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Current Research In Building Moisture Control

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INTRODUCTION

The control of condensation and moisture in buildings is an important practical issue, and traditional explanations of its causes have been found to be deficient. Evidence of the importance of air infiltration in the moisture control in building structures has been steadily accumulating. This paper outlines recent work by the Building Research Association of N.Z. on moisture control, with particular reference to practical and experimental studies.

BACKGROUND

Several years ago, a paper (1) at the NZIE annual conference on the Keiper method for moisture control design, demonstrated that in spite of the almost exclusive previous emphasis on vapour diffusion flow, even trace levels of ventilation in structural caviaties can have crucial effect on the moisture levels. A handful of other references (2,3) from Canada and U.S.A. have reached similar conclusions.

Recent theoretical work at BRANZ has offered a much more general model of the moisture behaviour in structures. This model includes for the effects of cavity air leakage, for the hygroscopic behaviour of timber, for the effects of condensation, and various geometric factors.

It indicates that structures will behave in one of 3 ways, as "loose", as "tight" or as intermediate structures, in respect of their moisture. Most N.Z. timber structures are "loose". Their initial drying rate is likely to be similar to the natural free air drying rate of the timber, and their subsequent behaviour will depend on the degree of condensation to which they are exposed, particularly by airborne or convective moisture supply. There are hopes that this work will lead to reatively simple engineering design tools which may account for several important factors taken as "too hard" at present - such as the influence of periodic condensation or stray moist air sources. Fig. 1 illustrates how ventilation even at trace levels can play a large or controlling part in the moisture behaviour.

Theoretical work such as above needs to be supported by a supply of reliable measured data on moisture properties and moisture behaviour. Before a formula can be used the value of relevant material properties must be available. Before a formula can be trusted its predictions must be shown to be compatible with observed real-life performance. For these reasons, a series of BRANZ projects have been undertaken, as outlined below.

SUMMARY OF CURRENT MOISTURE PROJECTS

a) Sorption Properties of N.Z. Building Materials

The sorption properties, or equilibrium moisture content curves, of a material express its ability to absorb water. They are usually expressed as a graph or table of the absorbed moisture content as a function of relative humidity. This information is needd wherever calculations involving moisture storage are done. For example, the humidity in a typical house skillion roof space can rise from say 70% to 80% only if the 2000 kg or so of timber rises from ...%m.c. to ...%, thus absorbing ... kg of water. The sorption properties of timber have been known for a long time, but it is often overlooked that other materials - plasterboard, insulating materials, building papers, masonry etc - also absorb water. This project aims to provide data on the absorption in these other materials.

As an example, Fig. 2 shows the sorption (or e.m.c.) curve for typical N.Z. macerated paper insulate. Notice how the dessicant behaviour of the ammonium sulphate fire retardant treatment increases absorption sharply above 75% humidity.

b) Combined Heat/moisture Transfer in Cavities

Engineers have been conditioned to regard the moisture transfer resistance across building cavities as being effectively zero, or at least unknown. It is common for the cavity moisture transfer resistance to be small compared with that of the whole structure, but that only has any relevance in steady state conditions. In normal conditions where temperatures are fluctuating, sometimes rapidly, moisture can evaporate from one place and condense in another quite independently of any general moisture flow through the structure. It therefore is necessary to be able to predict the moisture transfer rates in virtually all conditions, but the basic measurement of these rates has not yet been carried out.

Engineers will be familiar with the extensive data available on (dry) heat transfer coefficients for convection in closed building cavities. There seems every reason to expect that a corresponding set of moisture transfer coefficients can be delivered for the same conditions. A research contract with University of Canterbury has been arranged for the work.

In this project both sensible and latent heat transfer across closed cavities will be measured for a range of temperature and moisture conditions, under natural convective heat flow. The design of the test equipment is proceeding at present.

c) Ground Evaporation

One of the most important moisture sources in buildings with suspended floors is evaporation from the subfloor soil. Standard practices for ventilating subfloor spaces have evolved, but there is no engineering basis for evaluating these practices or adapting them. The importance of subfloor evaporation extends far beyond the subfloor zone, as is discussed later.

The subfloor hygrometric conditions will clearly depend on 3 things:

- the rate of evaporation from the soil
- the rate of ventilation
- the temperature and humidity of the subfloor space.

It will be also clear that these 3 things are not entirely independent of each other. But to acquire a proper understanding of all 3 simultaneously was deemed too great a task, and so another research contract has been arranged to collect information about just one - that is, evaporation rates. More details of this project are given in another paper to this conference (4), and for present purposes it is sufficient to record just the following provisional conclusions:

- the evaporation rate is largely unaffected by soil type.
- the evaporation rate is largely unaffected by soil moisture content (Unless soil is extremely dry to great depth
- the evaporation rate is equal to that of a free water surface.

The average evaporation rates observed were about:

400 g/m^2 day
(17 $g/m^2.h$
5.10^{-3} $g/m^2.s$

40 kg/day per house)

This corresponds to an upward water velocity of about:

5.10^{-9} m/s
(0.4 mm/day)

The rate varied during a 2 month observation period from about 120 to 1200 g/m^2.day day average. Within a day, the rate varied typically by up to about 8 g/m^2. hour (equivalent to 200 g/m^2. day) between the lowest and highest evaporation rates for the day. The highest evaporation rates occurred during night when outdoor temperatures were lowest, and dropped during day and when outdoor temperatures increased.

There is at this stage no information about seasonal variation, (it would be expected that evaporation is highest in winter, lowest or negative in summer).

From the above information, it can be deduced that the average ventilation rates needed to remove the ground evaporation from the subfloor space will be at least 5-10 air changes/hour. Relatively few N.Z. measurements of ventilation have been made, those available (from less than 10 houses) show spot-rate ventilation at the particular time of measurement, to be between 2 and 8 air changes/hour.

All of the above deductions are tentative. Only when results from wider surveys embracing different climatic regions, construction practice, building use, and local topography are available will conclusions become definite.

d) Field Studies

To get a real appreciation of the nature and importance of moisture problems in buildings, there is no substitute for investigating real buildings. The Building Research Association has always maintained close association with on-site performance, but in recent years there has been a step-up of field studies of all types.

An important current field survey concerns the evaluation of several possible remedial treatments for a severe form of roof space condensation problem which has been noted in recent years. Although found all over N.Z., this problem has been particularly common in Invercargill, where this survey has been conducted.

The project was mounted as a result of fairly routine "enquiry report" analysis. These reports showed a rather disturbing number of cases where severe roof space condensation as indicated in Figure 3 were reported. Initial attepts to explain these problems, in terms of vapour diffusion through the ceilings,f ailed because there was found to be no correlation between the ceiling "quality" and the presence of roof condensation. Exploration in terms of indoor air entrainment into the roof space failed for the same reason.

The true explanation emerged after it was noted that this problem was found only in masonry veneer houses, whilst it seemed to be absent in veneer houses with skillion roofs rather than pitched roofs. This suggested that the source of water may be the subfloor, which could be carried by airborne convection up the veneer cavity to the roof space. This process would not be available with, say, weatherboard claddings, or skillion roofs.

Further statistical and field tests were undertaken and confirmed this interpretation, and as a result the present survey was set up. Ten veneer houses known to have had this roof condensation problem were selected. These were divided into 4 groups, and the following treatments applied:

- ground covered with polythene film
- veneer cavity closed at floor level
- veneer cavity closed at eaves level
- no treatment.

since then the 10 houses have been inspected each month during winter, each 2 months outside of the winter period. In each inspections the physical conditions and the moisture contents of subfloor and roofspace temperatures were recorded. The rate of air exchange between subfloor and roof spaces was measured in some cases using tracer gas methods, but spot results only were possible.

The following results were observed:

a) All houses where ground has been covered are showing substantial or dramatic drying, in both subfloor and roof space. These have mostly been accompanied by onset of squeaking floors, formation of shrinkage cracks inpaint.

b) All houses where ground has not been covered, are showing alarmingly and persistently high moisture contents of all subfloor timbers.

c) Both houses in which the veneer cavity was closed at the top have shown little improvement over their previous winter performance.

It may be significant that these two houses had clearly the wettest subfloor conditions encountered.

d) Both "control" houses with no treatment have shown some drying of the subfloor timbers since inspections began.

They have not shown an unambiguous drying behaviour in the roof space, but they have avoided very high moisture contents in the roof space.

e) There are a number of unexplained internal anomalies in the data as reported. For instance there are several cases where roof timber moisture contents have risen but observed condensation and/or roof space humidity dropped, or vice versa.

Clearly the most important result is the sharp improvement in those houses where ground has been covered. This is taken as confirmation that the moisture source was indeed the subfloor soil - a conclusion further reinforced below.

The non-effectiveness of closing the top of veneer cavities is the most important negative result. This result is attributed to a failure to prevent passage of subfloor air to the roof space. A tracer gas test of the subfloor-to-roof space ventilation coupling in one of these cases carried out in early August 1982, confirmed that a major part of the roof space ventilation was being supplied from the subfloor space, which was exceptionally wet. It has since been confirmed that this failure resulted from undiscovered coupling paths other than the veneer cavity.

Since 3 of the 4 cases where veneer cavity was closed show this feature, it seems clear that closing veneer cavities is not a sufficiently reliable procedure, and that covering the ground is a necessary requirement in all cases affected.

The occupant comments were highly favourable in the 4 houses where ground was covered, and rather negative in all other cases.

A coincidental case of some significance was inspected during this study, concerning a house not included in the study. This was a weatherboard clad house, with no veneer cavity via which subfloor air could pass to roofspace, and yet it had as severe roof space condensation as any other known case. Significantly, this house also had a complete foil vapour barrier over the entire ceiling, which even after 9 winters of condensate ponding on the ceiling was in apparently good condition. In this house, SF_6 tracer gas tests showed that a substantial part of roof space air was coming from the subfloor, presumably via a built-in garage space with large openings to subfloor and to roof space. The presence of a sound vapour barrier at ceiling had not prevented this problem, thus confirming that moisture was not entering the roof via the ceiling.

However, once again, installation of polythene ground cover during July, had resulted in almost total roof space drying approximately 3 weeks later.

e) Laboratory Tests

Finally, laboratory projects are coming forward in which the moisture behaviour, and related heat flow behaviour, in several roof types is to be monitored in detail, under reproeduced real climatic conditions. Only by such methods can the predictions offered by calculation models really be verified.

The only methods for moisture prediction which can be considered worthy of verifying are dynamic ones. That is, they take some sort of account of the fact that (weather) conditions are not constant during service. This lack of constancy has large effects on the moisture behaviour, and verification will therefore require to be done under similarly changing conditions. A set of controlled climate chambers to provide such conditions have been put into service for this purpose.

There are two projects involved. The first centres on the initial drying rates of skillion roofs, and comparison between observed drying behaviour and that predicted from a comprehensive numerical computer model. The second project centres on the possibility that moisture may move backwards and forwards in a daily cycle, carrying latent heat and bypassing the insulation system. It aims to determine whether and in what circumstances this could be a problem so that solutions can be considered.

SUMMARY

Moisture control engineering in buildings has been an insufficiently developed topic for too long. A whole battery of research projects aimed at bringing the subject to a proper maturity for reliable design has been set in motion, and are at this stage progressing encouragingly.

This paper outlines the major projects in hand, with some commentary on their implications. It points out that the previous exclusive attention to vapour diffusion is seriously deficient and that at least as much emphasis must be given to air leakage.

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