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by M.K. Kumaran and J.C. Haysom

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To reduce the probability of incorrect placement, the 1990 NBC included a restriction on the location of low-permeance air barriers. These air barriers had to be placed so that the inner surface remained above the dew point of the interior air when the outside temperature was 10^{o}C above the January 2½% temperature. This restriction, however, prohibited the use of certain insulating sheathings that had long been used without problems on the outside face of wood stud walls. Manufacturers argued that the restriction was unnecessary and asked that it be removed in the 1995 NBC. Concerns were also raised about the potential for condensation on low-permeance materials placed towards the outside even if they weren't designated as the air barrier.

IRC Study Solves Problem

In a landmark study, researchers at IRC studied the problem using an advanced computer model developed with colleagues at the Technical Research Centre (VTT) in Finland. Unlike previous models, this model is not a steady-state model but dynamically and iteratively treats the inter-relationships of heat transfer, air movement, moisture diffusion and air-borne moisture transport using real weather data for typical years for a number of locations. It can be used to study the effect of changing a building envelope assembly or the properties of its components on the accumulation of moisture within the assembly.

The first part of the study involved a wall consisting of 38 x 89-mm studs, batt insulation in the stud cavity, and a Type II vapour barrier. The interior temperature was 21^{o}C and the interior relative humidity (RH) was 36% and 48%. The exterior temperature and RH were -15^{o}C and 60%. The air leakage rate of the assembly varied between 0.001 L/(m^{2}·s) and 10 L/(m^{2}·s) at 75 Pa pressure difference between the interior and exterior.

The modelling showed that the rate of heat flow per unit area through the wall increased as the air flow rate increased. The moisture accumulation also increased but only to a certain point; beyond that point it decreased and then became insignificant. The reason for the decrease is that the temperature within the cavity increased as the rate of air flow increased. At a certain point, the cavity became so warm that the conditions required for condensation ceased to exist.

The researchers then did simulations with an added 25-mm-thick mineral-fibreboard sheathing on the outside of the studs. The simulations confirmed that the cavity in this case was warm enough to prevent condensation on the interior face.

To determine the effect of air leakage and of exterior insulation on the performance of a wall, the researchers then varied such design parameters as air leakage rate, vapour permeance, and interior RH. The studs used were 38 x 140 mm, and the insulation batts were rated at RSI 3.52. One wall also had an external insulating sheathing with RSI 0.75.

The simulations analyzed the moisture and thermal behaviour of the cavity for one full year on an hourly basis using weather data for the City of Ottawa. Figure 1 shows the moisture accumulation within the cavity for three of these walls, which are described below the figure.

Figure 1. Annual moisture accumulation within the cavity (the moisture index is the daily average on a relative scale).

Curve B0 gives moisture accumulation due to diffusion only.
Curve B2 gives moisture accumulation due to diffusion and air leakage.
Curve B2R shows the beneficial effect of the exterior insulating sheathing on moisture accumulation since moisture diffusion and air leakage were the same as for B2. The moisture accumulation in B2R was less than in B0.

Wall B0 – Type II vapour barrier, zero air permeance (no air leakage), interior RH 36%.
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These results show that condensation was less likely to occur in the wall with low-permeance insulation on the outside than in the other walls studied. The simulation determined that the ratio of outboard to inboard thermal resistance used (0.75/3.52 = 0.214) was adequate to control condensation for an interior RH of 36%, in the Ottawa area. Simulations for other Canadian cities showed that the required ratio is proportional to the degree-days. Thus the colder the location, the more external insulation required to maintain the necessary temperature in the cavity to control moisture accumulation.

As a result of this study, Table 1was incorporated into Part 9 of the 1995 NBC (as Table 9.25.1.2.

Table 1. Ratio of outboard to inboard thermal resistance for increments of 1000 degree-days

Heating degree days of building location, Celsius degree-days	Minimum ratio, total thermal resistance outboard of material's inner surface to total thermal resistance inboard of material's inner surface
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12000 or higher	0.75

Using Low-Permeance Exterior Insulation

Where a low-permeance material is used in a wall, the ratio of outboard to inboard thermal resistance must equal or exceed that needed to control condensation.

The thermal resistance of a wall is the total of the resistance of all the materials that make up the wall, such as insulation, sheathings, finishes, air spaces and air films. The inboard thermal resistance is the sum of the thermal resistance of all the materials on the warm side of the low-permeance insulation. To calculate the minimum thermal resistance of the outboard insulation, first the inboard thermal resistance is multiplied by the ratio from Table 1 that applies to the climatic conditions. This result represents the total thermal resistance for all outboard elements including exterior insulation, exterior finish material and air film. Adding up the thermal resistance for all other outboard elements and subtracting this subtotal from the total outboard thermal resistance gives the minimum thermal resistance of the exterior insulation.

More details on this subject are contained in Construction Technology Update No. 41, available from IRC.

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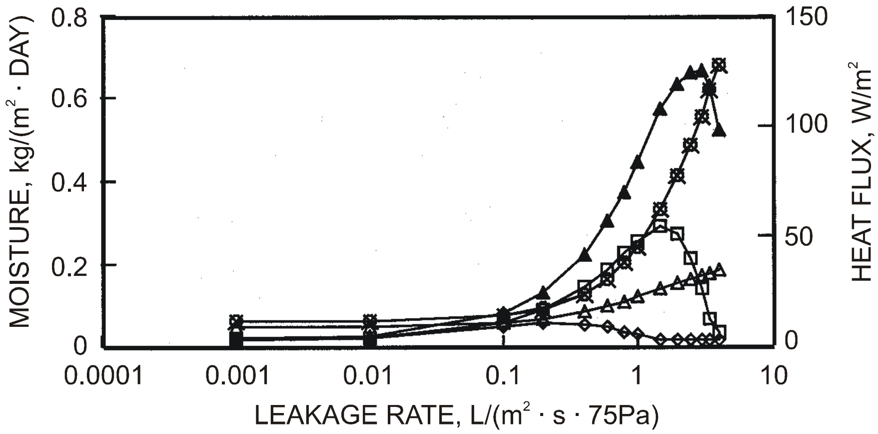

Figure 3. The effect of the additional thermal resistance provided by the exterior sheathing

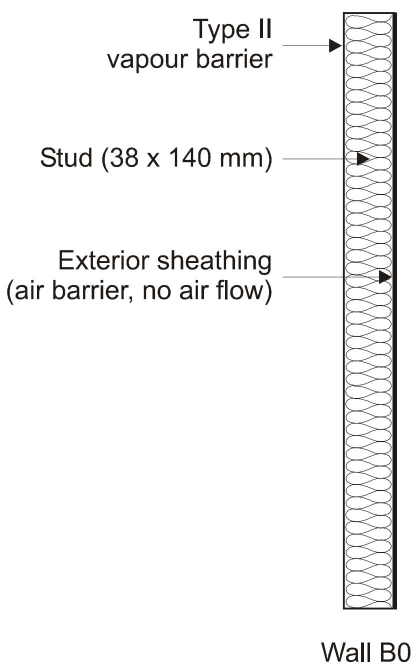

Figure 4. Wall B0

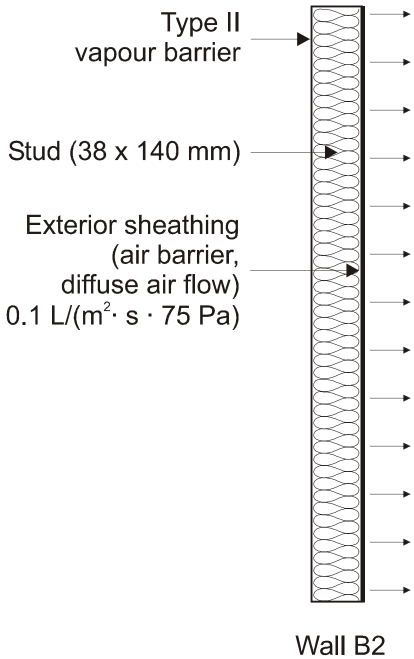

Figure 5. Wall B2

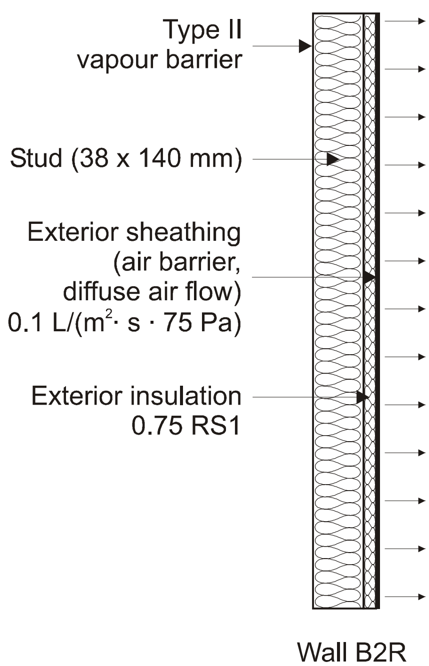

Figure 6. Wall B2R

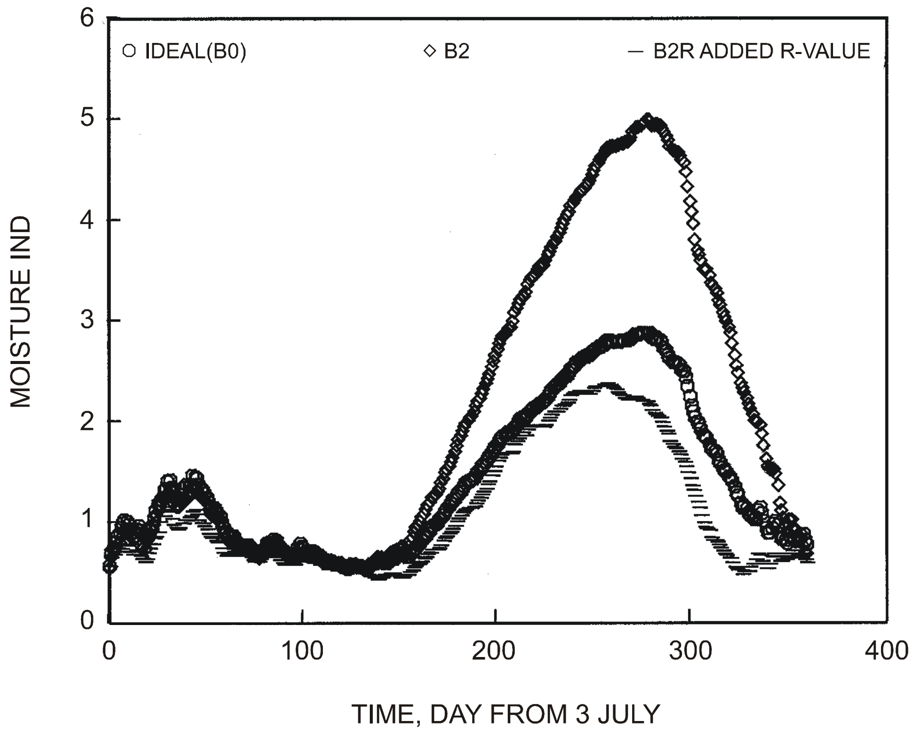

Figure 7. Annual moisture accumulation within the cavity. The moisture index is the daily average on a relative scale.

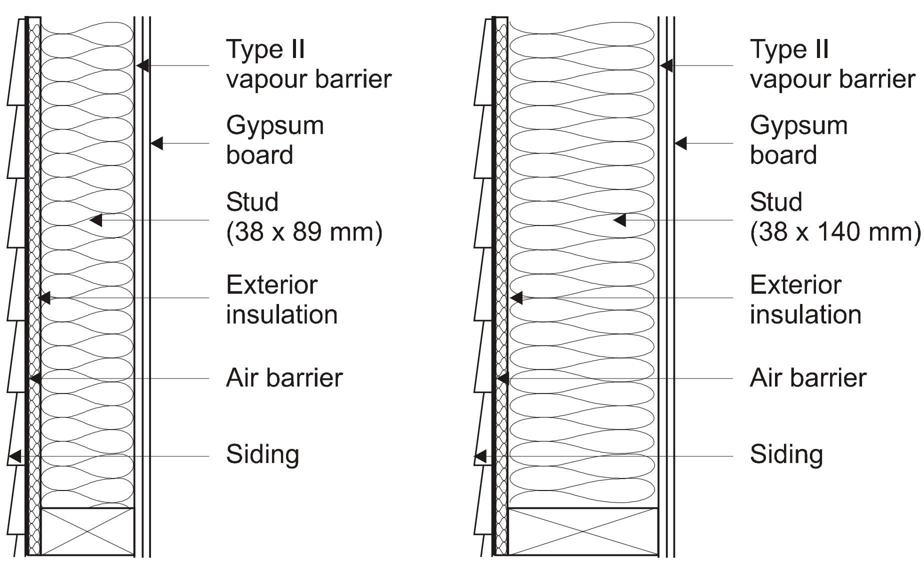

Figure 8. Calculation of outboard thermal resistance for wall in the Winnipeg area. Minimum ratio of outboard to inboard thermal resistance is 0.3.

Table 1. Ratio of outboard to inboard thermal resistance (from 1995 NBC, Table 9.25.1.2)

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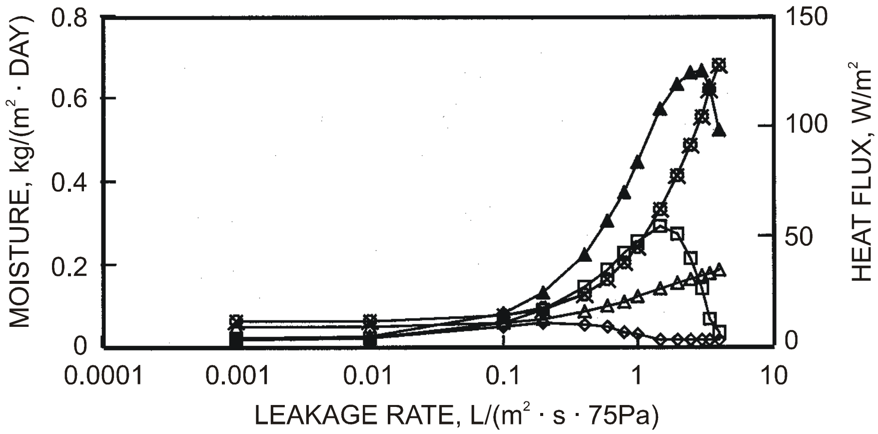

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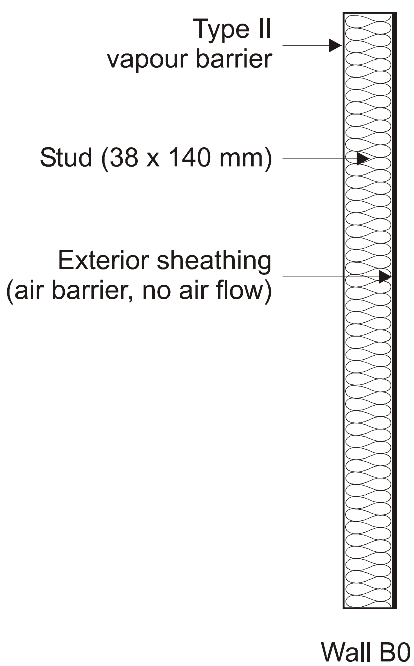

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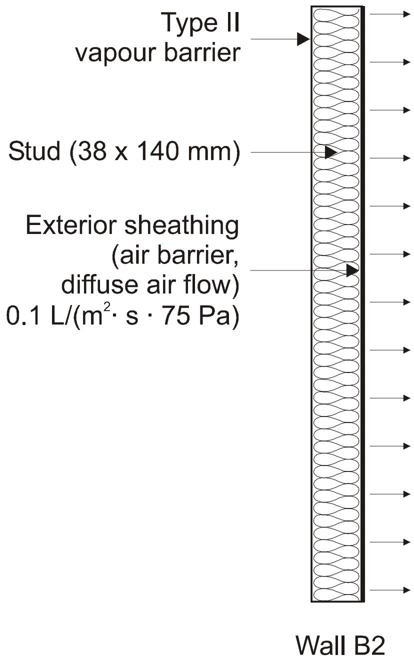

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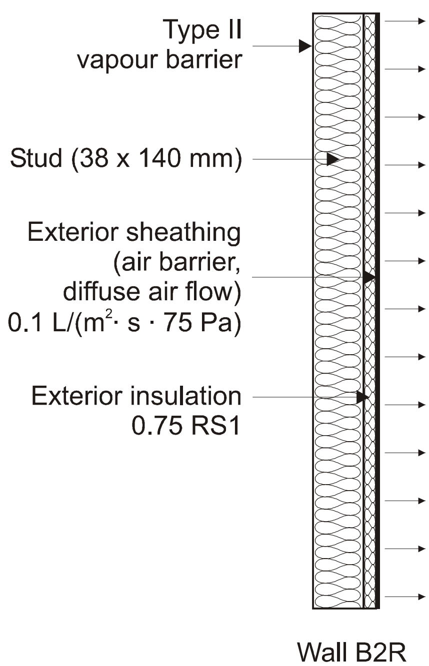
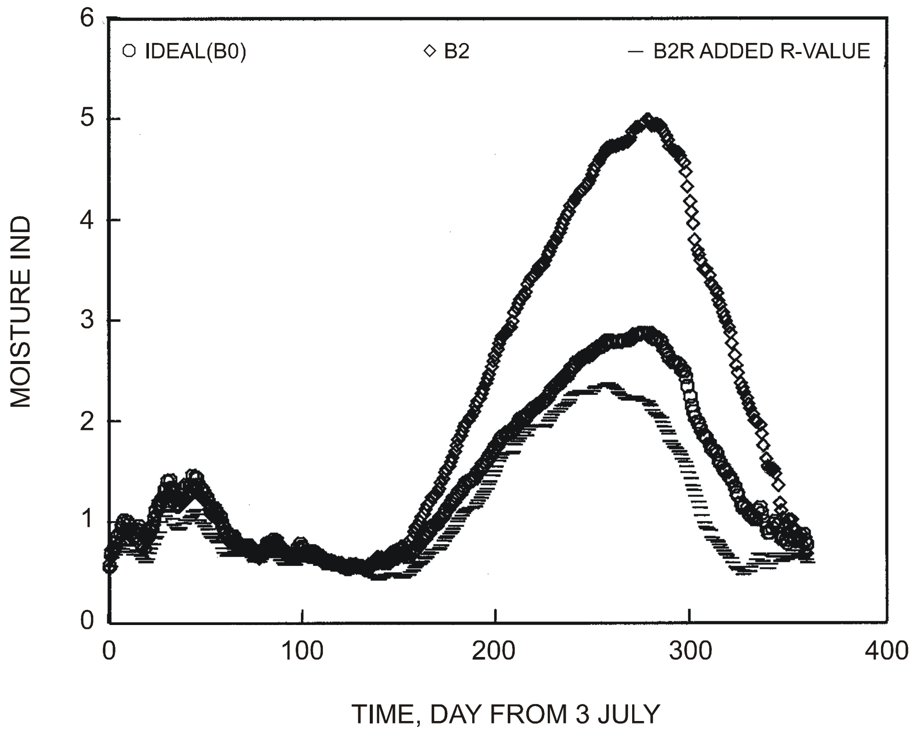


Figure 6. Wall B2R



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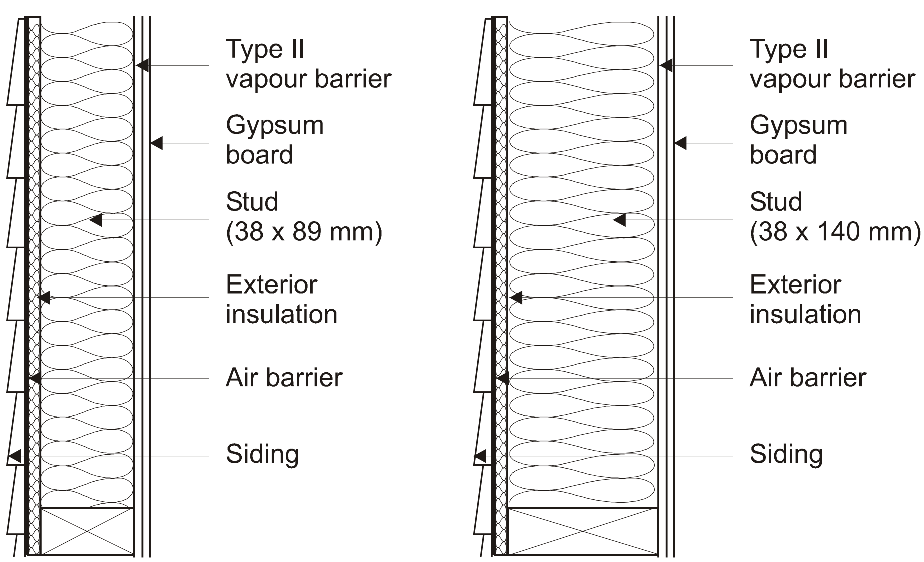

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