RESEARCH HIGHLIGHT

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Study of Highrise Envelope Performance in the Coastal Climate of British Columbia

INTRODUCTION

Over the past few years, moisture-related problems in highrise residential buildings have become more common in the coastal climate of British Columbia. Although research has been conducted in British Columbia on building envelope performance in lowrise wood frame buildings, it does not address the unique characteristics of highrise buildings.

The materials used in highrise buildings differ from those used in lowrise construction. The primary structure is concrete, with steel stud framing, instead of wood. There are also differences in the environmental forces that act on highrise envelope assemblies. For example, exposure to wind and rain is generally more severe, and a stack effect can create sustained inward and outward forces on the envelope. Mechanical systems play a role in pressurizing parts of the building, and mechanical ventilation can be a key factor in managing interior moisture sources.

These differences in materials and environmental forces result in corresponding differences in the way in which highrise buildings respond, how problems manifest themselves and are investigated, when failures occur, and the extent, nature and urgency of the repairs required.

This study, undertaken by Canada Mortgage and Housing Corporation in partnership with the Homeowner Protection Office, City of Vancouver, the EIFS Council of Canada and Vancouver Condominium Services Ltd., focused on identifying causal relationships that have resulted in either building envelope problems or successes in non-combustible highrise residential buildings in coastal climate areas of British Columbia.

In doing so, it facilitates identification of key factors that contribute to successful design and construction of building envelope assemblies, interfaces, details and associated mechanical systems.

The strategies and methodology used in a previous CMHC study entitled *Survey of Building Envelope Failures in the Coastal Climate of British Columbia (Lowrise Survey)* provided a foundation for this study on highrise envelope performance.

METHODOLOGY

The study involved a small sample of 35 buildings. The buildings included were chosen based on the availability and quantity of information. As such, the study is not statistically representative, and the findings and conclusions cannot be extrapolated as an indication of failure rates or trends for the general population of highrise residential buildings. In addition to looking at problems, the study also examined reasons why building envelopes have performed successfully.

The specific attributes of the buildings for inclusion in the study were as follows:

- Residential buildings located in coastal area of BC; that is within 30 km of the Strait of Georgia, including the lower mainland and Vancouver Island. The buildings were five stories or more, and included both market and non-market housing as well as strata and rental buildings.
- No more than 19 years of age, in order to study buildings that have experienced relatively rapid deterioration, with one exception: a building constructed in 1974, using a drained cavity design in its major assembly walls, which has experienced good performance.
- Sixteen different combinations of wall and window/door assembly types
- Four problem-free buildings
- Repairs exceeding $400 per suite multiplied by the age of the building at the time the repair was under taken. This amount represents more than double the expected capital cost allowance or reserve fund allocation for the building envelope of a typical suite in a highrise building.

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FINDINGS

Several opportunities for improvement emerged from the data analysis, which were grouped as follows: building form complexity; building exposure conditions and overhangs; mechanical systems; assembly interfaces and details; and assemblies, components and materials.

Building form complexity

The research findings suggest that the complexity of the exterior facades of buildings is not a significant causal factor in the occurrence of failures or problems. This was contrary to the research team's expectations, but it could conceivably be explained by the fact that virtually all assembly interfaces and details analyzed in this project had failures and problems. This may have masked the building form complexity contribution.

Building exposure conditions and overhangs

No relationship was found between overhang ratio and the occurrence of damage in wall assemblies. This likely reflects the general lack of meaningful overhangs on buildings in the study. Given the small overhang ratios, other factors are more significant in causing problems.

No relationship could be found between door assemblies and the occurrence of problems. This reflects the low exposure conditions that exist for most door assemblies on a typical highrise building. Although the doors on upper levels of the buildings in the study (no overhang protection provided by balconies) had experienced failures, their limited numbers prevented them from being considered problems as defined in the study.

Mechanical systems

Mechanical ventilation provisions in highrise buildings are not adequately controlling interior moisture conditions. This may be attributable to a variety of factors, including unusual sources of moisture from the exterior (water infiltration) or interior (high occupant load or use characteristics, disconnected humidistat), inadequate fans and controls, and possibly problematic in-slab duct configurations.

Assembly interfaces and details

Exterior moisture penetration at details within wall assemblies are significant contributors to moisture problems in highrise buildings. It appears to be not so much the type of detail but rather an interruption in wall assembly continuity caused by any detail that results in a problem.

Exterior moisture penetration at wall-to-wall assembly interfaces, and at wall-to-window assembly interfaces, is a significant contributor to moisture problems in highrise buildings. The use of non-planer geometry at interfaces (one assembly is out of plane with respect to the adjacent assembly) between assemblies was found to improve performance; for example, where one assembly overhangs another and the inherent need to use flashing at many non-planar interfaces.

Assemblies, components and materials

Window assemblies are significant contributors to problems, although the nature of failures was not determined in this study. Also, it was impossible to assess the relative contribution of window assembly failures versus failures at the window assembly to wall interface.

Corrosion of concealed metal components in wall assemblies represented the majority of moisture damage necessitating the need for repairs. These metal components included steel studs, fasteners, anchors and reinforcing mesh (stucco).

The study revealed significant levels of damage to exterior gypsum board. Wall assemblies containing glass fibre-faced gypsum board showed less damage in terms of extent and severity.

Most of the face seal wall assemblies, other than mass concrete wall assemblies, were found to be damaged and involved in problems.

Most of the wall assemblies incorporating an exterior drainage cavity were not damaged. None of these wall assemblies had experienced any problems.

RECOMMENDATIONS

Standards and guidelines

1. Determining exterior exposure conditions is fundamental to selecting assemblies and developing appropriate assembly interfaces and details. As such, there is a need for better guidance concerning environmental loads, such as exterior and interior design temperature and humidity conditions. In particular, there is a need to define exterior moisture exposure conditions (wind and rain), as well as a process for evaluating loads at the design stage.

2. Durability appears to have been largely ignored during the design and construction of the study group of buildings. Specific durability requirements for the building envelope should be established and reflect reasonable maintenance and renewal requirements. Durability expectations for many of the materials and components should also be clarified.

3. Guidance and standards exist for the corrosion resistance of metal components within masonry wall assemblies. Similar guidelines and standards should be developed and mandated for appropriate corrosion resistance of metal components used in all wall assemblies. They should reflect relative durability requirements for materials, components and assemblies. Further research is needed on the durability of corrosion resistant coatings in installed conditions.

Assemblies

4. Wall assemblies should be selected and designed to reflect exposure conditions for each building, and possibly wall regions within buildings that have differing exposure conditions. Rainscreen wall assemblies should be used for the high moisture exposure situations typical of non-combustible highrise buildings. In addition to meeting performance expectations set out in Part 5 of the National Building Code (NBC) with regard to moisture control, these assemblies should reflect reasonable durability, maintenance and renewal expectations.

5. Window assemblies should be selected and designed to reflect exposure conditions for each building, and possibly wall regions within buildings that have differing exposure conditions. Rainscreen window assemblies and sub-sill flashings should be used for the high moisture exposure situations typical of non-combustible highrise buildings. In addition to meeting moisture control performance expectations set out in Part 5 of the NBC, these assemblies should reflect reasonable durability, maintenance and renewal expectations.

Assembly interfaces and details

6. Interfaces between assemblies and at details are the focal point for water ingress and resulting damage. Both the design and the construction of these details could be improved. Clearer durability requirements and better wall and window assemblies will likely result in improved interfaces. However, there are some specific measures that could be taken:

- Add a new module to the Architectural Institute of British Columbia's Building Envelope Education Program dealing with interface details.
- Encourage education and training of all design and construction team members with respect to assembly interfaces and details.
- Require mandatory testing of building mock-ups to confirm performance of interface details.
- Develop a design guide for assembly interfaces and details.

Mechanical

7. Using mechanical ventilation and air flow within highrise residential buildings to control interior humidity levels requires more research and more consistent application of principles. Although some aspects are well understood (such as flow in ducts and exterior wall airtightness levels), there is a need to develop guides that integrate recent research and knowledge of air flow and pressure differences within buildings and relative levels of airtightness of interior wall and floor assemblies to arrive at appropriate ventilation strategies. The study makes some specific recommendations which could be considered on a project by project basis:

- Carefully assess system static pressure drops, and avoid long lengths of duct.
- Keep duct runs as straight as possible.
- Avoid using small opening screens or grilles for dryer exhaust ducts, as they easily plug with lint.
- Match system pressure losses with exhaust booster fan curves.
- Consider using dryer exhaust booster fans for long runs.
- Consider using lint filter boxes within suites to prevent lint build-up within the exhaust system.
- Consider using continuous vertical exhaust systems, as found in some hotels. These systems ensure continuous removal of high humidity in suites, plus they ensure an adequate and measurable amount of outside air as required by ASHRAE standards.

Materials

8. Use of glass fibre faced gypsum board and other more moisture-resistant products should be encouraged, if not mandated, for highrise construction. Paper-faced exterior gypsum board should not be used as exterior sheathing in highrise building construction.

CONCLUSIONS

This study confirmed that the nature of the problems experienced in highrise buildings are similar in many ways to those identified for buildings in the *Lowrise Survey*. The predominant moisture source (exterior), path (details) and sensitive assemblies (face seal) were common to both types of buildings. However, performance problems in highrise buildings manifest themselves quite differently than in wood frame lowrise buildings.

In highrise buildings, the key damage issues are damage to interior finishes; deterioration of exterior gypsum board due to softening of the core and mould growth on the paper facing; and corrosion of metal components of the cladding attachment system, including steel studs (the secondary structure), clips, metal reinforcing and fasteners.

The study identifies opportunities for improvement of the design and construction process that will impact positively on highrise building envelope performance and provides a number of recommendations on how these improvements can be achieved.

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Research Report: *Study of Highrise Envelope Performance in the Coastal Climate of British Columbia, 2001*

Research Consultants: RDH Building Engineering Ltd.

Housing Research at CMHC

Under Part IX of the ***National Housing Act***, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

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