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Vapour Barriers: What are they? Are they Effective?

Originally published March 1976.

J.K. Latta

Please note

For many years considerable stress has been placed upon the need to control the movement of water vapour into the enclosing walls and roofs of buildings. It is generally advocated as a design principle that the entry of water vapour from the warm side (interior) should be restricted and freedom for it to escape on the cold side (exterior) facilitated. In an endeavour to meet this sound principle it is frequently specified that a vapour barrier should be installed on the warm side of the insulation, but unfortunately merely to do so is no guarantee of success if other aspects of the construction are neglected. Moreover, there appears to be some confusion as to what a vapour barrier actually does and what, in consequence, its limitations are. An effort will be made in this Digest to clarify the situation and to compare the relative importance and ease of controlling entry of water into a wall by diffusion and air currents.

It is difficult to find a clear definition of a vapour barrier in the technical literature. One reads as follows:

> *"A moisture-impervious layer applied to the surface enclosing a humid space to prevent moisture travel to a point where it may condense due to lower temperature."*

This is an all-embracing definition that refers to "moisture travel," not moisture diffusion. It becomes clear in the text, however. that only moisture movement by diffusion is being considered. Other authorities either explicitly or by inference define a vapour barrier with respect to its resistance to the passage of water vapour by diffusion. A Canadian Government standard limits the permeance of a Type I vapour barrier to 0.25 perm and of a Type II vapour barrier to 0.75 perm before aging and 1.0 perm after aging.

It would be more precise to define a vapour barrier as a vapour impermeable layer that resists the diffusion of water vapour under the action of a difference in vapour pressure. By defining it with reference to its resistance to the diffusion of water vapour it has been implied that diffusion is the prime cause of condensation problems. It is probably more accurate to say that vapour diffusion by itself never initiates a problem.

Air leakage is now considered to be the prime cause of most condensation problems in walls and roof spaces. If, therefore, a building can be made tight against air leakage it may not need a vapour barrier, as defined. On the other hand, if there are openings that permit air to leak from the warm side to the cold side of the insulation, adding a vapour barrier (even of zero permeance) that does not seal off the openings will be useless. In order to assess the effects of various features of design or construction on the movement of water vapour it is useful to compare the relative amounts of water that should be deposited in a wall or roof by vapour diffusion on the one hand and a current of air on the other. Such comparisons are difficult to make because two essentially different processes are being considered. A wide variety of conditions affect each process and it is not possible to say that any given air leak is the equivalent of a specific condition for diffusion. A typical situation will be presented.

Consider the case of an infill masonry wall insulated on the inside, as shown in Figure 1, and consisting of 4 in. of face brick, a 1 ½-in. air space, 8 in. of concrete block, 1 ½ in. of glass fibre insulation and ½-in. gypsum board interior finish. No vapour barrier of any sort has been incorporated in this wall; and if the gypsum board is assumed to painted with two coats of latex paint even this cannot be considered to be one. The component with the highest resistance to vapour diffusion is the face brick which is listed in the American Society for Heating, Refrigerating and Air-Conditioning Engineers Handbook of Fundamentals as having a permeance of 0.8 perm. Other sources give it a permeance of 2 perms, however, and in view of the probable leakage characteristics of face brick with weep holes at each shelf angle this higher value has been adopted for purposes of calculation.

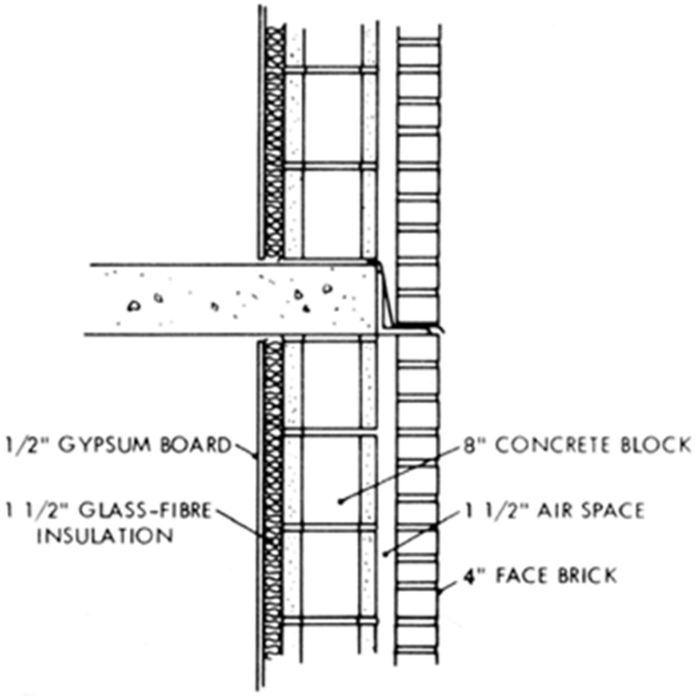

Figure 1. Vertical section through wall.

In a wall of this type it is not unusual for a crack to develop between the blockwork and floor slab above and the blockwork and columns as the blocks dry out and shrink. With insulation on the inside, these cracks open further by thermal contraction in cold weather. Thus, it is not unreasonable to anticipate a crack of 1/16 in. in width on three sides of each panel of blockwork. As the air leakage characteristics of actual walls are not readily available, the leakage through this 1/16-in. crack can be compared to that for a double-hung window of average fit, also reported to have a crack width of 1/16-in.

If it is assumed that internal conditions are 73°F and 35 per cent RH and those outside are 0°F and 80 per cent RH, the rate of movement of water vapour by diffusion can be calculated. In addition, if the building is assumed to be 10 stories (or 1000 ft) high with a neutral zone at mid-height, the pressure difference through the wall at the top due to stack effect can be calculated as 0.113 in. H_2.

With all these assumptions it can be calculated that condensation as a result of vapour diffusion will take place on both the inside face of the concrete block and the back of the brickwork. The rates of accumulation of water from this process will be 1.04 grains sq ft hr on the block and 0.12 grain sq ft hr on the brickwork. A further small amount (0.07 grain hr) will diffuse through each foot length of crack. With the 10-ft storey height the total rate of accumulation of water by diffusion in each foot length of wall will be 10.4 grains hr on the blockwork and 1.2 + 0.07 = 1.27 grains hr on the brickwork.

For comparison 84 grains of water per hour will be swept through each foot length of crack as a result of air leakage. Not all of this will condense because at least the quantity of water contained in saturated air at the outside temperature of 0°F will pass to the outside. Even so, there is a potential for condensation of 73 grains/hr for each foot length of wall, neglecting the cracks at the columns. What the actual rate of condensation might be is virtually impossible to predict. Air that passes quickly through the wall following a short and direct path may not be cooled to below the dew-point until it mingles with and is diluted by the outside air. On the other hand, air that follows a longer path on the cold side of the insulation as in the present case where it flows down the air space to escape at the weep holes, may deposit the full amount of water possible on the back of a cold cladding.

Thus there is the probability that, in each foot length of this particular wall under the assumed conditions, six or seven times as much water can be deposited as a result of air leakage as by vapour diffusion, even through a wall with no vapour barrier in it. The addition of a vapour barrier with a permeance not greater than 0.25 perm on the warm side of the insulation would eliminate condensation (in this wall) as a result of vapour diffusion. The vapour barrier face on many insulations may be adequate. Merely providing a film of oil base paint having a permeance of one perm would eliminate condensation on the concrete block, although in this instance there would still be condensation on the brickwork. While the rate of vapour diffusion through small gaps in these vapour barriers will be greater than that through the barrier, such small gaps are not serious because the increase is quite small, as may be seen from the amount that was diffused through the crack at the top of the blockwork. Air leakage through these same gaps can, on the other hand, be most serious and is the raison d'être for this Digest. Furthermore, air leaks are much more difficult to prevent than is the diffusion of water vapour: many building materials are of themselves air permeable; the joints between building units are frequently incompletely filled, for example, mortar joints in masonry construction; and cracks may develop as a result of building movements.

Although vapour diffusion may not deposit as much water in a wall as does air leakage, it may still be necessary to control it, depending upon its effect on the wall or roof system. In the wall used in this example, if one assumes that conditions remain steady for one month, 1.09 lb or more than three-quarters of a pint of water would be deposited in the concrete block. This might at first appear to be serious, but with a block that has an absorptive capacity from dry to saturated of 10 lb/cu ft, and may already be at 40 per cent of saturation, the extra pound of water can readily be absorbed by the inner face shell alone, raising saturation to 50 per cent. This is hardly a serious matter, and it is probable that the presence of such a quantity of water would go undetected in this particular wall. It would, however, be unwise to assume that this will always be the case, and each wall or roof design should be examined separately. Wall components such as metal panels with little or no absorptivity could collect considerable quantities of water as hoar frost. This might be released all at one time with a change in weather conditions, leading to icicles on the outside or damaged floor coverings or wall finishes if the moisture were to run inward. Any water that passes a defective vapour barrier in a flat roof with a highly impermeable exterior membrane will be trapped between the two layers, leading to premature failure of the roof system. For this reason, amongst others, it is desirable to use the single protected membrane system on flat roofs.

In the process of examining and analysing building problems, many cases have been found in which moist air leaking outwards into a wall has been identified as a prime cause of trouble. So often is this the case that one initial line of investigation is to look for possible paths of air leakage. In very few instances has vapour diffusion been identified as a major factor. Water which enters between two layers having relatively high resistance to vapour diffusion may damage the construction if it does not dry out again. The double vapour barrier has in this case compounded a problem initiated by the defect that allowed the water to enter. It is important therefore to design walls and roofs which are "fail safe" in that any water which may enter is removed by drainage or ventilation. This is precisely the principle given in the opening paragraph of this Digest, a principle that applies just as much, if not more, to the movement of water vapour by air leakage as to the diffusion of water vapour through materials.

Summary

A particular wall subjected to particular conditions has been analysed in order to assess its ability to control the accumulation of harmful quantities of water resulting from vapour diffusion and migrating air currents. In the first instance it was deliberately made weak in its ability to resist vapour diffusion in that no vapour barrier was incorporated in it. Even so, it could be shown that vapour diffusion was unlikely to create a problem. The accumulation by this mechanism of any water within the wall could easily be stopped by the simple expedient of using several coats of a more impermeable paint. Such a vapour barrier would not have to be continuous since diffusion through small cracks would be negligible. Air leakage, on the other hand, would be a more serious problem and considerably more difficult to control.

Many walls are relatively porous and allow air to pass directly through them; others are initially air-tight but develop cracks as a result of shrinkages and deflections. Field investigations indicate that holes big enough to permit a hand to be passed through them have sometimes been left inadvertently in walls, either through faulty design or poor construction. Designers and builders must make every effort at all stages to avoid such errors and to anticipate and allow for wall movements by providing suitably caulked or gasketed joints. The control of air movement is probably the single most important factor in obtaining a problem-free building envelope.