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WIND COOLING OF STRUCTURES

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Wind Cooling Of Wood Frame Buildings

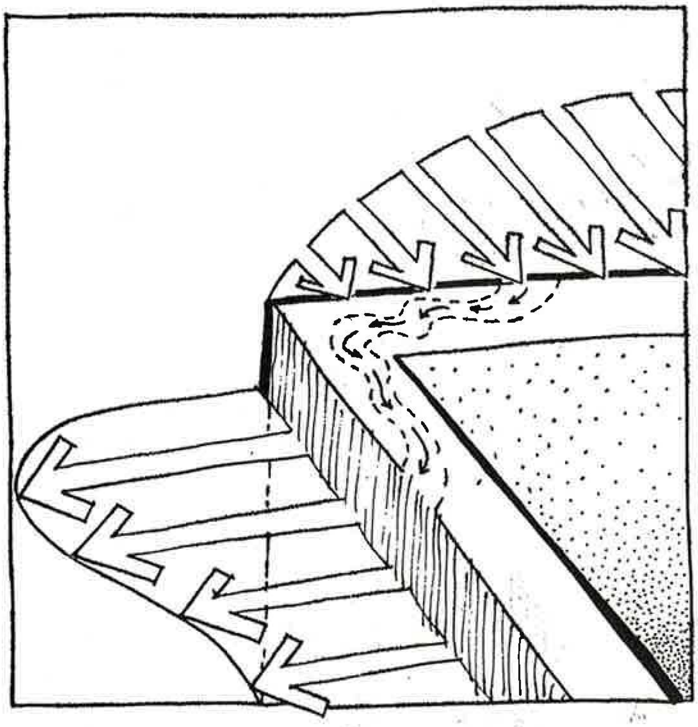
Changes in building materials and construction methods since 1945 have, in some cases, created air quality and moisture problems. Even before the 1973 oil embargo houses were becoming too tight for natural ventilation to control indoor moisture and pollutants. The problem in leaky cold-climate houses was lack of moisture, but the reverse became the issue when building envelopes became too tight. Better fitting doors and windows, polyethylene vapour retarders, low permeability siding and sheathing material and taped gypsum board all contributed to the problem.

Perhaps the most important culprit was flueless heating. In the traditional house heated with a fuel furnace, the chimney acted as a powerful exhaust fan, removing spent air and moisture. However, in electrically heated houses 'natural ventilation' had to be relied on. This kind of ventilation, unless controlled manually by the home owner through the appropriate opening and closing of windows, is essentially ventilation driven by the weather; too much during cold and windy weather, too little when warm and calm.

Thus it is not surprising that air quality and moisture problems appeared in housing, often in social housing where there seems to be an incompatibility between the building's design and operation. Such moisture problems are not exclusive to cold-climate regions, nor peculiar to wood frame housing. If anything, moisture problems are more serious in the thermally massive houses of moderate climates than in the wood frame houses of northern regions.

A Canada-wide study of moisture problems in housing produced some interesting observations. Although moisture problems were found to occur, they were generally considered superficial, falling into the 'less than adequate serviceability' category. Not a single incident was encountered where decay of timber could have resulted in structural collapse. One of the most common problems was mould and mildew on interior surfaces of exterior corners. Where exterior walls came together, or where an exterior wall met an insulated ceiling, surface temperatures were low enough to create moisture conditions generating mould and mildew growth.

A number of factors are responsible for the lowered surface temperature in such locations. Framing techniques concentrate studs and wall plates in corners creating thermal bridging. Heat flow in corners is two-dimensional, so the thermal bridge affectively is large. A reduction of radiation received from the interior of the room also contributes to added heat loss. In the soffit area, space is not always adequate to accommodate the desired thickness of insulation.



Cold air pushed by wind pressure can flow right through porous insulation and out the leeward side, this cooling the wall.

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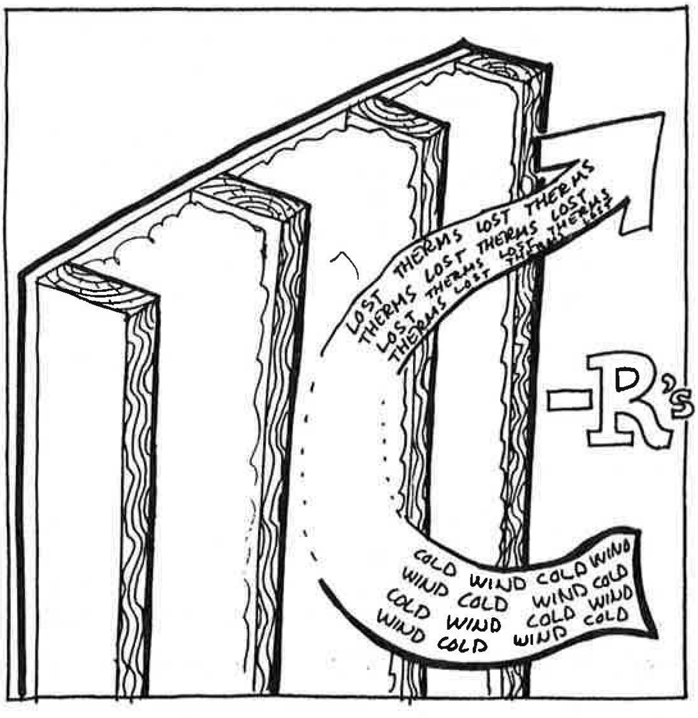
However, simple calculations suggest that these factors are not enough to explain the mould and mildew growth that is often observed. Defects in the sheathing and siding permit wind to blow in and out of the wall cavities without actually penetrating the wall itself. The rapid change from positive to negative wind pressure at an outside corner results in cold outside air taking a short cut through the wall. For this to happen, there must exist continuous air passages into the wall through the siding and sheathing, around the corner within the wall and out again through the siding-sheathing. These continuous air passages are due to the careless installation of sheathing, to the air permeability of glass fibre insulation and to spaces between studs and gypsum board caused by shrinkage.

Similarly, air pressure under the windward soffit can cause wind to blow through the exposed face of attic insulation. Unfilled corners between the ceiling gypsum board and the attic joists present passages with little resistance to wind. In some instances air velocities into the attic have been high enough to scour away unprotected loose fill insulation. Wind-driven snow can also blow into the attic through the soffit vents.



These phenomena are due to deficiencies in the wind protection provided for the insulation (allowing forced convection to cool the weather-side of the gypsum wall board to near-outside temperatures) and on the other hand, to indoor relative humidities high enough to lead to surface condensation and mould growth.

Forced convection through parts of the thermal envelope will also result in an increase in heat loss. The lack of mould and mildew in corners does not necessarily mean that wind cooling of walls is not taking place. It could be that the indoor relative humidity is too low to cause corner condensation.

Investigations dealing with moisture problems in wood frame houses suggest that wind cooling of walls can be reduced by moving the air barrier from its traditional location on the room-side of the insulation to the weather side. On the outside it would perform two functions: reduce air leakage through the walls and control wind cooling. Such an air barrier would, however, have to be sufficiently vapour permeable to avoid trapping condensed moisture in the wall construction.

LAB TESTS

A laboratory investigation of wind cooling of walls and suggested remedial measures was undertaken with funding made available by the Imperial Oil Limited University Research Grant Program. A full scale wood-frame wall corner unit was constructed in the laboratory. The header joist and the ceiling were insulated, and a baffle was provided to protect the exposed edge of the attic insulation. The soffit was equipped with a conventional vent running the full length.

In addition to creating "unintentional" air leakage paths through the sheathing and within the walls, gaps between the studs and polyethylene air barrier/vapour retarder were formed by means of thin shims. This simulated gaps formed by twisting or shrinkage of studs. Continuous air passages into the wall from the windward face, along the wall cavity and out again through the wall face exposed to wind suction were thus created. Tests were

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conducted for various combinations of sheathing gap openings and pressure gradients. Gaps in the sheathing were taped when tight construction was to be simulated.

Temperatures on the weather side of the walls, within the wall construction, and on the room-side surfaces were continually monitored.

The results showed surface cooling due to thermal bridges, two-dimensional heat flow at the corner, reduced convective and radiant heat gain into the wall from the interior. Temperatures in the extreme corner are lowest; the thermal bridge effect of the studs also is clearly evident. Insulating sheathing would significantly reduce such thermal bridge effects.

Based on the measured temperatures, condensation would occur when indoor relative humidity reaches 65%. When wind cooling is superimposed, condensation at 40% relative humidity. This is clearly within the range of humidities encountered in poorly ventilated houses.

Tests also demonstrated that furniture placed in the corner, without actually touching the wall, significantly cooled the wall surface by reducing radiant heat gain from the room and by interfering with air flow.

DEMONSTRATION HOUSE

A house was built to demonstrate the practicality of locating the air barrier on the outside face of the wall insulation. The house construction is shown in Fig. A.

After the building was closed in, but before installation of the drywall, the house was tested for tightness. Using a standard blower door, the air leakage rate at 50 Pascals was 1.56 air changes per hour (ACH). Calculations indicated that of this 57% was through the Tyvek membrane, the remainder through the usual air leakage openings in the thermal envelope (doors, windows and taped joints between Tyvek sheets). This showed that a Tyvek membrane can be used as the air barrier to control air leakage through the building envelope. Indeed, only some 0.66 ACH would fall into the 'objectionable' category where relatively large leakage openings could lead to

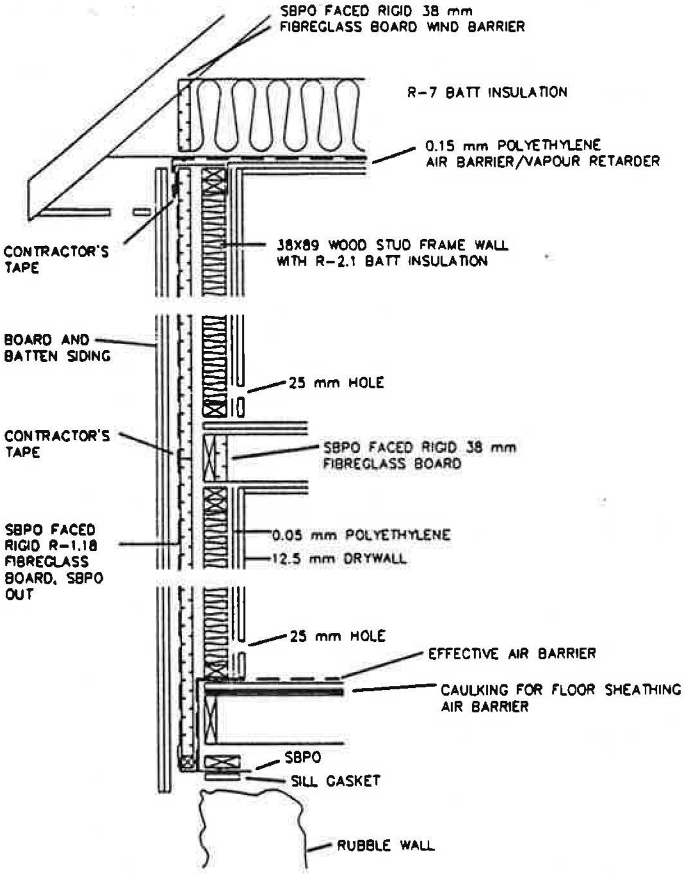

Fig. A

CROSS SECTION THROUGH THE THERMAL ENVELOPE OF THE TEST HOUSE.

cold drafts on infiltration or moisture damage on exfiltration.

When most of the gypsum board, electrical wiring and a wood stove had been installed, the air leakage rate (at 50 Pa) had decreased to 1.33 ACH reflecting the contribution of the gypsum wall board to air tightness. When 1" diameter holes were drilled through the gypsum board (one hole for roughly half the stud cavities in the house) the air leakage rate only increased to 1.51 ACH. The purpose of these holes is to admit ventilation air when the house is operated under a slight negative pressure. The ability of such walls to recover part of the heat otherwise transmitted through the wall as well as to capture solar energy to prewarm the incoming ventilation air has been described, elsewhere (this is the **dynamic wall**, described in SOLPLAN REVIEW No.14. April-May 1987).

There are several arguments in favour of achieving the air tightness by locating the air barrier on the weatherside of the insulation. The air barrier is not penetrated by partition walls, electrical outlets or joist assemblies. Installation, inspection and, if necessary, remedial action can be carried out easily.

The effectiveness of the Tyvek as a wind barrier was observed in tests which measured the temperature of the inside wall surface of the windward corner. The interior surface was, as expected, warmer due to the insulating sheathing which reduces thermal bridging and the Tyvek air/wind barrier which prevents cold air from taking a short-cut through the wall from one wall face to the other.

While these readings were being taken the house was under a negative pressure strong enough to draw in ventilation air through the Tyvek and the wall.

In the design and construction of the soffit care was taken to prevent cold air from blowing into the exposed edge of the attic insulation by installing tight-fitting Tyvek covered pieces of insulating sheathing between the roof trusses. Entry of wind-driven snow into the attic was controlled by leaving a narrow gap between the top of the sheathing baffle and the roof sheathing. By making this gap narrower than the soffit vent opening, the velocity of the air through the soffit vent was reduced. Were any snow carried through the soffit vent, it would be deposited in the relatively large soffit box.

SUMMARY

Deficiencies in the sheathing can cool the exterior walls, especially at exterior corners. The cooling increases heat loss, and where there are high humidities, leads to mould growth on wall surfaces. Moving the air barrier from its customary location on the warm side of the insulation to the cold side where it is easier to make continuous, improves the performance of the wall.

This article is based on a paper presented at the 6th Annual International Energy Efficient Building Conference, April 27-29, 1988 in Portland, Maine.

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AIRTIGHT CONSTRUCTION

The following item was written by J.C. Currie, the retiring Director of the B.C. Building Standards Branch. (The agency responsible for the Building Code in British Columbia).

This item was widely circulated by the B.C. Building Standards Branch, as a rationalization for moving backwards on changes to the building code. It represents widely held opinions in the building community. The question is, how far should codes and regulations go to ensure health, safety and comfort for residents?

We welcome reader comments on this issue.

Traditional wood-frame construction uses lumber in a way favorable to a long life. Wall studs, whether green or dry when used, dried to an acceptable moisture level in service through the permeability of wall construction, which allowed the ready passage of water vapour to the exterior. The shiplap sheathing plus a permeable cladding contributed to a "breathing" system.

Over the years various components have been "improved" through the development of new materials, and new philosophies have changed components to improve individual performances in response to perceived needs. With these changes it seems that sight has been lost of the basic fundamentals which ensured the longevity of wood-