

# Insulating Solid Masonry Walls

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## ABSTRACT

As building stocks continue to age and older buildings become increasingly in need of repair, we are often confronted with renovating existing buildings containing solid masonry exterior walls. In many cases, due to market demands, existing commercial and industrial buildings are being renovated and converted for residential use. To increase energy efficiency and occupant comfort in cold climates, the addition of thermal insulation on the interior side of solid masonry walls is often considered.

Because of the risks involved and the lack of information, there is currently much controversy and confusion within the building design and construction community with regards to the addition of thermal insulation to existing buildings with solid masonry walls, that are subjected to cold climate conditions. The main challenge with insulating solid masonry walls is to improve performance without compromising durability. Unfortunately, there are presently no means available to accurately predict the performance and long-term effects of solid masonry walls retrofitted using different insulation approaches. This paper provides general guidelines to help practitioners understand and avoid specific problems associated with insulating solid masonry walls. It will also provide an insight on current research work, which when completed shall yield field data and information that shall significantly improve the understanding of the behaviour and performance of newly insulated solid masonry walls.

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## INTRODUCTION

As building stocks continue to age and older buildings become increasingly in need of repair, we are often confronted with renovating existing buildings containing solid masonry exterior walls. In many cases, due to market demands, existing commercial and industrial buildings are being renovated and converted for residential use. In the case of historic buildings where the aesthetic features of the facades are to be conserved, the addition of new insulation is restricted to the interior side of the building.

To increase energy efficiency and occupant comfort in cold climates, the addition of thermal insulation on the interior side of solid masonry walls is often considered. However, adding thermal insulation to the inside of previously uninsulated walls, decreases the temperature of the masonry during the heating season in cold climates, which can increase the risk for condensation and frost inside the wall, as well as prolong the drying time of the assembly. This combination can adversely affect the integrity and durability of the building envelope.

Because of the risks involved and the lack of information, there is currently much controversy and confusion within the building design and construction community with regards to the addition of thermal insulation to existing buildings with solid masonry walls, that are subjected to cold climate conditions. The main challenge with insulating solid masonry walls is to improve performance without compromising durability.

This paper provides general guidelines to help practitioners understand and avoid specific problems associated with insulating solid masonry walls. It will also provide an insight on current research work, which when completed shall yield field data and information that shall significantly improve the understanding of the behaviour and performance of newly insulated solid masonry walls.

## CONCERNS RELATED TO INCREASED THERMAL RESISTANCE

The addition of thermal insulation on the interior side of solid masonry walls is often considered as a retrofit option in order to increase energy efficiency and occupant comfort. In their original state, solid masonry walls with little or no thermal insulation are submitted to a relatively important temperature gradient. During the heating season, this temperature gradient promotes heat flow from the interior side of the wall, which increases the temperature of the masonry and

favours the drying of moisture within the wall. Although insulating from the exterior side would provide optimum performance and ensure the integrity of the masonry walls, in the case of historic buildings where the aesthetic features of the facades are to be conserved, the addition of new insulation is restricted to the interior side of the building.

Adding thermal insulation to the inside decreases the overall temperature of the masonry during the heating season in cold climates, which can increase the risk for condensation and frost inside the wall, as well as prolong the drying time of the assembly. In the case of the conversion of original commercial or industrial buildings into residential use, the new residential vocation may also suggest higher indoor relative humidity levels and different air pressure regimes than those maintained in the past. The combination of colder temperatures, longer drying time, increased relative humidity levels and different air pressure regimes can adversely affect the integrity and durability of the building envelope. To minimize the risks related to increasing the thermal resistance from the inside, it is recommended to follow several basic guidelines that aim at controlling exterior and interior humidity sources.

**i) Minimize rain penetration into the wall assembly:**

Rain penetration is a large potential source of water ingress within a wall assembly and is often reflective of the quality and condition of the masonry units and mortar joints. The addition of insulation must be combined with a detailed inspection and repairs of the exterior face of the masonry and mortar joints in order to minimize water intrusion.

**ii) Minimize penetration of indoor humidity into the wall assembly through water vapour diffusion:**

In order to prevent humidity transfer through diffusion, it is necessary to include a continuous vapour barrier within the wall assembly. The vapour drive and location and rate of condensation within a wall assembly depends on several factors, including the type of wall materials used and their order of installation, as well as the temperature and relative humidity conditions maintained inside the building during the heating season.

**iii) Minimize penetration of rain water and indoor humidity into the wall assembly through air infiltration and exfiltration:**

The assembly must include a continuous air barrier system across its entire surface to minimize humidity transfer into the wall system due to exfiltration of indoor air. The air barrier also contributes in minimizing the air pressure differential across the masonry wall assembly and reducing rain water penetration induced by air infiltration. Reduced air leakage also increases the level of occupant comfort and energy efficiency.

**iv) Minimize the temperature drop within the wall assembly:**

In considering occupant comfort and energy efficiency, it is often deemed necessary to increase the thermal resistance of the existing exterior walls. However, increasing the thermal resistance along the interior surface of solid masonry walls will also restrict indoor heat from warming the masonry wall during the winter season. As a result, the existing masonry will be subjected to greater cold temperatures than in its' past, increasing the potential for condensation and frost formation within the solid masonry wall. A balance must therefore be reached between objectives of durability and of thermal performance and comfort.

**v) Minimize the air pressure differential across the exterior wall assembly:**

It is the air pressure differential across the building envelope that is the driving force for exfiltration of warm, moist indoor air through the wall assembly (positive pressure in the building) and for rain penetration (negative pressure in the building). The air pressure differential across the exterior walls of a building is the result of stack effect, wind loads and the operation of the mechanical systems. Mechanical systems should ideally be balanced so that a relatively neutral air pressure exists across the building envelope.

## **RECOMMENDATIONS FOR INSULATING SOLID MASONRY WALLS**

Because of the potential risks with regards to the durability of the masonry, the question of whether the addition of insulation will significantly improve energy efficiency and occupant comfort needs to be addressed. For example, in the case of facades with a high window area over wall area ratio, increasing the thermal resistance of the wall may not provide a significant impact important enough to justify the addition of insulation on the opaque wall areas. It should be taken into account that air leakage is a significant source of heat loss and also one of the main sources of complaints of occupant discomfort. In the case of older buildings, because of their advanced age and construction, significant air leakage across the walls is to be expected. An emphasis should therefore be directed towards including a continuous and effective air barrier system including continuity at other wall component interfaces.

The addition of insulation must take into consideration occupant comfort and energy efficiency without drastically changing the temperature gradient within the wall assembly. When considering the choice of added insulating material, sprayed polyurethane foam with good air barrier characteristics provides several advantages, such as: (1) excellent air tightness characteristics, (2) continuity at junctions with walls, ceilings, floor and window perimeter, (3) applicability over irregular surfaces and (4) good control of total thickness. The polyurethane foam acts as the main air barrier material of the wall assembly with transition membranes installed at critical locations, such as around window perimeters. Continuity at floor joists, floor slabs and adjacent components is extremely important to avoid flow of indoor air at these

locations. It is important to note that discontinuities in the air barrier assembly will result in air exfiltration, which can particularly carry significant amounts of indoor moisture into the wall assembly.

Although polyurethane foam provides some vapour barrier characteristics, vapour permeance depends on the thickness of the insulation and the substrate to which it is applied. The addition of a liquid vapour barrier coating applied directly on the interior face of the sprayed insulation will provide a continuous high-performance vapour barrier to the wall assembly. Although important, if an effective and continuous air barrier is provided, the main moisture transfer mode is addressed and vapour permeance is not as critical.

Liquid vapour barriers are available from various manufacturers and certain types have been tested to ensure compatibility with different types of polyurethane foam. Using a compatible liquid vapour barrier coating applied directly on the polyurethane foam insulation has the following advantages when compared to a sheet vapour barrier system: (1) continuity at junctions (ceilings, floors, window perimeters, etc.) is easy to achieve without interfering with services within the finished wall assembly and (2) the coating, which is applied directly on the insulation, is protected from punctures during construction or by occupants.

The following general recommendations are suggested when adding polyurethane foam insulation over existing solid masonry walls.

- i) Repair all holes in the interior surface and consolidate loose masonry to ensure a sound substrate for the application of the foam insulation. Remove all loose materials (mortar, plaster parging) and clean all surfaces to ensure that the insulation will adhere adequately to the substrate;



- ii) The air barrier and insulation (sprayed polyurethane foam) should be continuous at the floor joists, floor slabs and adjacent components, including window interface, to ensure continuity of the air barrier and insulation system.



- iii) Transition membranes are recommended at critical locations, such as around window perimeters.
- iv) The National Building Code stipulates specific requirements with regards to fire stops in wall assemblies. It is important that these requirements be verified with your building code professional.
- v) Indoor relative humidity levels and building pressurization should be controlled to minimize vapour pressure gradients (and moisture migration) across wall assemblies.

## CASE STUDY EXAMPLE

This 11-storey building, known as Lofts St-James, was built in 1927 clustered among similar buildings within the fur garment district in downtown Montreal. The abandoned commercial building was recently converted into 120 upscale condominium units varying in living space from 650 ft<sup>2</sup> to 2,000 ft<sup>2</sup>.

The building includes a total living space of approximately 150,000 ft<sup>2</sup> and is partially adjoined to neighbouring buildings along its east and south elevations. The original brick and stone masonry of the building facades is supported by reinforced concrete columns and slabs. The original windows were steel framed and single glazed. Although the building structure was determined to be generally sound, the building envelope, including the exterior wall cladding, fenestration and roofing varied from minor to severely deteriorated due to many years of neglect.

The restoration work commenced with the complete demolition and removal of all interior non-structural elements including all interior walls, windows, doors, and all other architectural finishes. The entire electrical and mechanical systems were also completely removed.

The restoration work included major repairs and retrofit to the building envelope, including the exterior masonry, replacement of the existing windows as well as replacement of all the existing roofing systems.



*Figure 1: The building prior to renovation*



*Figure 2: Interior view prior to renovations*

One of the key technical challenges in the project was to provide a building envelope and living space which could ensure and accommodate the comfort and energy efficiency requirements for upscale residential occupancy. The presence of the existing uninsulated solid masonry walls of the building presented a serious challenge in terms of determining a plan of action to increase the insulative and air-tight properties of the exterior walls, without affecting the long term durability and aesthetics of the vertical building envelope.

To minimize the risks related to increasing the thermal resistance of the exterior walls from the inside, a two-part strategy was developed which involved corrective work to both the interior and exterior surfaces of the exterior walls.



**Figure 3: Original wall composition**

The repairs commenced with the restoration of the exterior masonry walls, which required extensive repointing of the mortar joints and stone repairs. The main purpose for this outside intervention was to reduce the scope of water penetration into the solid masonry wall assembly from the exterior. The water tightness of the exterior wall assemblies was considered essential in ensuring that the solid masonry walls would not be subjected to increased risk of freeze-thaw damage, which could arise following the addition of new interior insulation.

The second phase of the work included the application of one inch of polyurethane foam insulation along the entire interior surface of the exterior walls. Sprayed polyurethane foam was used as the main air barrier and insulation material of the wall assembly.

The original and renovated wall compositions are illustrated in the figures below, with a table summarizing hygrothermal analysis results for the original wall composition as well as the renovated wall composition, with and without the addition of a vapour barrier.



**Figure 4: Application of polyurethane foam insulation**

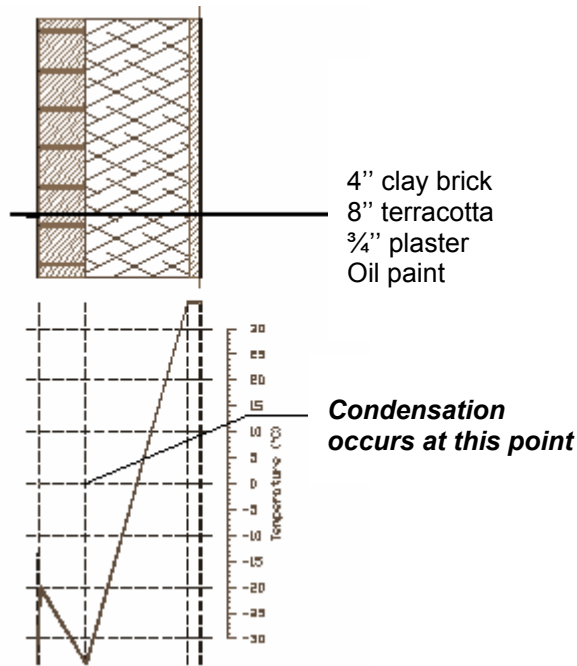


Figure 5: Original wall composition

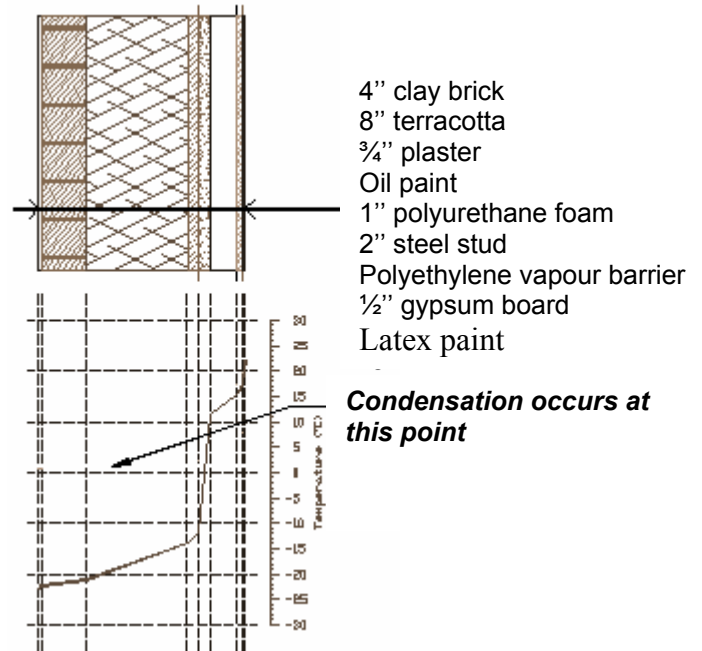


Figure 6: Renovated wall composition

Wall Composition	Insulation	Vapour Barrier	R-Value	Condensation (tea spoon/winter/m <sup>2</sup> )	Dew Point Temp.	Condensation Plane
Original Wall	None	None	3.9	20	11 °C	Brick / terracotta interface
Renovated Wall with no vapour barrier	1" Polyurethane	None	11.5	70	-1 °C	Exterior face of polyurethane
Renovated wall with vapour barrier	1" Polyurethane	Polyethylene	11.5	2	-19 °C	2/3 outside of terracotta

Figure 7: Summary of hygrothermal analysis

Particular care was taken to ensure continuity of the air-barrier assembly at the wall-window interface. A wood sub-frame was assembled around the window rough openings and covered with a self-adhesive bituminous membrane. The wood sub-frames were installed prior to application of the polyurethane foam insulation in order to ensure continuity of the air barrier assembly and insulation between the wall and window sub-frame interface.



Figure 8: Window frames prepared for installation

## **CURRENT RESEARCH WORK**

Work is currently in progress to create a knowledge base to help practitioners avoid specific problems associated with insulating solid masonry walls and allow them to elaborate a retrofit strategy with an increased level of confidence. This will be achieved by investigating and analyzing the condition of previously renovated buildings with solid masonry walls. The main objective of this study is to establish relationships between the initial composition of the wall, the retrofit approach and the condition of the building envelope after having been exposed to particular indoor and outdoor loads for a given period of time. This study is currently being undertaken by Patenaude-JBK Inc. with financing from The Canada Mortgage and Housing Corporation, through its 2001 External Research Program. The study entitled “Performance Evaluation of Retrofitted Solid Masonry Exterior Walls” is expected to be published in late 2003.

The project will be conducted in four stages: (1) identification and elaboration of a list of buildings having various types of solid masonry walls (including materials such as stone, terra cotta blocks or clay bricks) that have already been retrofitted using different approaches (such as no added insulation, with batt insulation, sprayed foam insulation, etc), (2) classification of the buildings according to their building envelope characteristics (composition of exterior walls, nature of retrofit approach, etc.), (3) evaluation of the general condition of their solid masonry walls (performed in a manner to ensure comparability of the results) and (4) analysis of the collected data, including hygrothermal analysis of the exterior wall assemblies to calculate the potential amount of condensation from diffusion under specified conditions, temperature gradient, dew point, etc., before and after renovation. A photographic record will also be taken for each building to have a visual documentation of the condition of the exterior walls. This record may prove useful in follow up studies to track the evolution of the condition of the building envelope over time.

The Institute for Research in Construction (National Research Council Canada) has also launched a research program that involves the long-term monitoring of the exterior walls of some renovated buildings: “Research consortium for the rehabilitation of masonry walls with little or no insulation”. Under this project, temperature and moisture content levels in the solid masonry exterior walls of rehabilitated buildings have been or are being monitored to understand how they perform in practice. The project looks at four buildings, in Winnipeg and Ottawa: the Customs Examining Warehouse, the Peace Tower, Laurier House and Building M-20 of the National Research Council. The retrofit strategies for these buildings are foil-faced insulation, no added insulation and insulation added on the cold side. The IRC research program is expected to yield very useful information that will significantly improve the understanding of the behaviour over time of solid masonry walls exposed to outdoor weather and controlled indoor conditions.

## ACKNOWLEDGEMENTS

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