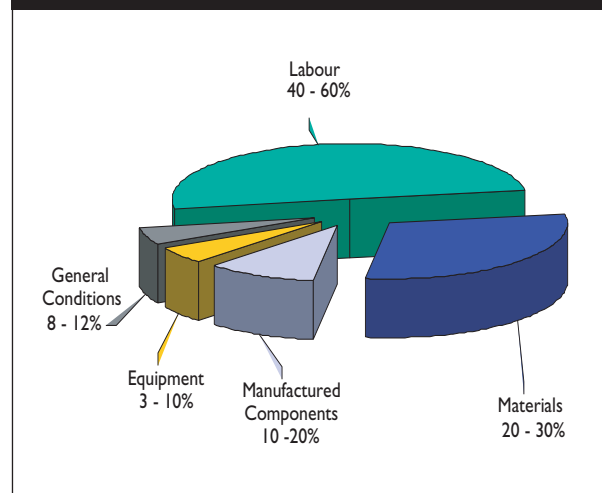
### 5.5.2 Construction costs

Construction costs are the most significant of the costs in the overall project budget. To understand how various factors may influence construction costs, it is helpful to see how the construction cost portion of the overall project budget is developed. Figure 5-6—Distribution of construction costs based on type of construction activity and Figure 5-7—Distribution of construction costs based on cost element show allocation of construction costs for a typical wood-frame rehabilitation project. Note that structural repairs in Figure 5-6 refer to work required due to wood decay and interior finish work, as well as other framing work required due to deficiencies in the original construction.

**Figure 5-6—Distribution of construction costs based on type of construction activity**



**Figure 5-7—Distribution of construction costs based on cost element**



Using this typical cost spread as the basis for discussion, the following sections explore how various factors may influence costs and the significance of such impacts in terms of the overall construction budget. With a better understanding of these factors, consultants, owner groups and contractors can make better-informed decisions about rehabilitation projects.

### 5.5.3 Wall assembly costs

For comprehensive restoration projects, one of the fundamental decisions is the selection of an appropriate wall assembly to replace the existing failed assembly. The *Best Practice Guide—Wood-Frame Envelopes in the Coastal Climate of British Columbia* and earlier chapters of this *Guide* present various options.

Table 5-3 is a relative cost comparison between assembly types in the context of rehabilitation construction.

For comparison, the face-seal stucco wall assembly is the base assembly with a cost at 100 per cent, including the construction costs identified in Figure 5-6 and Figure 5-7:

**Table 5-3—Relative total cost of construction using different wall assemblies**

<b>Best Practice Guide wall type (if applicable)</b>	<b>Description</b>	<b>Percentage</b>
Wall ST-1	Stucco—Face-seal wall assembly	100 % (base cost)
Wall ST-2	Stucco—Concealed-barrier wall assembly	+7 %
Wall ST-3	Stucco—Rainscreen wall assembly	+24 %
Wall ST-4	Stucco—Exterior-insulated rainscreen wall assembly	+50 %
N/A	Stucco—Dual insulation rainscreen assembly	+45 %
Wall BV-1	Brick Veneer—Rainscreen wall assembly	+52 %
Wall BV-2	Brick Veneer—Exterior-insulated rainscreen wall assembly	+75 %
Wall HS -1	Horizontal Siding—Concealed-barrier assembly	-2 %
Wall HS -2	Horizontal Siding—Rainscreen wall assembly	+14 %
Wall HS -3	Horizontal Siding – Exterior-insulated rainscreen wall assembly	+40 %

- General condition costs.
- Scaffolding.
- Demolition.
- New assembly components.
- Structural repair costs.
- Interior repairs.
- Contractor overhead and profit.

The relative cost of the other assemblies is measured against this base assembly. It should be noted that in rehabilitation, there are some structural issues relating to the brick veneer options that are not easy to overcome at any cost.

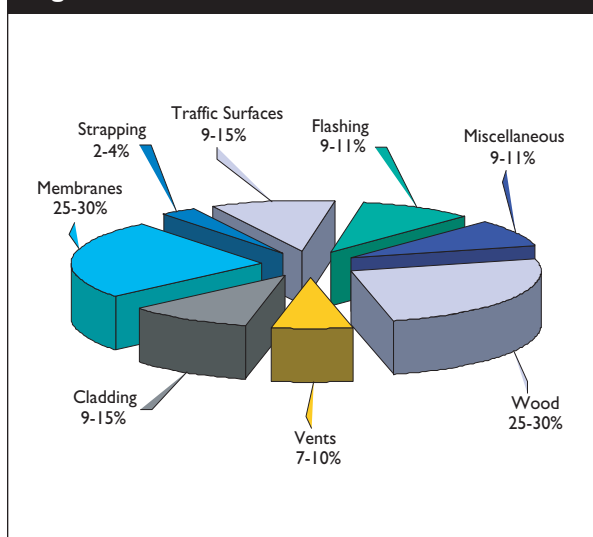
#### 5.5.4 Choice of materials

While building envelope rehabilitation projects have a relatively predictable distribution of costs, the value of materials can vary significantly depending on the nature of a specific project. Bulk material costs (not including manufactured components, such as windows) typically represent 20 per cent to 30 per cent of construction costs. They are generally distributed in accordance with Figure 5-8.

Based on this, a 20-per-cent cost saving in the value of wood or membranes (the more significant relative materials) would reduce the cost of work in the order of 1.8 per cent (20 per cent cost savings x 30 per cent of material costs x 30 per cent of total construction costs). In fact,

10 per cent saved on all materials would reduce the cost of work in the order of 2.5 per cent (10 per cent cost savings x 100 per cent of material costs x 25 per cent of total construction costs). It is therefore not likely that even dramatic changes in material selection will result in significant changes to the overall cost of the work.

However, consultants must pay particular attention to flashing details. Care must be taken to ensure that each detail is designed to achieve the overall objective and at the same time, ensure awareness of the limits of fabricating metal flashing and installation difficulty. Consultants should be aware of the limits to which sheet metal can be broken, joined, soldered and welded. The design of flashing without proper consideration can add significant costs to the project.

**Figure 5-8—Distribution of materials costs**

### 5.5.5 Labour cost

Since labour costs can represent 40 to 60 per cent of construction cost, any gain in labour efficiency results in the most substantial relative decrease in overall cost. Unfortunately, envelope rehabilitation is usually carried out in occupied buildings. This added complexity restricts the contractors' ability to work in the most efficient manner. Contractors must be sensitive to the needs of the occupants and use labour in ways that are not necessary in new construction. In order to obtain good pricing it is recommended that consultants and owners make every effort to facilitate the construction process and provide every opportunity for the contractor to work as efficiently as possible.

## 5.6 Tendering stage—consultant checklist

- ☐ Establish implementation approach with owners
- ☐ Prepare front-end documents to facilitate tendering of the work
- ☐ Invite bids on behalf of the owners
- ☐ Issue clarification of bid documents during tender period
- ☐ Review bids and assist owners in selecting a contractor
- ☐ Work with owners and contractor to develop a project schedule
- ☐ On behalf of owner, obtain building permit before construction starts
- ☐ Prepare contract between owner and contractor for review by owner's lawyer and subsequent execution of the agreement by the owner and contractor



# Chapter 6—Construction

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# Chapter 6—Construction

## 6.1 Introduction

After the tendering process and the award of the construction contract, the consultant's role expands. The consultant continues to act as the owner's agent with the responsibilities defined in the consultant–owner agreement. In addition, the consultant has certain responsibilities under the construction contract.

Although the contract is an agreement between the contractor and the owner, standard contracts such as CCDC-2 The consultant's fundamental role is to administer the contract fairly, without bias towards either the owner or contractor.

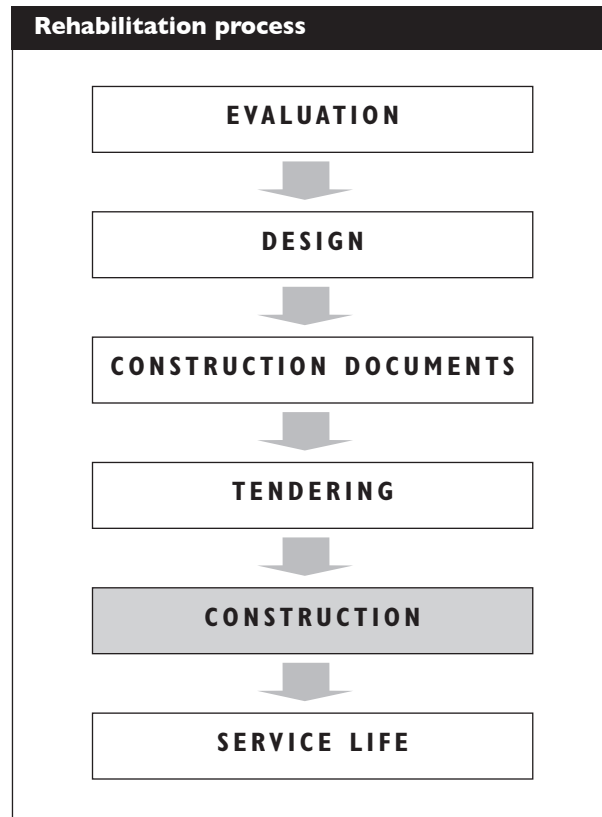
Because the consultant's role is defined by both the consultant–owner agreement and the construction contract, it is important that the contracts are complementary and that professional fees under the consultant–owner agreement are sufficient to discharge all of the consultant's responsibilities under the construction contract.

### Consultant's principal responsibilities

The consultant's principal responsibilities in the construction stage, based on a CCDC-2 contract, are to:

- Represent, advise and consult with the owner.
- Interpret the contract.
- Act on the owner's behalf to the extent provided in the contract documents.
- Conduct a general field review of the rehabilitation work.
- Issue certificates for payment.

It is important that owners, such as strata councils, who are not familiar with the design and construction process, clearly understand the roles and responsibilities under the construction contract. In particular the question of responsibility for performance of the work can be confusing.



The standard CCDC-2 contract, states in GC 2.2.5:

The Consultant will not be responsible for and will not have control, charge, or supervision of construction means, methods, techniques, sequences, or procedures ...in connection with the work ...

The Consultant will not be responsible for the Contractor's failure to carry out the Work in accordance with the Contract Documents.

The Consultant will not have control over, charge of, or be responsible for the acts or omissions of the Contractor, Subcontractors, Suppliers, or their agents, employees, or any other persons performing portions of the Work.

The consultant has two principal roles in the construction stage. The first is contract administration; the second is general review of the quality of the work. Depending on the implementation approach it is also possible that the consultant provides construction management services.

## 6.2 Warranties, guarantees and bonding

Owners often ask for information about the warranties, guarantees or bonding associated with the rehabilitation work. Although it is beyond the scope of this Guide to explain these terms and the options available in detail, educating in most instances falls to the consultant. Because consultants are one of the parties that owners look to for a guarantee, it is usually helpful to have the owner's lawyer assist in presenting this information to the owners.

After Sept. 30, 2000, legislation requires a third party warranty for all building envelope rehabilitation work. Minimum coverage must include two years of labour and materials. If 60 per cent or more of any wall is replaced, the legislation requires an additional five-year water penetration warranty. Some warranty providers may offer more than the mandatory coverage, such as 10-year water penetration coverage.

Exceptions to these general requirements include buildings with repair costs less than the greater of \$10,000 a building, or \$2,000 a unit in the building. Clearly, for most envelope rehabilitation projects, the five-year warranty requirement applies. The warranty must be provided by an insurance company approved by the B.C. Financial Institutions Commission and must meet the requirements of the Homeowner Protection Act and regulations.

The intent of this warranty is to ensure the quality of repair and rehabilitation work. The warranty providers will need to review and approve the project before providing a warranty, approve the consultants, approve the contractors, review the construction and possibly be involved in post construction inspections. It is recommended that a warranty provider be selected and involved in the rehabilitation process as early as possible. This allows the consultant to review the design with them. Early involvement also means that warranty costs can be identified and included in the budget so there are no surprises at the tender stage about coverage, availability of approved contractors and costs. For more information about the warranty program, contact the HPO and warranty providers.

The following types of performance guarantees should be explained to the owners:

- Bid bond.
- Labour and material payment bonds.
- Performance bond.
- Insurance provided by the general contractor.
- Warranty provided by contractor through CCDC-2 (or similar) form of agreement.
- Consultant professional liability insurance (including the possibility of project specific insurance.)
- Third-party warranty based on HPO mandatory program.

## 6.3 Administration

### 6.3.1 Pre-construction meeting

After awarding the contract, but before starting construction, hold a pre-construction meeting. The owner's representatives, the consultant and the general contractor should attend the meeting.

Discussion at the meeting will depend on the nature and scope of the project, but should include:

- Formal approval to proceed with the work (if a contract has not been signed.)
- Nomination and introduction of owner's representatives and consultant's and contractor's site and administrative staff.
- Means of communication, specifically that all communication between owners and contractor should be through the consultant. Emergency contact numbers should be exchanged for all parties.
- Discussion of procedural issues relating to contractor submissions.
- Establishing a schedule for regular project meetings.
- A review of the contractor's construction schedule.
- A review of the contractor's schedule of progress payments.
- A review of consultant and owner responsibilities for delivery of the contractor's progress payment.
- Establishing a process for resolving construction discrepancies identified by the consultant.
- An opportunity for each party to talk about any concerns.

The contractor may ask for evidence from the owners that they have sufficient funds to meet their contract obligations. The contractor may also ask for this information during the course of the work.

### **6.3.2 Project meetings**

There should be meetings throughout the project. Some will involve just the consultant and the contractor to resolve technical details so the contractor can proceed with the work.

These may be held weekly or each time the consultant visits the site.

There should be regular—generally every month—progress meetings with the owner, consultant and contractor. The agenda should include:

- A review of the schedule.
- A review of quality issues.
- A review of costs and overall budget.
- Any issues about the construction activity.
- Design clarifications and issues.

It is common for the contract documents to say that the contractor takes minutes for project meetings. In practice however, it is also common for the consultant to take the minutes.

### **6.3.3 Contract administration**

In addition to administering the contract—and interpreting contract documents fairly—the consultant represents the owner during construction. The consultant must therefore report to the owner about the progress and quality of work. The consultant also advises and consults with the owner about decisions required during construction. In addition to this overall liaison with the owner, other contract administration requirements include:

- Providing supplemental instructions to the contractor.
- Generally reviewing the work, as discussed previously, including the authority to reject work that does not comply with the contract documents.
- Assigning values to the rejected work.
- Determining the amounts owing to the contractor.
- Issuing certificates for payment.
- Interpreting the requirements of the contract documents.

- Providing written and graphic interpretations, clarifications and supplemental instructions.
- Reviewing contractor submissions and taking appropriate actions.
- Preparing change orders as required.
- Determining the date of substantial performance of the work. (The B.C. *Construction Lien Act* defines substantial performance as the point at which construction is 95 per cent complete.)
- Verifying and issuing certificate of final payment.

In addition to the consultant's contractual responsibilities, there are statutory responsibilities related to letters of assurance and to the consultant's role as a CRP and BEP.

### 6.3.4 Occupant safety

Building occupants are often thrust into rehabilitation projects without a full appreciation of what they are about to experience. Living in a construction site presents many challenges and occupant safety is particularly important. In order to promote occupant safety it is imperative that occupants be aware of sensible safety practices. Appendix D summarizes typical safety measures. It should be presented to the owners.

The contractor is responsible for ensuring that the site is safe for both the workers and occupants.

## 6.4 Quality assurance roles

CMHC's *Quality by Design: A Quality Assurance Protocol for Wood-Frame Envelopes in British Columbia* is a useful reference. It provides a series of guidelines, recommendations and templates to ensure quality design,

construction and maintenance of new or rehabilitated wood-frame envelopes.

There has historically been misunderstanding within strata corporations about the consultant's role in quality assurance during construction. It is critical that the consultant explain the distinct consultant and contractor roles in delivering quality construction to the owners.

The consultant does not control or supervise the contractors. The contractor is responsible for the means, methods, techniques and procedures used in construction. The contractor provides construction that is in general conformance with the intent of the contract documents. The consultant does a general review that involves examining and reporting on a representative sampling of the work. It is the contractor's responsibility to correct any discrepancies noted in the reviews and to make sure that all similar occurrences of the discrepancy are identified and corrected.

The consultant interprets the contract documents impartially. The consultant must promptly issue clarifications and reports documenting observations made during sampling of the construction.

The consultant's responsibility under both the consultant-owner agreement and the construction contract extends only to "general review" to determine "general conformity" with the contract documents. However, other documents and regulations may assign different and often greater responsibility. Letters of assurance require field review to ascertain that the work complies in all material respects with the plans and supporting documents for which the building permit was issued. Individual municipalities may require even greater levels of field review.

## 6.5 Shop drawings and submissions

Various submissions are required by the contract documents. These include samples of materials and components and shop drawings for some aspects of the work. Shop drawings are typically required for any manufactured components that must meet specified design criteria. These include metal fabrications, metal roofing or siding and glazed assemblies, including windows, skylights and canopies.

It has been common for some window suppliers to provide simplified standard details that do not reflect the actual conditions for a particular project. Since one of the primary purposes of shop drawings is to confirm that a particular component is consistent with the overall design intent, it is important that shop drawings reflect the specifics of the project and therefore show the interface with other assemblies.

Before a supplier or trade contractor prepares shop drawings, the consultant, general contractor and trade contractor should review the specific requirements at a project meeting to clarify expectations, review process and resolve as many of the technical issues as possible.

Considerable lead time is required, because often there are two review cycles before the drawings are approved. It is therefore important to anticipate and include the shop drawing review process in the schedule.

## 6.6 Mock-ups and testing

Mock-ups are an established and desirable part of the new building construction. Mock-ups and testing are just as important in rehabilitation.

Mock-ups are full-size construction of important or difficult assemblies and details. They can be done separately from the actual building (mock-up) or they can be "field demonstrations"—built so they can be incorporated in the final construction.

The purpose of the mock-up is to confirm and convey the design intent for typical and difficult interfaces. They are usually done before construction or at the start of the work for typical details and during construction for atypical details.

The key to successful use of mock-ups is to identify their scope, size and location as much as possible at the design stage and to include a mechanism for requesting additional mock-ups to deal with difficult detailing situations if they arise during construction. Furthermore, the trade contractors who will work on the building should build the mock-ups. On completion the mock-ups should be available as a reference for the quality expected for the balance of the envelope construction.

Testing has also become an accepted part of construction. Apart from the results of component testing, which can be requested before construction, on most projects there will be a need to test the installed assemblies to confirm performance of both the assemblies and the interfaces between them. Specification documents must include wording defining the extent and nature of testing on a building-specific basis.

Depending on the size and nature of the mock-ups, they can be used for performance testing. Or, field testing can be done on selected construction elements. Decisions about the number, location and timing of tests are made on an individual project basis. Testing early in the project is desirable to minimize the cost

of correcting problems. Testing should also be conducted throughout the project to help confirm continuity of quality control.

Windows and their integration into the wall assembly should be a primary focus of testing. This is equally true for installation of new windows or retention of existing windows. Testing existing windows confirms acceptable performance and identifies appropriate repair and maintenance to prolong their useful service life.

## 6.7 Field review

Field review of the rehabilitation construction is part of quality assurance and must be done by the consultant. Field review must be co-ordinated with the consultant and general and trade contractors. A specific plan must be developed to deal with:

- How are issues that the consultant identifies as discrepancies to be resolved?
- How are issues not dealt with in the construction documents to be resolved?
- How is the resolution of discrepancies tracked and who takes responsibility for completion of each item?
- What is the schedule for field reviews?
- Who receives copies of field review reports?
- How is information about discrepancies relayed to the trade contractors?

## 6.8 Deficiencies in existing construction

Consultants performing remedial work on an existing building have a responsibility to address deficiencies in the original construction that are uncovered during the work. The extent of a review of existing building systems needs

to be clarified with the owners. Typically, the review is limited to systems that are directly affected by rehabilitation: the building envelope, visible structural components, particular components of the plumbing and ventilation systems and some fire and life-safety systems.

Shoddy or substandard framing should be reframed to meet current code requirements. Examples of shoddy or substandard work include missing extra studs or blocking beneath point loads, missing framing hardware such as sill anchor bolts or joist hangers and lack of adequate bearing for beams or joists at supports. Inadequate balcony guardrails and attachments are another commonly found deficiency.

## 6.9 Changes in the work

Although every effort should be made to fully document the nature and extent of the work in the contract documents, some changes during construction are inevitable. Changes may result from a number of causes, including unforeseen site conditions, changes requested by the owner or required by municipal authorities and the need to correct errors or omissions in the drawings or specifications.

Only the owner can initiate changes in the work, whether additions, deletions or revisions, by issuing—through the consultant—a change order or directive. The owner must sign change orders and change directives.

### 6.9.1 What is fair?

Handling of changes that increase or decrease the contract price must be fair to all parties. Failure to do so can lead to bad relationships, disputes and litigation.



Owners and consultants must recognize that a contractor is entitled to recover the costs of a change—including the work itself, site overhead costs, office overhead costs and an amount for profit. Contractors must be aware that owners are entitled to a fair credit for work not completed and that costs for extra work must be fair and justifiable.

Clauses dealing with changes are included in most contracts, but generally cover:

- Increases or decreases in work items included as part of the contract.
- Changing the method of installation.
- Changing material selections.
- Changing the circumstances and conditions under which the work is undertaken.
- Costs of removal, replacement or unforeseen work not specifically covered in the tender documents, which cannot be measured or known at the time of bidding.

To minimize changes to a fixed price contract, the bid set of documents must:

- Be clear, precise and define the full scope of work.
- Be decisive about specifications, without ambiguous clauses, and customized for each project.
- Have scalable drawings that clearly show all relevant details.

The greatest unknown factor is the extent and resulting costs of carrying out structural repairs to walls, floors, balconies and support structures and, often, the added cost of repairing associated finishes.

In preparing tender and contract documents the consultant sets out ways to handle the cost of unforeseen work. These include:

- Payments based on a time-and-material basis.
- Unit-price method.
- Lump sum, fixed costs where a change can be clearly measured.

All these methods have a place in determining the cost of unforeseen work. The tender and contract documents must clearly define the method of payment for extra work or changes and include rates for labour, materials and equipment.

Consultants must review contractor change quotations as soon as possible and encourage the owners to respond promptly. Delayed decisions can affect the overall schedule and add cost.

### **6.9.2 Time-and-material method**

The tender form must allow the contractor space for hourly rates of labour for each classification and to give the percentage add-on to the net cost of materials and subcontractor invoices.

It must be clear what these hourly rates include, for instance, small tools, office overhead, profit, and so on. If poorly worded clauses create uncertainty about what is and is not included, there may be misunderstandings and disputes.

Items that are often not dealt with include added costs of site overhead: for instance, supervision, monthly rental of scaffolding, equipment and site office telephone. These must be dealt with at the tender stage. They are particularly important if the length of the contract is extended to deal with several change directives. Each relatively small change by itself may not add significant costs. However, many small changes can extend the contract time, resulting in extra costs not covered by hourly rates.

In an effort to deal with the difficulty of changes and contract extensions, some consultants include contingency hours in the base contract. These hours are used by the contractor at the hourly rates. This total is then added to the balance of the contractor's bid price. In this way, costs of all bonds, insurance and site overhead are included in the bid price and provide the contractor and owner with a better understanding of the overall scope of work, its size and value. A further advantage of contingency hours is that the owners benefit from competitive pricing of all unforeseen work being included in the original, fixed lump-sum bid.

Adjustments are based on the hourly costs. Actual hours worked are compared to the contingency hours. If less, a credit is given; if more, they are paid for at the hourly rate.

The consultant's experience and knowledge from the investigation provide a reasonable number of contingency hours. The best guess at determining contingency hours should be based on similar, previously completed projects.

Buildings in much poorer condition than could have been foreseen place an additional financial burden on the owners. Contractors and consultants should keep a running estimate of all change orders and regularly tell owners the projected estimated total cost. This gives owners the opportunity to provide extra funds or adjust the original scope of work to meet their ability to pay.

If this method is used, the contractor should maintain daily work sheets giving work conducted, personnel and hours and materials. Work sheets should be reviewed at every site visit by the consultant and signed. This constant monitoring and ongoing agreement about additional work will result in good assessment of the budget and minimize disputes during the review of the monthly progress draws.

### **6.9.3 Unit-price method**

The tender form must give the contractor the opportunity to include unit rates for each type of unit-price work in the same way the contractor has an opportunity to give hourly rates of labour. The unit-price method should be used when the type of work can be clearly defined, but not the quantity or extent. A good example is the installation of deck drains to relieve ponding or poor drainage on existing balconies. The specific drain type, substrate and membrane may be described but the exact location and number can not be determined until each balcony is reviewed on site.

Using unit rates for the replacement of structural components of walls, floor joists, posts, beams, and so on, should be avoided. Replacement of these components often includes other items, such as shoring, weather protection and extensive repair of finishes. Such items cannot be clearly defined by the contractor in the bid. Unit rates for similar items of work can vary as much as 1,000 per cent between different contractors and the time spent to prepare changes by the consultant and the contractor is considerable.

### **6.9.4 Lump-sum, fixed price**

This method can be used when the extent of the extra work is clearly defined and measurable, often after a large section of the existing cladding has been removed. The contractor submits a lump-sum price for the change to the consultant for review, negotiation and recommendation to the owners. The costing of the work and approval by the consultant occurs in its entirety as the work progresses, after the tender process.

## **6.10 Mold**

The presence of mold must be recognized by the consultant and the contractor and dealt with during the construction stage of a rehabilitation project. See "Mold—general" for guidance.

# Chapter 7—Service life

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# Chapter 7—Service life

## 7.1 Record drawings

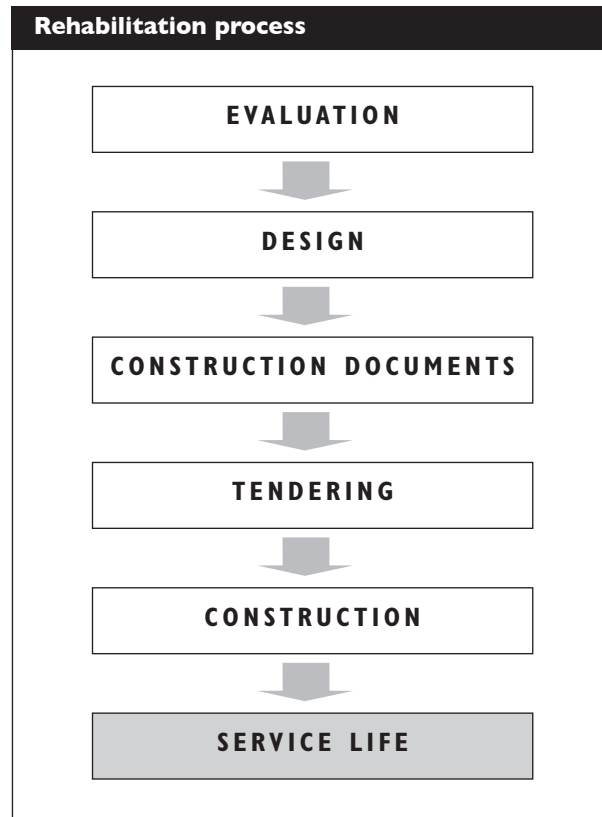
It is not customary in rehabilitation work to prepare a set of as-built drawings for the work, although this could be done as an additional service. It is more common to require the contractor to use one set of the contract drawings to prepare record drawings. The record drawings are to record deviations from the contract documents caused by site conditions and changes ordered by the consultant. The extent to which the record drawings include new-wood framing members needs to be clarified, preferably within the general requirements section of the contract documents. The drawings should also show locations of concealed mechanical and electrical services. Upon completion of the project the record drawings must be turned over to the owner. Municipal authorities may also require the drawings.

Maintenance activities are also a fundamental part of the warranty program. Failure to undertake some specified warranty activities may void warranty coverage. In addition, inspections to identify warrantable items should be included in the maintenance plan.

## 7.2 Building envelope manual

Near the end of the construction stage, the consultant—with the assistance of the contractor—should prepare a building envelope manual. The manual gives the framework for developing, updating and incorporating detailed maintenance and renewal plans in the continuing operation of the building. Preparation of this manual is consistent with the *Strata Property Act* (1998) and the *Strata Property Amendment Act* (1999).

Chapter 3—Design, focuses on factors influencing decisions about the durable construction of the building envelope. A logical extension of this is providing guidance about maintenance and



renewal so the owners can continue to manage their building with durability and long-term performance in mind.

Although maintenance and renewal plans form the core of a building envelope manual, the manual could also include:

- A description of the building envelope assemblies.
- A description of how each assembly is intended to control various moisture sources.
- Guidance to controlling interior conditions and their impact on the envelope.
- A list of materials and components used in construction, with product data sheets where appropriate.
- A list of consultants and contractors involved in the project and their areas of responsibility.
- Warranty documents for building envelope assemblies.

This section discusses development of a maintenance plan and a renewal plan for the envelope assemblies. Similar plans could be developed for the entire building and integrated into one document. Although usually presented as separate documents, maintenance and renewal plans are very dependent on each other. Poor maintenance could mean higher renewal costs or having to spend money on replacement earlier than would have been required with a more responsible maintenance plan. For this reason, it is critical to update both the maintenance plan and the renewal plan regularly, usually every two to three years.

The concept of maintenance and renewal planning for an envelope assembly is analogous to the life of automobile tires. Tires may provide 80,000 km of reliable service if regular care is given to inflation pressure, alignment and abnormal hazards—operations and maintenance. After 80,000 km, tires may continue to perform, although if inspected there will be much less tread and the walls will show signs of cracking. Continued use of worn tires carries well-known risks, ranging from the inconvenience and cost of a flat tire to injury and loss of life from losing control of the vehicle because of tire failure. Prudent automobile owners replace tires at the end of their useful life and avoid exposure to unacceptable risks—renewal.

A more comprehensive discussion of durability, life cycle costing and the relationship between initial design and construction, maintenance and renewal is in CSA S478-95 *Guideline on Durability in Buildings*.

## 7.2.1 Maintenance planning

Maintenance of the building envelope increases the probability that components and assemblies fulfil their intended functions and realize their intended service lives. Failure to maintain can result in damage to other envelope components and assemblies, including interior finishes, and reduce the structural capabilities of the envelope assembly. Maintenance planning for the building envelope assemblies involves describing inspection and maintenance tasks and scheduling them. The maintenance plan for each building is unique. It must reflect the functional characteristics of each envelope assembly. For example, an existing wall assembly in medium-exposure conditions uses a face-seal exterior moisture control strategy. Because there is no damage, the wall is left in place. The maintenance plan for the wall is quite different than a plan for a rainscreen wall assembly that places little reliance on the sealant to fulfil intended functions. The sealant in a face-sealed assembly would require frequent—once a year— inspection and maintenance. The rainscreen assembly may require inspection only every second year and sealant replacement or repairs every five years.

Table 7-1 gives maintenance recommendations and time frames for a horizontal, wood-siding, concealed-barrier assembly incorporating a vinyl concealed-barrier window assembly.



**Table 7-1—Sample maintenance plan**

<b>Recommendation</b>			
<b>Component</b>	<b>Inspection</b>	<b>Maintenance</b>	<b>Time frame</b>
Wood siding	Inspect finish on wood siding for evidence of staining, discolouration, fading, chalking or peeling.	Maintenance activities could include repairs to item creating concentration of water leading to staining, localized refinishing or cleaning.	Twice a year
Sealant	Inspect sealant for cracking, loss of adhesion or bulging.	Maintenance work may include replacement of sealant at some locations, or addressing excessive joint movements through modification of a detail	Annual
Windows	Inspect hardware and weatherstripping.	Adjust to ensure good operation and fit.	Annual
Doors	Inspect hardware and weatherstripping.	Adjust to ensure good operation and fit	Annual
Exhaust vents	Inspect exhaust vent screens for lint collection.	Clean if required.	Annual

The maintenance plan must reflect the competence of the individual inspecting the component. For example, more specific guidance in the form of checklists and resulting actions is required if a property manager or an untrained resident of the building is doing the inspection. Very little guidance is needed for a professional who is regularly involved in the design, construction and maintenance of the building envelope. Inspection checklists are in the National Research Council's (NRC) *Protocols for Building Condition Assessment*. Ideally, a customized checklist and resulting action list should be created which is specific to each individual building.

Inspection and maintenance may trigger a renewal activity and is a good way to keep the renewal plan up to date. For example,

if maintenance notes frequent adjustment for window hardware, it may make sense to replace it with less maintenance-intensive hardware.

The maintenance plan may also include operating guidance. In particular, the building's mechanical ventilation system should be addressed since it can have a significant impact on the performance of the envelope assemblies. Cleaning of exhaust vents, as described in Table 7-1, is one example. Another may be instructions about when to use bathroom and kitchen exhaust fans, or about keeping interior relative humidity below critical levels. Repeated inspection findings of humidity-related damage may prompt a recommendation to install humidistat controls on exhaust fans.

## 7.2.2 Renewal planning

During a building's service, planning for renewal activities identifies the timing, cost and nature of both the expected repair and replacement and for renewal activities resulting from premature deterioration of a component. At the time of construction however, the plan will be largely based on theoretical or textbook knowledge of typical life expectancies for components and assemblies.

The development and funding of a renewal plan is independent of the mandatory contingency fund contribution in the *Strata Property Act*. The mandatory amount may or may not be enough for a specific building's renewal needs.

As with a maintenance plan, a renewal plan should ideally consider all elements of the building, not just the building envelope. Once the renewal needs are identified, a funding plan can be established. A plan allows for gradual funding, through monthly fees, for anticipated expenditures rather than the surprise of special assessments. It is usually considered adequate to plan for likely renewal expenditures within the next 20 years. Forecasting beyond 20 years is difficult and it is unlikely that building owners will start to save for expenditures that far in the future.

Table 7-2 is an example of what could be incorporated into a renewal plan.

The plan can be much more detailed if desired, to include, for example, component and material specifications for each recommendation.

**Table 7-2—Sample renewal plan**

Item	Recommendation	Time until renewal	Cost
Roof	Replace roof and associated perimeter flashing	20 years	\$100,000
Stucco wall assembly	Clean and recoat wall with new acrylic coating	10 years	\$30,000
Stucco wall assembly	Replace sealant at window perimeters	5 years	\$6,000
Windows	Replace insulating glass units	Phased—to be done as units fail over 10 years, beginning in year 15	\$2,000 a year
Doors	Replace door hardware	20 years	\$3,000

Renewal requirements depend very much on maintenance activities and the quality of the original design and construction. For this reason, renewal plans should be updated once every two or three years. At that time, the condition of each component can be assessed and the timing and cost of the renewal activities adjusted to reflect the actual in-service condition.

### **7.3 Commissioning meeting**

A final project meeting should be held involving the consultant, contractor and owner. The purpose of this meeting is to hand over all project completion documents, including product warranties, record drawings and the building envelope manual. Minutes should be taken so there is documentation of the handover.

### **7.4 Warranty reviews**

Within one month of the end of the project warranty period (usually one or two years), the consultant must review the performance of the building envelope, and document and notify the contractor of items that require the attention of the contractor to complete the work.



# Appendix A

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## Owner–occupant questionnaire

Building envelope condition assessment

Project name:

Project no.:

Date:


Owner–occupant questionnaire

Please complete and return the following questionnaire to ..... by .....  
Your help will assist us in identifying any moisture-related problems with the building.

Unit no: \_\_\_\_\_ Owner or occupant name: \_\_\_\_\_

Phone no. \_\_\_\_\_ Exterior walls facing: North ☐ East ☐ South ☐ West ☐

**Does your suite have current leaks (within the last year)?** Yes ☐ No ☐

If so, in which rooms and at what location does water appear (walls, ceiling, windows, floor etc.)?

Room \_\_\_\_\_ Location \_\_\_\_\_

Room \_\_\_\_\_ Location \_\_\_\_\_

Room \_\_\_\_\_ Location \_\_\_\_\_

**Has your suite experienced leaks in the past which have now been corrected (no leaks within last year)?**

Yes ☐ No ☐

Room \_\_\_\_\_ Location \_\_\_\_\_

Room \_\_\_\_\_ Location \_\_\_\_\_

Room \_\_\_\_\_ Location \_\_\_\_\_

**Do you have problems with condensation?** Yes ☐ No ☐

Room \_\_\_\_\_ Location \_\_\_\_\_

Room \_\_\_\_\_ Location \_\_\_\_\_

Room \_\_\_\_\_ Location \_\_\_\_\_

**Do you have problems with mold, fungi or mildew?** Yes ☐ No ☐

Room \_\_\_\_\_ Location \_\_\_\_\_

Room \_\_\_\_\_ Location \_\_\_\_\_

Room \_\_\_\_\_ Location \_\_\_\_\_





# Appendix B

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## Use of exterior insulation rainscreen wall assembly

The use of exterior insulation rainscreen wall assemblies is becoming more common in wood-frame buildings. With all of the insulation placed to the exterior side of a waterproof membrane, a very moisture tolerant assembly is created which is appropriate for higher exposure conditions.

Creating a wall assembly which captures many of the advantages of the exterior insulation rainscreen wall assembly but combines insulation to the exterior and the interior of the membrane is desirable because it reduces the overall wall thickness. The following factors must be considered when determining the quantity of insulation that is required on the exterior of a vapour impermeable air-barrier membrane:

- What is the required thermal resistance of the wall assembly?
- How much of the existing insulation in the stud cavity should be maintained?
- What are the interior and exterior environmental conditions?
- Are there limitations on the quantity of insulation that can be placed on the exterior side of the air-barrier due to constructability? For example, the structural implications of separating a heavy weight cladding a significant distance from the primary structure of the wall.
- Are there practical limitations on the width by which the exterior walls can be increased? For example, as the thickness of the exterior walls is increased, there can be interference at door and window openings. Recessing the windows into the wall assembly will alter the aesthetics of the building.

Three examples are illustrated in the attached assembly sheets. Each of the proposed rehabilitation wall assemblies has been modeled using EMPTIED to predict the potential for condensation. (CMHC's EMPTIED Software can be accessed through a dedicated Web site link referenced in the enclosed CD-ROM.) EMPTIED is a computer model developed to predict Envelope Moisture Performance Through Infiltration, Exfiltration, and Diffusion. To assist with comparison of the results of the analysis of each assembly, the following information was kept constant:

The geographic location has been selected as Vancouver. Changing the geographic location would alter the results. For example, if the proposed remedial wall assemblies were to be constructed in a colder climate, such as Prince Rupert, additional insulation would be required on the exterior of the air-barrier.

The openings in the air-barrier have been selected as 1cm<sup>2</sup> per m<sup>2</sup>. Increasing the size of the openings in the air-barrier increases the air leakage rate hence increasing the quantity of condensation that will occur on the interior face of the sheathing. If the size of the predicted openings in the air-barrier is increased, additional insulation would be required on the exterior of the air-barrier. The values selected are relatively small – larger values should be selected for remedial wall assemblies that utilize air-barrier systems that more difficult to install.

The interior environmental conditions have been set to be constant throughout the year. The values selected are 23°C and 50 per cent relative humidity. Decreasing the interior temperature in the winter months will result in a decrease in temperature of the sheathing subsequently increasing the potential for condensation.

The interior relative humidity could be higher than 50 per cent if the building has a high occupancy load or if the life styles of the occupants generate large quantities of moisture (boiling of food, drying of laundry, etc.). Increasing the interior relative humidity will also increase the potential for condensation. If the interior relative humidity is increased, additional insulation would be required on the exterior of the air-barrier.

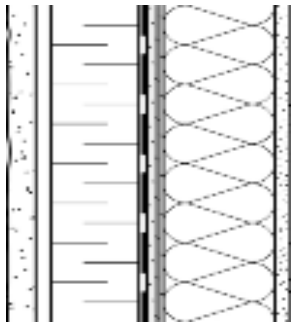
If the interior temperature is reduced the temperature of the exterior sheathing will be lower. Decreasing the temperature of the exterior sheathing increases the potential for condensation on the sheathing. If the interior temperature is decreased, additional insulation will be required on the exterior of the air-barrier.

When designing remedial wall assemblies, the interior conditions must be adjusted to reflect the building use and occupancy. It is recommended that intended operating conditions be provided to the owners with the maintenance manual issued at project completion. A humidistat controlled fan can be used to maintain acceptable relative humidity levels within a suite.

An average differential pressure of 5 Pa has been used. If the anticipated average differential pressure is greater than 5 Pa the potential for condensation will be increased. For example, a higher differential pressure could be anticipated if the building is mechanically pressurized.

It is illustrated in Example 3 that for the conditions selected, 100 mm of semi-rigid insulation (RSI 3.0) is required on the exterior of the vapour impermeable air-barrier if 140 mm of glass fiber insulation (RSI 3.26) is left in the stud cavity. It is probable that for most remedial projects extending the cladding 119 mm (100 mm of insulation plus 19 mm cavity) from the face of the sheathing is not a feasible option. Therefore, in conventional 38 mm by 140 mm frame construction, the quantity of insulation in the stud cavity will have to be decreased to adequately reduce the potential for condensation on the interior face of the sheathing.

**Example 1: Exterior air-barrier approach**

		<b>Thermal Resistance (m<sup>2</sup>K/W)</b>	<b>Vapour Resistance (Pa s m<sup>2</sup>)/ ng</b>
	air film	0.17	0
	22mm stucco	0.14	0
	19 mm cavity	0.16	0
	50 mm exterior insulation	1.51	.00054
	0.1mm waterproof sheathing membrane	0	0.6
	12 mm plywood sheathing	0.1	.05
	89 mm insulation in stud space	2.1	.00054
	12 mm interior drywall—painted	0.08	.005
	air film	0.12	0
	<b>Total</b>	<b>4.38</b>	<b>0.656</b>

**Failed wall assembly**

The failed wall assembly consists of 38 mm by 89 mm stud construction with 89 mm of glass fiber insulation in the stud cavity and a polyethylene vapour barrier on the interior of the insulation. The exterior cladding consists of face sealed stucco.

**Remedial approach**

The remedial approach consists of adding a vapour impermeable air barrier/moisture barrier to the exterior of the sheathing. When this approach is taken, the interior vapour barrier must be removed and insulation must be added to the exterior of the air barrier to reduce the potential for condensation. In this example, 50 mm of semi-rigid insulation is proposed for the exterior. The new stucco cladding is to be separated from the exterior insulation by a 19 mm cavity.

**Assumptions**

The following assumptions have been made to assist with computer modelling of the remedial wall assembly:  
 An air leakage area of 1cm<sup>2</sup>/m<sup>2</sup>  
 An average differential pressure of 5 Pa between interior and exterior  
 Year-round interior conditions of 23°C and 50 per cent relative humidity  
 Geographic location is Vancouver (determines exterior conditions)

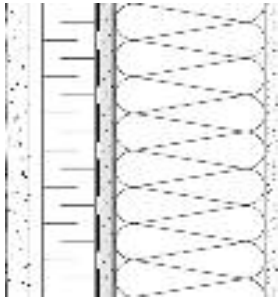
**Analysis**

The wall assembly was modelled for a one-year period. During the one-year period condensation was predicted to occur on the interior face of the sheathing from October through April. Drying through evaporation also occurred during the winter months. The quantity of moisture that accumulated on the face of the plywood was not predicted to exceed the quantity of moisture that could be absorbed by the plywood (the moisture content of the plywood will increase as water is absorbed). Hence, no water was predicted to drain down the face of the sheathing.

**Commentary on analysis**

Based on the results predicted by the analysis, condensation within the remedial wall assembly should not be a problem. However, the results of the analysis will change with many factors including, geographic location, interior conditions, air leakage, etc.

**Example 2: Exterior air-barrier approach**

		<b>Thermal Resistance (m<sup>2</sup>K/W)</b>	<b>Vapour Resistance (Pa s m<sup>2</sup>)/ ng</b>
	air film	0.17	0
	22mm stucco	0.14	0
	19 mm cavity	0.16	0
	50 mm exterior insulation	1.51	.00054
	0.1mm waterproof sheathing membrane	0	0.6
	12 mm plywood sheathing	0.1	.05
	140 mm insulation in stud space	3.26	.00054
	12 mm interior drywall—painted	0.08	.005
	air film	0.12	0
	<b>Total</b>	<b>5.54</b>	<b>0.656</b>

**Failed wall assembly**

The failed wall assembly consists of 38 mm by 140 mm stud construction with 140 mm of glass fiber insulation in the stud cavity and a polyethylene vapour barrier on the interior of the insulation. The exterior cladding consists of face sealed stucco.

**Remedial approach**

The remedial approach consists of adding a vapour impermeable air barrier/moisture barrier to the exterior of the sheathing. When this approach is taken, the interior vapour barrier must be removed and insulation must be added to the exterior of the air barrier to reduce the potential for condensation. In this example, 50 mm of semi-rigid insulation is proposed for the exterior. The new stucco cladding is to be separated from the exterior insulation by a 19 mm cavity.

**Assumptions**

The following assumptions have been made to assist with computer modelling of the remedial wall assembly:  
 An air leakage area of 1cm<sup>2</sup>/m<sup>2</sup>  
 An average differential pressure of 5 Pa between interior and exterior  
 Year-round interior conditions of 23°C and 50 per cent relative humidity  
 Geographic location is Vancouver (determines exterior conditions)

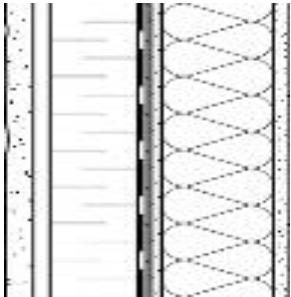
**Analysis**

The wall assembly was modelled for a one-year period. During the one-year period condensation was predicted to occur on the interior face of the sheathing from September through May. Drying through evaporation also predicted to occur during these months. The quantity of moisture that accumulated on the face of the plywood exceeded the quantity of moisture that could be absorbed by the plywood. Hence, water was predicted to drain down the face of the sheathing.

**Commentary on analysis**

Based on the results predicted by the analysis, water will drain down the inside face of the sheathing during the winter months. Moisture that drains down the face of the sheathing will not dry as easily as moisture that is evenly absorbed by the sheathing. Water that drains down will saturate the sill plate. The performance of the proposed remedial wall assembly could be increased by the application of a vapour retarder paint on the interior face of the gypsum board. Alternatively, the quantity of insulation in the stud cavity could be reduced to 89 mm, which would provide results similar to Example 1. The model used does not include drying to the interior. Drying to the interior will increase the drying potential of the wall.

**Example 3: Exterior air-barrier approach**

		<b>Thermal Resistance (m<sup>2</sup>K/W)</b>	<b>Vapour Resistance (Pa s m<sup>2</sup>)/ ng</b>
	air film	0.17	0
	22mm stucco	0.14	0
	19 mm cavity	0.16	0
	100 mm exterior insulation	3.0	.00054
	0.1mm waterproof sheathing membrane	0	0.6
	12 mm plywood sheathing	0.1	.05
	140 mm insulation in stud space	3.26	.00054
	12 mm interior drywall—painted	0.08	.005
	air film	0.12	0
	<b>Total</b>	<b>7.03</b>	<b>0.656</b>

**Failed wall assembly**

The failed wall assembly consists of 38 mm by 140 mm stud construction with 140 mm of glass fiber insulation in the stud cavity and a polyethylene vapour barrier on the interior of the insulation. The exterior cladding consists of face sealed stucco.

**Remedial approach**

The remedial approach consists of adding a vapour impermeable air barrier/moisture barrier to the exterior of the sheathing. When this approach is taken, the interior vapour barrier must be removed and insulation must be added to the exterior of the air barrier to reduce the potential for condensation. In this example, 50 mm of semi-rigid insulation is proposed for the exterior. The new stucco cladding is to be separated from the exterior insulation by a 19 mm cavity.

**Assumptions**

The following assumptions have been made to assist with computer modelling of the remedial wall assembly:  
 An air leakage area of 1cm<sup>2</sup>/m<sup>2</sup>  
 An average differential pressure of 5 Pa between interior and exterior  
 Year-round interior conditions of 23°C and 50 per cent relative humidity  
 Geographic location is Vancouver (determines exterior conditions)

**Analysis**

The wall assembly was modelled for a one-year period. During the one-year period the model predicted condensation to occur on the interior face of the sheathing from October through April. Drying through evaporation also occurred during these months. The quantity of moisture that accumulated on the face of the plywood did not exceed the quantity of moisture that could be absorbed by the plywood. Hence, the model did not predict water to run down the face of the sheathing. The quantities of predicted condensation are low.

**Commentary on analysis**

Based on the results predicted by the analysis, the wall should perform adequately. Moisture that does accumulate in the sheathing will probably be dried to the inside.  
 The wall will have a very high thermal resistance after the 100 mm of semi-rigid insulation is added to the exterior. The construction of a wall assembly with this quantity of thermal resistance may not be cost effective. It may not be practical to construct a wall assembly with a distance of 119 mm between the face of the sheathing and the exterior cladding.





# Appendix C

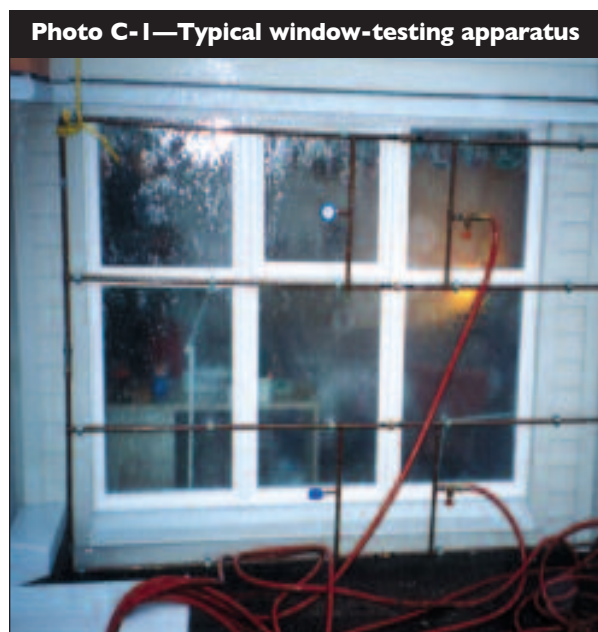
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## Window evaluation

In developing potential refurbishment and replacement alternatives for consideration, it is reasonable to begin by evaluating the ability of the existing windows to manage rain penetration effectively. If the existing refurbished windows and interface details with adjacent wall assemblies can not provide acceptable rain penetration control then the other performance criteria for the refurbishment option need not be considered. The focus can then be limited to selection of appropriate new window assemblies. The enclosed CD-ROM contains a three-dimensional presentation of a wall rehabilitation at a window location.

## Water penetration control

Test a representative sample of existing windows (see Table 7.8.4 of *Best Practice Guide—Wood-Frame Envelopes in the Coastal Climate of British Columbia*). Typical test apparatus is shown in Photo C-1.



The sample should be large enough to be statistically significant. If a small sample is used and a high percentage of failures are found it is usually significant, whereas a small sample with few failures is not statistically significant.

For example, consider a sample of 500 windows of which 95 per cent are supposed to meet or exceed a B3 water leakage test. If a random sample of five windows is tested the statistical probability of having zero, one or two failures is 99.9 per cent. Therefore, results in this range do not provide statistically significant information about the population. If these results are obtained, there are two options; more windows can be tested in order to obtain a statistically significant sample size, or, engineering judgment regarding the problems experienced, anticipated future performance, can be combined with the test results in order to determine if remediation will be required or if the existing windows can be left as is. Conversely, this also means that if five randomly selected windows are tested and three or more fail, it is very unlikely (less than 0.1 per cent chance) that 95 per cent of the population of windows meet or exceed a B3 water leakage test. In this case, it is likely that some remediation of the existing windows will be required.

In many cases the initial windows tested on a project are those known to exhibit water leakage. Sampling on this basis is not random and the above discussion is not valid. It is recommended that in addition to these initial tests undertaken for characterizing known leaks, that a random sample of windows also be selected and tested.

Check frame type and exposure conditions and compare to Table C-1 which is reproduced from the *Best Practice Guide—Wood-Frame Envelopes in the Coastal Climate of British Columbia*. The current window assembly or refurbished window assembly should be consistent with these recommendations.

**Table C-1—Acceptable window assemblies for exposure categories**

Window assemblies	Exposure level			
	None	Low	Medium	High
AL-1: Aluminum—face seal	✓	✓		
AL-2: Aluminum—concealed barrier	✓	✓		
AL-3: Aluminum—concealed barrier (improved)	✓	✓	✓	
AL-4: Aluminum—rainscreen	✓	✓	✓	✓
VY-1: Vinyl —concealed barrier	✓	✓	✓	
VY-2: Vinyl—rainscreen	✓	✓	✓	✓

Investigate reported performance problems and confirm that refurbishment will be able to resolve these problems.

Ensure that historical problems are related to the components that are being proposed to be replaced or refurbished. If there are other factors contributing to water infiltration, the remediation solutions will have to be modified.

How does the performance of a new window compare to refurbished windows?

Compare the expected performance of the refurbished option with potential replacement windows.

Based on the results of the assessment of rain penetration control outlined above, develop a conceptual refurbishment and a conceptual replacement strategy.

The development of both a refurbishment and a replacement strategy based on water penetration resistance performance allows for the evolution of the strategy based on other performance issues.

## Window interface

Examine refurbishment and replacement strategies for integration with wall cladding.

Is it possible to obtain an effective interface seal between the existing window and the remedial wall assembly? New windows that are specifically made for a project may require less detailing at interfaces. All cost savings, potential performance improvements and maintenance issues should be considered when comparing strategies. See Chapter 5 for further discussion on window interface detailing.

## Air leakage

Examine refurbishment and replacement options for airtightness of the window and ease of integration with wall air barrier.

Reducing air leakage will reduce drafts and the potential for condensation. Air leakage primarily affects occupant comfort and energy usage, but can, on pressurized higher humidity buildings, result in condensation related damage to interior wall components.

The air leakage rates for retrofit strategies can be determined both quantitatively and qualitatively using standardized air leakage tests.

Investigate reported performance problems. If performance problems with air leakage exist, ensure that both refurbishment and replacement options will resolve these problems.

Ensure that reported problems are related to the components that are being replaced or refurbished. If there are other factors contributing to air leakage performance problems, additional steps will have to be added to the remediation strategy.

## **Condensation resistance**

Investigate historical condensation related problems. If problems with condensation have occurred, ensure that refurbishment and replacement options will address these problems.

There are a number of methods available to reduce condensation. New windows can be selected with a number of condensation potential reducing features such as vinyl framing, thermally broken aluminum framing, low emissivity coatings, argon filled insulating glass units and specialized spacers in the glazing units. Other indirect options that are used in remediation programs include reducing interior humidity, increasing air flow over the window surface and adding additional heating to the perimeter of the building in the vicinity of the windows. The effects of many of these changes can be predicted using computer software.

## Durability and renewal

Compare durability and remaining economic performance life expectancy of refurbished window to replacement window.

All assemblies, components and materials have a finite life expectancy and windows are no exception. New windows usually have a longer life expectancy than the existing windows. Some window retrofits extend the performance life of the window, however most retrofits are less durable than new windows.

Compare quality control of refurbished window to replacement window.

Window refurbishment can range from basic improvements such as adding a cap bead from the exterior to more complex and labour intensive upgrades such as resealing interior butt and mitred joints within the window assembly. If this work is carried out on site it will be difficult to achieve the same quality control as new windows in a manufacturing plant. It is worthwhile to compare the consequence of reduced quality control when comparing retrofit and replacement options. For example a window that requires extensive and complicated remedial work will require much more stringent quality control. If this same window is installed in a wall assembly that is very sensitive to water infiltration the requirements for quality control may be so high that the cost of repairing the windows is uneconomical. Conversely, a simple window refurbishment used in a very moisture-tolerant wall assembly requires far less quality control.

Compare remaining anticipated performance life of existing glazing units to that of new glazing units.

Insulated glazing units are an expensive component of the window. Unfortunately glazing units cannot be economically maintained and are usually replaced when they are broken or when the perimeter seals fail and allow condensation to occur between the two lites of glass. There are numerous types of insulated glazing units on the market and they have a wide range of life expectancies. If an unusually high number of insulated glass units have failed prematurely in the past, an extensive window repair that involves de-glazing or significant movement of the frames can add to the frequency of failures for years after the remedial repairs have been completed. A discussion of sealant and insulated glass units is located in Chapter 7 of the *Best Practice Guide—Wood-Frame Envelopes in the Coastal Climate of British Columbia*. The expected performance of the specific insulated glass units in the windows, the historical performance of the sealed units and the severity of the remedial repairs need to be considered when comparing strategies. For example, if 25 per cent of the sealed units are likely to require replacement in the 5 years following a refurbishment this cost should be added to the life cycle cost of the refurbishment option.

## Maintenance requirements

Compare expected maintenance requirements of refurbishment strategy and replacement strategy.

Different window types require different levels of maintenance. For example, if the existing windows are painted wood

in an exposed application they will likely require repainting every five years. Vinyl and aluminum windows will not require re-coating for 15 to 25 years. This difference in maintenance requirements should be considered in the life cycle cost comparison of remediation strategies. Other maintenance issues include; cleaning of mold and condensation in non-thermally broken frames, interior repainting of windowsills due to damage from condensation, replacement of operating hardware, replacement of gaskets and replacement of glazing splines and tapes.

## **Acoustics**

Investigate reported acoustic related problems. If reported problems with noise transmission have occurred ensure that refurbishment and replacement options will address these problems.

Two main factors influence sound transmission through windows—the type of glass and the airtightness of the frames. Increasing the airtightness of windows and their interfaces is an economical and effective method of reducing the sound transmission of windows. Adding laminated insulated glass units is a more expensive method of increasing the acoustical performance of the window. As a refurbishment solution the addition of laminated glass to an existing window frame would not make much sense. However, if the decision has already been made to replace the windows the additional cost of adding laminated glass is relatively small. A STC test combined with computer modeling can be used to assess if problems exist and what performance can be expected with various retrofit strategies.

## **Life-cycle cost analysis**

Modify both refurbishment and replacement strategies to address performance requirements other than the water penetration control.

Wherever possible assign present and future costs for each aspect of both the refurbishment and replacement strategies. Make a list of all remaining intangible benefits such as increased comfort, etc. for each option.

Areas of the building where there is only one remediation strategy that will provide acceptable performance.

No life-cycle cost analysis required. Present final strategy to owner to verify assumptions and conclusions.

Areas of the building where both refurbishment and replacement strategies provide acceptable performance.

Perform a life-cycle cost analysis, including future expenditures for maintenance and renewal. Bring all future cost to a net present value and compare alternatives. See "Cost analysis of alternatives". Present final strategies to owner along with life-cycle costs and the associated intangible benefits and allow owner to select a strategy and verify assumptions and conclusions.

## Appendix D

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## Safety measures for building occupants during construction

Consultants should provide a list of basic safety precautions to owners. Elements of such a list may include the following:

**Scaffolding**—A scaffolding system is essential for access to the building exterior. Many workplace accidents are scaffolding related:

- Do not walk under the scaffolding. Use access points as directed by the contractor which are specifically designated for pedestrian traffic.
- Maintain a distance of 10 feet from any scaffolding, especially during work hours. Debris, tools, or equipment may fall from the scaffold.
- At no time are building occupants to climb the scaffolding. Sections may be in a stage of dismantling and not be safe.
- Do not remove or adjust any component of the scaffolding. Scaffolding is quite often an engineered system and cannot be altered without approval of the design engineer.
- Do not allow other tenants, especially children, to play on or near the scaffolding.

**Ladders**—Ladders are a source of potential danger:

- Do not climb any ladder used on the site for construction purposes. It may not be secured from falling!
- Do not remove ladders or alter them in any way. A worker may not be aware that the ladder has been altered or left unsecured. It is a requirement of the WCB regulations to restrain a ladder from falling.
- Maintain a distance of 10 feet from any

ladder in case of falling debris.

**Debris (loose, flying, falling)**—Debris will be removed from the construction site on a continuous basis, but occasionally it will accumulate. It is always a hazard:

- Watch for falling and flying debris. As materials are removed from the building they are sometimes difficult to contain.
- Watch for wood or boards with protruding nails. If rusty nails break the skin, they can cause severe infection.
- Loose debris and materials can be a slipping and tripping hazard. Do not walk on or through accumulated construction debris.

**Caution tape and signage**—These are widely used on construction sites to warn people of potential dangers. Respect all caution tape and signage:

- Caution tape and/or signage will be used to cordon off a danger area for a variety of potential safety reasons.
- A normal route of entry or exit may be cordoned off with caution tape and/or signage to prevent access or egress. Use an alternate route.
- Do not remove caution tape or signage, even after workers have gone for the day. There may still be existing dangers such as trip hazards, holes, or debris.
- Signage such as "Overhead Hazard" means just that. Beware of what is happening above.

**Materials storage area**—This is where construction materials used to repair the buildings are stored. Some may be hazardous materials, others may be stacked items:

- Do not allow children to play in material storage areas. Hazardous or poisonous materials may be in the storage area.

- Stacked materials such as lumber can sometimes fall, especially when prompted to do so by being knocked or heavily jarred. Maintain a safe distance.
- Respect designated storage areas.

**Tools and equipment**—Many tools and equipment will be used to repair the building. These tools and equipment can maim or injure if used by unqualified personnel:

- Do not use or borrow tools and/or equipment.
- If a tool or piece of equipment is inadvertently left unlocked after workers have left the construction site, turn it in to the building manager or strata council construction representative.

**Walkways**—Walkways will sometimes be re-routed to facilitate construction procedures. Walkways will be restored as soon as possible but alternate routes are to be used in the interim:

- Do not use walkways cordoned off with signage or caution tape;
- If walkways are littered with construction debris it is only a temporary situation. Use an alternate route.
- Ensure that emergency exits and access routes are maintained throughout construction or alternate arrangements are implemented.

**Waste containers**—Waste containers are necessary for removal of debris from the construction site. They will be present for the duration of the project:

- Do not climb into the waste container. There are nails, sharp wire, hazardous materials and many other dangers present.

- Do not park in the immediate vicinity of the waste container. Materials and debris are routinely thrown into the container, sometimes missing. Vehicles parked too close could be damaged.

**Privacy**—Privacy is a significant concern while construction proceeds on residential buildings. There are a few simple ways to maintain privacy:

- Keep drapes or blinds closed while work proceeds in your area of the building.
- Construction crews may require access to suites to repair drywall and touch up paint. These times will be arranged with occupants in advance.

**Security**—The use of scaffolding will make it easier for people to access all parts of the building exterior. During the construction, homeowners should be aware of an increased risk of criminal activity. Keep doors and windows locked at all times. If suspicious activities are observed contact the construction representative for confirmation. Contact the police if circumstances warrant it.

**Areas of Work**—During the course of construction all decks and balconies will be likely be dismantled and restored. Do not explore these areas while they are under construction. Supporting members may have been removed and/or guardrails may be unfastened and not secure.

**Insurance**—The strata council should review the insurance provided by the contractor (under the terms of the contract) and consult with the strata's insurance agent with respect to obtaining additional forms of insurance during the course of construction.

**Special Needs**—Identify any tenants with special needs that may be relevant to the contractor, i.e.: wheel chair access, sensitivity to dust and pertinent medical conditions or disabilities.

**Emergency Accident Procedure**—If a serious accident is witnessed during construction, follow the procedure outlined below. A serious accident is one in which the injured person (worker or tenant) is unable to help himself or herself:

- Call 911 and state the address.
- 911 will require a brief description of the accident. Tell them what is known.
- Try to contact the site first aid attendant and project superintendent.
- If able, go to the area where emergency crews will arrive and direct them to the accident scene or have another person do this.
- Before going to the accident scene to help the injured person assess the area to ensure it is safe.
- It is very important that children or adults with impaired judgment be closely supervised once construction work commences.

## Appendix E

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## Building Envelope Professional— guidelines for professional practice

At the time of production of this document, the BEP designation was not being granted by the AIBC and APEGBC. Nonetheless, the scope of services set out below accurately reflects those items typically undertaken by professionals operating as consultants in the field of envelope rehabilitation.

### 1. Basic Building Envelope Professional services

The role of the Building Envelope Professional (BEP) is to provide review of the building envelope design to the project architect or co-ordinating registered professional with respect to environmental separation and the performance of materials, components and assemblies of the building envelope. The responsibility for the design and field review of the construction of new buildings rest with the project Architect, except when a professional engineer is providing architectural services under the AIBC/APEGBC Memorandum of Agreement.

The usual phases of the *Basic Services*, as discussed below, are generally organized in a consulting agreement according to the sequential stages of a typical project. They are intended to assist the *Building Envelope Professional* (BEP) in addressing the *Building Envelope* performance issues around control of Heat, Air and Moisture as defined in Part 5 of the Building Code.

For the purposes of this document, element means an assembly, component or material forming part of the *Building Envelope* and performance means performance with respect to Part 5 of the Building Code.

#### 1.1 Conceptual or "schematic" design phase

In the conceptual or schematic design phase, the *BEP* shall:

- 1.1.1 Attend as required, meetings with the Consultant and design team to obtain information regarding the functional, esthetic, cost and scheduling requirements. The *BEP* review should focus on the *Building Envelope* elements and performance requirements defined in Part 5 of the Building Code.
- 1.1.2 If required, assist the *Co-ordinating Registered Professional (CRP)* in identifying the need for any specialist envelope consultants who may be required for the project.
- 1.1.3 Review the design criteria and environmental loads for the *Building Envelope* assemblies in consultation with the CRP.
- 1.1.4 Review applicable codes, standards, regulations, restrictions, insurance requirements and other factors affecting the performance of the building envelope.
- 1.1.5 Review compatibility and interaction with other building systems.
- 1.1.6 Review the preliminary design concept, together with alternate design concepts where appropriate.
- 1.1.7 Consider the requirements of other design professionals and provide information relating to the *Building Envelope* design, as they require.

### 1.2 Design development phase

In the design development phase, wherein the accepted conceptual design is developed in sufficient detail to enable commencement of the *Contract Documents* by all participants in the design team, the *BEP* shall:

- 1.2.1 Review preliminary drawing of such *Building Envelope* elements as: walls, windows (and glazed elements), roofs, balconies, decks and typical interface details between elements of the *Building Envelope*.

- 1.2.2 Review durability of *Building Envelope* elements and consider maintenance, renewal and service life requirements. Specific consideration should be given to the following items:
- (a) Expected service life of the *Building Envelope* elements;
  - (b) Consideration of the layering of *Building Envelope* elements, so that repair and replacement of elements with shorter service lives does not require the removal or replacement of items with longer service lives; and
  - (c) Materials compatibilities and resistance to various mechanisms of deterioration, given the nature, function and exposure of the materials.

### 1.3 Contract documents phase

In the contract documents phase the *BEP* shall:

- 1.3.1 Review the construction documents to verify that they describe *Building Envelope* elements that achieve the performance criteria that were established during the Schematic Design Phase and further developed during the Design Development Phase.
- 1.3.2 Provide technical input into the specifications.
- 1.3.3 Assist in establishing testing and inspection requirements.
- 1.3.4 Assist the client in obtaining the required approvals, licenses and permits, including preparation of the relevant documentation required by the authority having jurisdiction.

### 1.4 Bidding and negotiation phase

In the bidding and negotiation phase the *BEP* shall:

- 1.4.1 Provide assistance to the CRP in preparing addenda to the design and clarification of the construction documents as required.

### 1.5 Construction phase

In the construction phase, the *BEP* shall provide services for all Building Envelope elements which the *BEP* has reviewed in earlier project phases.

Some items reviewed by the *BEP* may also require review by other members of the design team or by testing or inspection agencies. Such work may include waterproof membranes, glazing, pre-cast concrete elements, welding, proprietary products and primary and secondary structural elements.

Construction phase services shall include, but not necessarily be limited to the following and may vary depending upon the complexity of the job and the experience of the contractor.

- 1.5.1 Attend construction meetings, if required.
- 1.5.2 Assist in confirming, reporting and scheduling procedures for testing and field reviews.
- 1.5.3 Assist in confirming that the qualifications of fabricators meet the specifications.
- 1.5.4 Assist in review of submissions for general compliance with the contract documents.
- 1.5.5 Assist with the review of *Building Envelope* related shop drawings and other submissions for general conformance with the contract documents and the intent of the design.
- 1.5.6 Provide enhanced field review, visiting the site at sufficiently frequent intervals, appropriate to the stage of construction and review a substantial number of the details (rather than just a representative sampling) to observe the quality and the progress of the construction of those elements reviewed by the *BEP*. The term "enhanced field review" is used to differentiate the level

of review which a *BEP* shall provide, which supplements the level of field review and assurances which shall be provided by the architect and other registered professionals.

- 1.5.7 Review reports provided by material and component manufacturers, as well as other reports prepared by professionals reviewing *Building Envelope* elements.
- 1.5.8 Prepare site visit reports outlining observations and deficiencies in the work and bring them to the attention of the CRP.
- 1.5.9 Make site visit reports available to the authority having jurisdiction upon request.
- 1.5.10 Assist in arranging for and observing the mock-up and/or testing of key envelope elements such as wall assemblies or window installations, where required.
- 1.5.11 Review the continuity of thermal insulation, moisture, air and vapour barriers.
- 1.5.12 Review drainage paths.
- 1.5.13 Review the acceptability of the moisture content of wood products.
- 1.5.14 Review that components and materials used are those specified in the contract documents.

## **2. Additional *Building Envelope Professional* services**

In addition to the *Basic Services*, the *BEP* may be required to provide the following *Additional Services* if they become necessary during the course of the project. They are generally not considered part of the basic services, as discussed in the preceding sections and may require a review of the service agreement between the *BEP* and their client.

Examples of Additional Services are:

- 2.1 Work resulting from changes to the project as originally described and agreed to under the contract between the *BEP* and client, such as changes in scope, schedule, cost, complexity, diversity or magnitude of the project;
- 2.2 Review of alternate designs and related documentation after selection of the *Building Envelope* designs are made during the conceptual design and design development phases;
- 2.3 Review of alternate or substitute assemblies if requested by the *BEP*'s client for tendering to obtain competitive bids for such items such as propriety products;
- 2.4 Work connected with the review of documents for tendering segregated contracts, pre-tendered contracts, phased or fast-track construction;
- 2.5 Assistance in preparing or reviewing construction cost estimates;
- 2.6 Review of alternate designs or products after completion of the contract documents;
- 2.7 Special physical model analysis such as wind-tunnel;
- 2.8 Full-time inspections of construction;
- 2.9 Review of additional submissions when occasioned by improper or incomplete submissions;
- 2.10 Work resulting from corrections or revisions required because of errors or omissions by others; and
- 2.11 Work resulting from damage during construction as the result of fires, man-made disasters, or natural disasters.



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# Acknowledgements

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## Web sites

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<http://www.acec.ca/>

AIBC—Architectural Institute of B.C.

<http://www.aibc.bc.ca/>

APEGBC—Association of Professional Engineers and Geoscientists of B.C.

<http://www.apeg.bc.ca/>

ASTM—American Society for Testing and Materials

<http://www.astm.org/>

B.C. Buildings Corporation

<http://www.bcbc.bc.ca/>

B.C. Housing—British Columbia Housing Management Commission

<http://www.bchousing.org/>

B.C. Ministry of Municipal Affairs and Housing

<http://www.gov.bc.ca/marh/>

Barrett Commission

[http://www.sdes.gov.bc.ca/housing/  
barrett.htm](http://www.sdes.gov.bc.ca/housing/barrett.htm)

BOMA BC—Building Owners and Managers Association BC

<http://www.boma.bc.ca>

BOMA Canada—The Building Owners and Managers Association of Canada

<http://www.boma.ca/>

Canada Mortgage and Housing Corporation  
[www.cmhc-schl.gc.ca](http://www.cmhc-schl.gc.ca)

Canadian Association of Home and Property Inspectors-B.C.

<http://www.cahi.bc.ca/>

Canadian Home Builders' Association of British Columbia

<http://www.chbabc.org/>

Canadian Home Builders' Association  
<http://chba.ca/>

Canadian Institute of Treated Wood  
<http://www.citw.org/>

Canadian Standards Association

<http://www.cssinfo.com/info/csa.html>

CCDC—Canadian Construction Documents Committee

<http://www.ccdc.org/>

CHOA—Condominium Home Owners' Association of BC

<http://www.choa.bc.ca/>

City of Vancouver

<http://www.city.vancouver.bc.ca/>

Forintek Canada

<http://www.forintek.ca/>

HPO—B.C. Homeowner Protection Office

<http://www.hpo.bc.ca/>

ICBA—Independent Contractors and Businesses Association of British Columbia

<http://www.icba.bc.ca/>

IREM—Institute of Real Estate Managers

<http://www.irem.org/>

Mold

Canada Mortgage and Housing Corporation and Health Canada both have information about mold. To get to the information, go to the Web addresses below and search for "mold."

Health Canada

<http://www.hc-sc.gc.ca/>

CMHC

[www.cmhc.schl.gc.ca](http://www.cmhc.schl.gc.ca)

PAMA—Professional Association of Managing Agents

<http://www.landcentre.ca/pama/>

*Strata Property Act* information page

[http://www.fic.gov.bc.ca/strata/  
index.html](http://www.fic.gov.bc.ca/strata/index.html)

Urban Development Institute

<http://www.udi.bc.ca/>

Vancouver Island Strata Owners Association

<http://www.visoa.bc.ca/>

Workers' Compensation Board of B.C.

<http://www.worksafebc.com>

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# Chapter Title

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RDH Building Engineering Ltd. prepared this *Guide*. The technical content of the *Guide* was developed by RDH Building Engineering Ltd., Levelton Engineering Ltd., Morrison Hershfield Ltd., Neale Staniszkis Doll Adams Architects and Read Jones Christoffersen. In addition to many external reviewers, the project team included Sheltair Scientific Ltd., B.R. Thorson Consulting Ltd., Frido Consulting, Heatherbrae Construction, Highland Restoration Services Ltd. and Mr. D. Onysko, for review of specific technical aspects or sections of the *Guide*.



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