A3.1 Case Study: British Columbia, Canada

Investigations carried out on performance failures of housing construction in British Columbia through the 1980s and 1990s, known as the ‘Leaky Condo Syndrome’, by the Canadian Mortgage and Housing Corporation (CMHC) of 46 buildings of various construction types, of which 37 were reported as having problems, concluded that exterior water penetration was the principal cause for failure. The survey also assessed the cost of repairing problems, the types of wall construction details and statistical analysis of wall details and various building features such as window openings, roofs and flashing details.

The following tables of data are taken from the CMHC report and summarise the findings of the study. The fundamental observation is that nearly all the problem categories relate to interface details and penetrations rather than the basic construction of the wall. Table A3.1 identifies the number of problems observed at particular locations on the buildings. Almost 25% of problems were related to windows; 17% to decks, balconies and exterior walkways; and it was usually the lack of good design and/or construction of joints that precipitated the reported problems. The largest single problem area occurred at saddle joints of balconies with surrounding walls where 22 instances of failure were recorded.

Table A3.1 Problems Observed

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Number of problems</th>
<th>Total no. of Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Stucco</td>
<td>Vinyl</td>
</tr>
<tr>
<td>1</td>
<td>Windows: No sealants at frame/cladding joint</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Windows: No sealants at corner joints</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Windows: Poor flashing at head or sill</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Windows: Poor breather membrane installation</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Poor deck/balcony waterproofing</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Poor deck/balcony junction with walls</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Subtotal</td>
<td>66</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>Poor guardrail saddle joints</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>Poor guardrail cap flashings</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Poor parapet cap flashings</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Subtotal</td>
<td>28</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>Poor base/transition/control/joint flashings</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>Poor roof/wall joint flashings</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>Poor eaves troughs/downspouts</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>Poor slab/wall joints</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>Poor dryer vents</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>Poor vents</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>Other poor details</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>17</td>
<td>Material/insulation/cladding/weather barrier/sheathing defects</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Subtotal</td>
<td>52</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Totals</td>
<td>146</td>
<td>17</td>
</tr>
</tbody>
</table>
Based on the collected data, it is clear that the most numerous problems observed were with those buildings directly clad in ‘stucco’, a synthetic render system over polystyrene insulation, also referred to as EIFS (Exterior Insulation Facing System).

Table A3.2 Penetration Past Sheathing Paper

<table>
<thead>
<tr>
<th>Mode of failure</th>
<th>Percentage of total symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>No exterior breather membrane</td>
<td>14%</td>
</tr>
<tr>
<td>Discontinuities in breather membrane</td>
<td>30%</td>
</tr>
<tr>
<td>Material degradation</td>
<td>11%</td>
</tr>
<tr>
<td>No or reversed lap</td>
<td>10%</td>
</tr>
<tr>
<td>Penetration at flashing</td>
<td>16%</td>
</tr>
<tr>
<td>Penetration at opening</td>
<td>16%</td>
</tr>
<tr>
<td>Others</td>
<td>3%</td>
</tr>
</tbody>
</table>

The data in Table A3.2 identifies the path taken by moisture to penetrate the building. The absence of or discontinuities in the breather membrane accounted for 44% of the total symptoms of moisture penetration, whereas material degradation accounted for 11%. These basic errors are easily corrected by the builder when identified prior to cladding as part of a quality control procedure. The overall results of the survey are summarised in Table A3.3.

Table A3.3 Summary of Overall Problems Identified in CMHC Study

<table>
<thead>
<tr>
<th>Rating</th>
<th>Design</th>
<th>Construction</th>
<th>Maintenance</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of ratings</td>
<td>No. of problems</td>
<td>No. of ratings</td>
<td>No. of problems</td>
</tr>
<tr>
<td>Acceptable</td>
<td>47</td>
<td>0</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>Poor</td>
<td>90</td>
<td>90</td>
<td>149</td>
<td>149</td>
</tr>
<tr>
<td>Not designed</td>
<td>29</td>
<td>27</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Not maintainable</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Not rated</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TOTALS</td>
<td>166</td>
<td>117</td>
<td>166</td>
<td>149</td>
</tr>
</tbody>
</table>

Poor design, quality control and construction were inextricably linked with reported building problems. CMHC concluded that:

- Water penetration through the external cladding was the principal cause for failure in the affected buildings.
The vast majority of the problems for all construction types were related to the interface between openings and flashing details.

Very few problems were related to the basic assembly of the cladding details in the field areas of the walls. However, in some cases, such as directly clad ‘stucco’ (EIFS) the impermeable nature of the material and lack of ventilated and drained cavity traps moisture within the wall structure for prolonged periods which contributes to the development of decay.

It should be recognised that failure was also detected within the timber frame of brick or timber clad buildings where poor design and construction was evident.

A lack of clear details on technical drawings illustrating the construction sequence was also identified as a contributory factor to poor building performance.

Poor construction, i.e. poor workmanship irrespective of drawing detail clarity was also identified as a contributory factor.

Ineffective monitoring of quality control on the part of the municipalities which left poor construction practices to continue unabated.

British Columbia’s urban centres are located in a geographic and climatic region most affected by significant rainfall and mild weather. The CMHC report acknowledges that these conditions ‘increase the likelihood of water ingress, intensifying the process of wood rot’. The primary cause for water retention within the load-bearing, external stud walls has been the adoption of face sealed cladding systems which are fixed directly to the timber frame which became prevalent in the 1980’. In climates characterised by high rainfall and driving winds, these directly clad systems are very sensitive to failure. The investigation concluded that rain screen wall assemblies, i.e. a ventilated and drained cavity between the stud walls and external cladding, offered the most robust resistance to fungal decay and that directly clad ‘stucco’ (EIFS) finishes were unsuitable for use in the British Colombian climate.

A moratorium on most EIFS construction became effective in Vancouver in January 1996. Vancouver City issued a mandate that all forms of timber frame construction must include a drained and ventilated cavity between the exterior cladding and the frame. However, this mandate has not been extended to other municipalities throughout British Columbia. In 1999 the Canadian Wood Council launched their ‘Best Practice Guide for Wood-frame Envelopes in the Coastal Climate of British Columbia’, the primary focus of which is moisture management.

Following the incidence of building envelope failure, the Building Envelope Research Centre (BERC) was formed in 1995 and acts as a coordinator for industry and research to address the issues of building envelope failure. The aim of BERC is to improve construction industry technology.
and practice through the application of research knowledge. One of the primary recommendations of BERC is for designers to produce large-scale 3D technical drawings so builders can clearly understand the construction process.

In a report prepared by a specially appointed commission of inquiry entitled ‘The Renewal of Trust in Residential Construction’, June 1998, the commission concluded that the failures were attributable to leaks in the external skin of the buildings of all construction types including masonry buildings, concrete frame and timber frame. Of these failures, timber frame buildings were affected by subsequent rotting of timber frame structural components. In the executive summary of the report all elements of the building process and building science were faulted including:

- Ineffective building control
- Lack of responsibility of builder/developer
- Poor detailing
- Poor workmanship
- Poor guarantee system

The commission also cites ‘economic pressures, climatic conditions and a systemic failure of the building process . . .’ They also outlined factors related to building technology including:

- Economic measures
- Poorly interpreted building technology codes
- Use of new materials without understanding how they are affected by climate
- ‘. . . A lack of conventional wisdom, among inspectors, architects, engineers, developer and contractors regarding the requirements of effective building’, and ‘ineffective communication and transfer of knowledge . . .’

### A3.2 Case Study: New Zealand

‘Leaky building’ problems in New Zealand have led to substantial damage to relatively new buildings. Following reports of relatively new building failures, the government appointed the Building Industry Authority (BIA) to launch an enquiry with the objective of gauging the extent of the potential problems. Estimates of the size of these problems are difficult because the problems can remain undetected for years. It is believed that the scale of the problems in New Zealand is only beginning to emerge and that the repair bill could exceed 1 billion dollars (NZ).

In 1955, it became mandatory to pretreat all structural timber components with a wood preservative. In the main, preservatives based on boron salts were used. After 1995, pretreated (preservative treated) timber components were permitted to be omitted. During the 1980s and
1990s face seal direct clad render systems (EIFS) became prevalent. As with the Canadian experience, a number of homes were constructed where the external cladding material comprised a face seal system directly fixed to the timber frame. This combination of a lack of timber preservation, directly clad face sealed systems and poor detailing and/or construction led to premature failure of a number of dwellings in New Zealand.

In 2002, the BIA appointed a Weathertightness Overview Group to inquire into weather tightness of buildings in NZ in general and in particular into the concerns regarding housing that is leaking and causing decay. The causes were wide ranging, some relating to the industry standards and the way the industry operates and others to do with changing social and economic factors.

Some of the proposed recommendations to do with weather tightness were to:
- Issue a public warning concerning the risk of collapse in untreated timber frame buildings (especially of cantilevered balconies)
- Resolve upon the best manner to identify and take precautions against potential health risks associated with fungal decay
- Continue to exclude from the Approved Documents E2/AS1 External Moisture, face sealed cladding systems in high risk areas
- Sponsor research into better methods of moisture management and include these in the Approved Documents on their conclusion
- Review and upgrade the level of detail with respect to weathertightness required for planning applications
- Develop guidelines for an inspection regime as part of the compliance certification process
- Develop more prescriptive Acceptable Solutions and Verification Methods for Approved Documents on Durability and External Moisture and promote a national performance-based standard for domestic building weathertightness
- Review the current practice for product appraisal and develop formalised requirements

Recommendations for the building sector included to:
- Improve compliance process efficiency without compromising building standards or quality
- Optimise ‘whole-life’ costs
- Develop tertiary qualifications relevant to building inspectors and certifiers
- Review apprenticeship of carpenters and associated trades
- Advocate a national register of builders and related trades
- Consider the accountability of all parties for the quality of construction
New Zealand has a climate similar to Ireland in relation to rainfall and humidity. The recent exclusion of a timber preservative treatment appears to be a fundamental contributor of fungal decay in timber buildings constructed after 1995. The report found that, in the Auckland climate, the behaviour of rain both vertically and horizontally and the prevalence of humidity and condensation should lead to a more appropriate design response than evidenced by the Overview Group.

‘When water penetrates cladding systems, the water is held and cannot get out easily. Retained water or moisture affects all the materials involved. Primary of these is the now generally used untreated kiln dried timber used for framing although steel frame and strapped masonry can also be affected.’ (Report of the Overview Group on the Weather tightness of Buildings, Building Industry Authority, August 2002).

The current remedial course of action is to replace decayed components, to remove the external cladding and to fix battens to sound external walls before re-installing the new external cladding system. This introduces a ventilated and drained cavity so water and vapour control is improved.

**A3.3 Case Study: North Carolina, USA**

Performance failures within the last two decades in housing construction that utilised direct clad exterior insulation facing systems (EIFS) have been reported in North Carolina, USA. There is ongoing legal action to determine whether failure within the timber frame of the dwellings has been the result of an inherent flaw in the EIFS cladding system or inappropriate installation of EIFS by the contractor on site.

EIFS entered the US market in the late 1960s and was promoted throughout the industry on the basis that EIFS were more uniform and attractive than traditional stucco finishes, provided superior thermal insulation and offered lower maintenance.

In the summer of 1995, the New Hanover County Inspection Department in South Carolina believed that they had discovered a significant correlation between moisture damaged timber frame dwellings and EIFS cladding. A task force was set up to further investigate the link between EIFS and moisture damaged dwellings. The task force drew the following conclusions:

- Water is most likely to infiltrate EIFS cladding where EIFS abuts rooflines, windows, doors and decks.
- A lack of inadequate flashings at rooflines often contributes to water penetration behind the EIFS cladding.
Perimeter caulking around windows, doors and other penetrations and junctions in EIFS clad homes has often been omitted in contravention of most manufacturers’ specifications and details had not been applied adequately to repel moisture.

Water has penetrated behind the EIFS cladding through the outer assembly of the window frame.

Their conclusions demonstrated that water does not penetrate the EIFS cladding itself but at openings and flashing details. These findings indicate that the system is sensitive to poor installation or lack of installer experience and, as such, would appear to have poor buildability. The experience of EIFS and coincident premature rotting of timber frame dwellings has resulted in many mortgage lenders and insurers withholding finance from dwellings clad with EIFS. Some state or local building authorities ban or restrict the use of EIFS.

In 1996, the North Carolina Building Code Council adopted guidelines that effectively ended the use of foam-based barrier EIFS. The requirements were for a 20-year warranty and internal water drainage system to be contained in any EIFS installation, effective in 1997 in North Carolina and Georgia. The United States Gypsum Company (USG Corporation), a major manufacturer of EIFS, announced at this time its intention to pull out of the ‘barrier’ EIFS market and to focus on ‘water-management’ systems only.

A3.4 Case Study: Social Housing Project, Ireland

Brief: 54 no. 1 and 2 Storey Terraced Houses for a local authority

Design
A local authority procured 54 units of housing using their standard procurement method. The design and specifications were prepared on the basis of typical masonry cavity wall construction and external cladding consisting of a combination of brick and rendered block-work.

Procurement
The project was tendered in an open tender process based on drawings, specifications and measured bill of quantities. After the tender process the awarded builder proposed an alternative construction method utilising an open panel timber frame system supplied in kit form. The alternative was accepted by the council on the basis that it would comply with their requirements, standards, programme and cost.
Construction
The manufacturer prepared drawings based on the general arrangement and submitted them for service and comments.

In the view of the local authority the details of construction, especially where non standard and in response to complex design, required considerable effort on both part of the local authority and the manufacturer before being agreed. Fire stopping and fire protection details in particular, between housing units and at overhangs and complex stepped or staggered wall junctions were not readily agreed. Prior to and during construction, on site seminars were held and attended by the local authority, erectors, builders and sub-contractors to review the timber frame aspect of the works. During construction the local authority monitored the quality of the works. It was the view of the local authority that the construction of the timber frame system was lacking in quality when installed on-site and in some cases did not meet their expectations. The manufacturer’s view was that the local authority did not understand timber frame construction. During the process of the works details were eventually agreed and the site quality control issues were resolved. The project was completed satisfactorily.

The local authority noted the following:

- Marking of the timber frame locations on the breather membrane would facilitate installation of masonry ties which are required to be secured to solid timber through the external sheathing.
- Clearer details and instruction for installation of fire stopping and cavity barriers would eliminate ambiguity on site.
- Method for installing and inspecting fire stopping and cavity barriers prior to installation of next floor level construction should be included in the manufacturers site quality control procedures.
- More flexibility in temporary floor subfloor to allow for expansion, if wet and without buckling.
- Improved methods of coordinating masonry works such as chimneys with the timber frame should be developed by the timber frame manufacturers by inclusion of easily adjusted fillers and/or larger tolerances.
- Improved tolerances for installation of services and post design modifications.

A3.5 Case Study: Private Housing Project, Ireland
Brief: 80 no. 2 and 3 storey terraced houses and duplex units
The completed housing is constructed of timber frame open panel platform method construction on concrete foundations and masonry rising walls. The exterior is finished with an outlook leaf of brick masonry, block and sender and localised timber cladding.

Design
The design was originally set out as masonry construction and with spaces and building sizes meeting the Housing Standard guidelines. The developer/builder, concerned about the possible delays and labour shortages desired to use timber frame as the main structural component.

The change from masonry to timber required a redesign of the development as a result of the increased dimensions of the thickness of the separating walls between house units which, when added up in long terraces of houses, amounted to a shortfall available site area.

Detail Design by the Manufacturer
Prior to construction the manufacturer was required to engineer and prepare detailed design drawings of the timber frame. The project architects reviewed the manufacturers’ detail design drawings for compliance with the general arrangement drawings. Additional reviews and comments were required before the project architects accepted the manufacturers’ detail design. The manufacturer’s engineer certified the detailed design drawings.

Procurement
The developer was free to choose a method of construction. There was no tender process in the design build contract.

Construction
The builder complied with HomeBond requirements during construction. In the architect’s view the timber frame kit components delivered to site were of appropriate quality. The architects reported installation problems, which appeared to occur as a result of inaccurate setting out of the masonry rising wall elements to meet required tolerances required by the manufactured frames. These difficulties required site adjustments to the timber frame and rising walls with obvious time implications.

Following Trades
Services installations required battened out service zones at kitchens when located against party walls, which resulted in lost floor space. Electrical service points also could not be located in party walls and this required change to service locations. Timber structural elements also prevented
placement of some electrical service points such as light switches where they conflicted with studs and built up load-bearing timber elements around windows and doors.

The party wall construction was closely monitored as defects were found which would have affected their performance in control of both sound and fire.

**Key Points**

- Design for masonry wall required major adjustments to this largely terraced housing scheme.
- Services in masonry wall design required redesign and small loss of floor space in the timber design.
- Service routes and locations are required to be planned in advance of the detailed design and result in less flexibility to handle late changes to the design.
- Quality control on site is essential including the accurate setting out and confirmation of setting out of ground works and rising wall elements.