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ITEM 9 (COMMITTEE DATE 2/84)

Interstitial condensation Assessment of risk

ABSTRACT

This item brings up to date Bulletin 125 Item 5 dated December 1979. It sets out more fully the mathematical techniques for determining:

(a) the most likely position of the condensation plane;

(b) the limiting humidity at a given room temperature, below which condensation will not accumulate within the structure;

(c) the rate at which condensate is likely to accumulate at the plane if the relative humidity within the structure persistently exceeds the limiting humidity.

The technique is a graphical one and assumes that the conditions chosen for the purpose of the analysis remain constant indefinitely, a condition known as " steady state". Warnings are given on the limitations of the steady state approach to the analysis of heat and vapour flow situations, and advice is given on the interpretation of the results.

A few hints are given to those interested in writing a simple computer program to use the techniques described.

LOCATION OF THE CONDENSATION PLANE

This technique is based on the well-established method for finding the plane within a wall, roof or floor system at which the temperature is most likely to fall below the dew point of the air in its vicinity. It has the advantage over other generally used techniques of indicating in addition the level of humidity within the building below which condensation will not accumulate.

This minimum level of humidity is of course the highest "safe" level and may be used as a basis for comparison with other systems in order to assess which of them offers the least risk.

PROCEDURE

The temperature gradient graph

The thermal resistances of every element of the system are calculated from the relationship resistance = thickness/conductivity (Table 1).

A graph is then drawn, the horizontal axis of which is calibrated in units of thermal resistance (m²K/W) and the thermal resistance of each element and of the cavity and surfaces, marked off on it in order, from inside the building to outside. Vertical lines are then constructed at each element "boundary" on the graph (Fig 1).

The vertical axis is calibrated in degrees Celsius and a sloping line is drawn connecting the interior design temperature with the external temperature considered appropriate for the purpose of the analysis. From this graph the steady state temperatures at each interface may be determined.

Example

Table 1 — Calculation of thermal resistances

Element	Thickness m	Conductivity W/mK	Resistance m²K/W
Rsi	—	—	0.120
Plaster	0.015	0.160	0.094
Concrete blockwork	0.100	0.180	0.555
Cavity	—	—	0.180
Brickwork	0.115	1.150	0.100
Render	0.015	0.800	0.020
Insulant	0.020	0.035	0.572
Rso	—	—	0.060

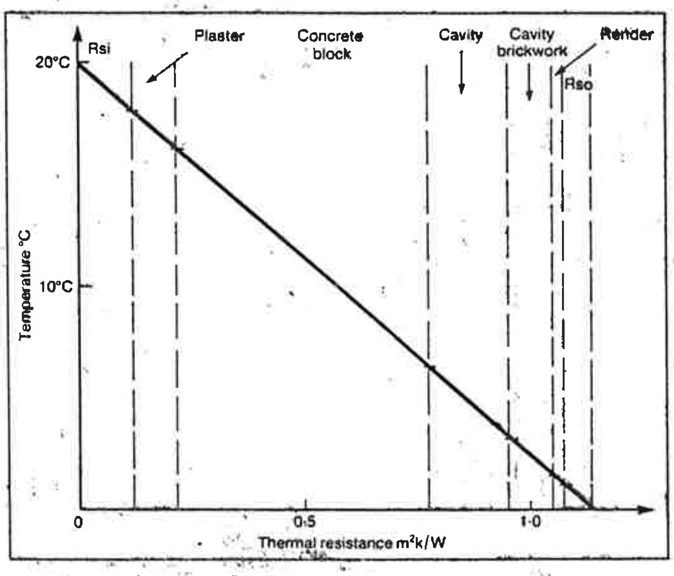

Fig 1: Temperature gradient diagram — cavity wall.

The saturated vapour pressure (svp) graph

The points on this graph are the saturated vapour pressures at each element interface corresponding to the interface temperatures obtained from the first graph. These values may either be obtained by reading them off a psychrometric chart, which is illustrated in Fig 2, or by reference to the tables published in CIBS Guide C1/2, or by the use of the equation given below, which course is recommended only if a computer is to be used:

$\log_{10}p_s = 30.59051 - 8.2 \times L + 2.4804 \times 10^{-3} \times T - 3142.31/T$

Where

T is the absolute temperature in Kelvin given by $T = (t + 273.15)$

t is the temperature in degrees Celsius

L is equal to $\log_{10}T$.

Axes

The condensation risk diagram (or svp graph) is drawn against axes calibrated in vapour pressure (vertical kN/m²) and vapour resistance (horizontal MNs/g).

The vapour resistance of each element is first calculated from the relationship

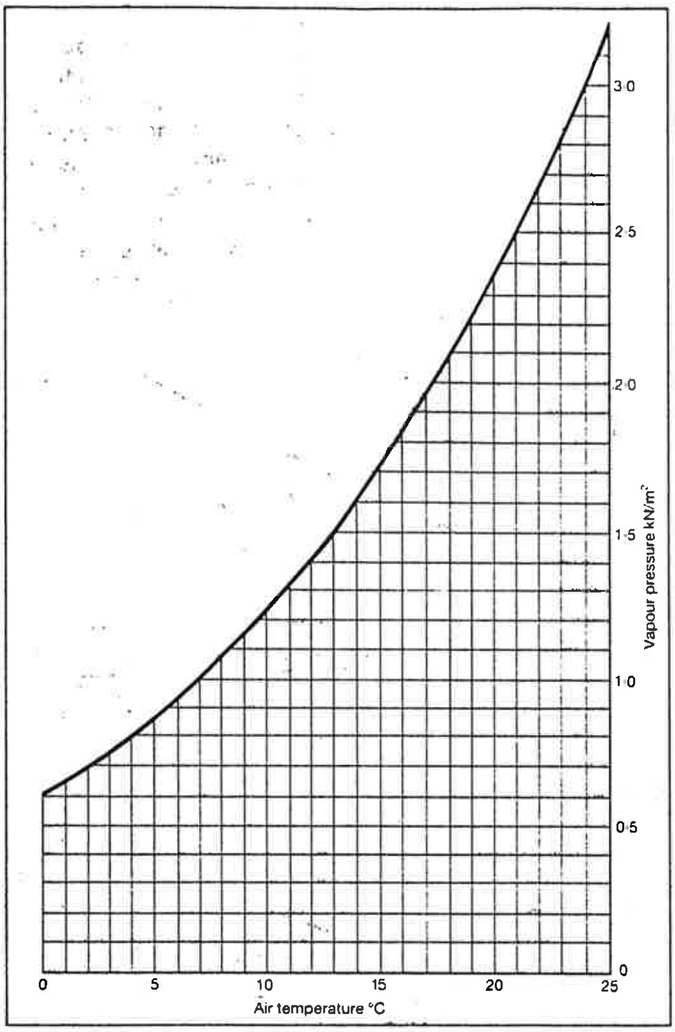

Fig 2: Psychrometric chart.

resistance — thickness x resistivity
and marked off along the horizontal axis in sequence commencing with the internal surface, vertical lines being drawn at each interface. The corresponding saturated vapour pressures are plotted and the graph constructed by connecting them.

Example

Table 2 — Calculation of vapour pressure resistance

Element	Thickness m	Resistivity MN/sgm	Resistance MNs/g
Plaster	0.015	60	0.9
Concrete blockwork	0.100	40	4.0
Brickwork	0.115	60	6.9
Render	0.015	60	0.9
Insulant	0.020	300	6.0

Fig 3: Condensation risk diagram — cavity wall.

Location of plane of condensation
A point corresponding to the assumed vapour pressure of the external air is marked on the vertical line corresponding to the external surface of the system and a straight edge placed horizontally against it; the straight edge is then pivoted around the point until it touches the graph.

The plane represented by the vertical line through the point of contact and parallel with the face of the wall is the plane at which condensation is most likely to accumulate, and the intersection with the vertical axis gives the vapour pressure

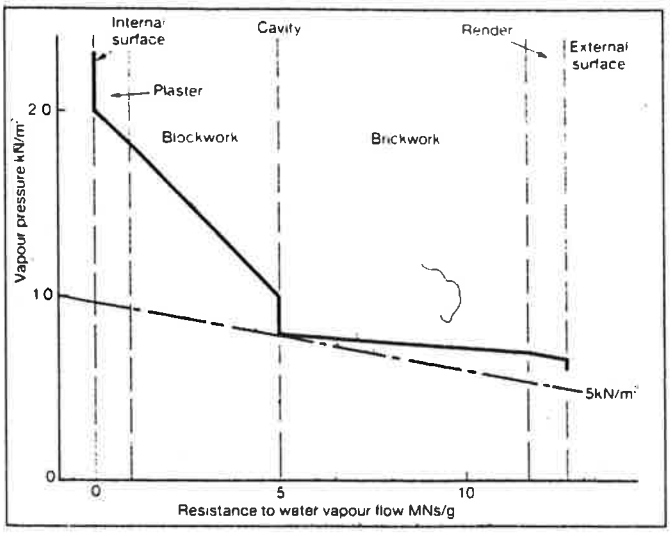

Fig 3: Condenstion risk diagram — cavity wall.

which, if continuously exceeded within the building, would eventually result in the accumulation of moisture in this plane.

Another way of describing this point of contact, which might be useful when devising a computer program, is that it is the point on the graph which is joined to the point indicating the external vapour pressure by the line of least gradient.

Limiting humidity
The relative humidity at the internal design temperature corresponding to this limiting vapour pressure is simply calculated by expressing it as a percentage of the saturated vapour pressure corresponding to the internal design temperature.

By comparing the "limiting humidity" of a variety of structures, the one least prone to interstitial condensation may be chosen.

Rate of accumulation of water
While the internal relative humidity remains at or below the "limiting humidity", there is no risk of condensation accumulating within the system.

If, however, the internal relative humidity is persistently above this value, then condensate could accumulate at a rate which may be calculated as the differences in the rates at which water vapour flows from inside the building to the condensation plane, less the amount which flows from the condensation plane to the exterior.

Rate of flow of water vapour from the condensation plane
This is constant while the internal relative humidity is equal to or greater than the "limiting humidity" and is given by the expression:
$R_o = (P_{sc} - p_o)/r_{co}$ where:
p_{sc} is the saturated vapour pressure at the condensation plane
p_o is the external vapour pressure
r_{co} is the resistance to water vapour flow between the condensation plane and the outside

R_o is the rate of flow of water vapour in g/s through an area of one square metre of structure.

In the example under analysis in this item:
p_{sc} = 0.79 kN/m²
p_o = say 0.50 kN/m²
r_{co} = 7.8 MNs/g = 7800 kNs/g
Thus R_0 = 0.0000371 g/sm².

Rate of flow of water vapour to the condensation plane
The rate at which water vapour flows into the structure from the interior of the building is given by a similar expression:
$R_i = (p_i - p_{sc})/r_{ic}$ where:
p_i is the interior vapour pressure
r_{ic} is the resistance to water vapour flow between the inside of the structure and the condensation plane
R_i is the rate of flow of water vapour in g/s through an area of one square metre of structure.

Suppose, in the example, the internal vapour pressure rises to 1.5 kN/m² (about 64% relative humidity), then:
p_i = 1.5 kN/m²
p_{sc} = 0.79 kN/m²
r_{ic} = 4.9 MNs/g = 4900 kNs/g
Thus R_i = 0.0001448 g/sm².

The rate of accumulation of water at the condensation plane
This is given by: $W = R_i - R_o$
In the example this is equal to 0.0001077 g/sm², which is equivalent to 0.39 g per hour or 9.3 g per day over an area of one square metre, and is the maximum rate at which water could accumulate at the condensation plane if the specified conditions were maintained for long enough for the system to come to a state of equilibrium.

Assessment of risk
Clearly no part of a structure ever arrives at a state of equilibrium with respect to temperature and water vapour, because the time taken to reach equilibrium is very long and the rates at which temperature and water vapour conditions of the air-change are comparatively rapid. Added to this is the fact that all the data used are in the nature of average values obtained from laboratory results obtained from time to time and are not necessarily closely related to the actual materials used in the construction under analysis.
Computer programs have been devised by which one can assess the effects of the climates of different parts of the country or even the world and thus, hopefully, avoid such errors as those made in the past, when construction systems, found to be satisfactory in one part of the world, fail in another.
In any case a computer program enables the user to derive considerable educational benefit from being able to examine a great many variations in a short space of time.

If one carries out the calculation described in this item using data relating to the most adverse conditions, then the predictions arrived at will be extremely pessimistic and even if the data relates to mean winter conditions, in a heavyweight structure, the predictions are still likely to be over-pessimistic.

If the structure under consideration is of low thermal capacity and offers a low resistance to water vapour, then events will come about more rapidly and the predictions will be more realistic.

Thus if a structure is to be exposed to levels of humidity which frequently exceed the limiting value, the rate at which the structure is likely to approach equilibrium and the quantity of heat energy which is likely to be made available to it should be considered.

APPLICATIONS OF THE TECHNIQUE

Timber-frame structures
The analysis is carried out on a section through a plasterboard lining, 50 mm of fibre insulant, a breather membrane, cavity and brickwork.

It can be seen from Figs 4 and 5 that the effect of using a high resistance membrane in place of the breather membrane over the external surface of the insulation, to protect it from the weather during construction, is to move the condensation plane from the inside surface of the membrane, with the consequence that condensate may accumulate in the insulant or the supporting timber framework.

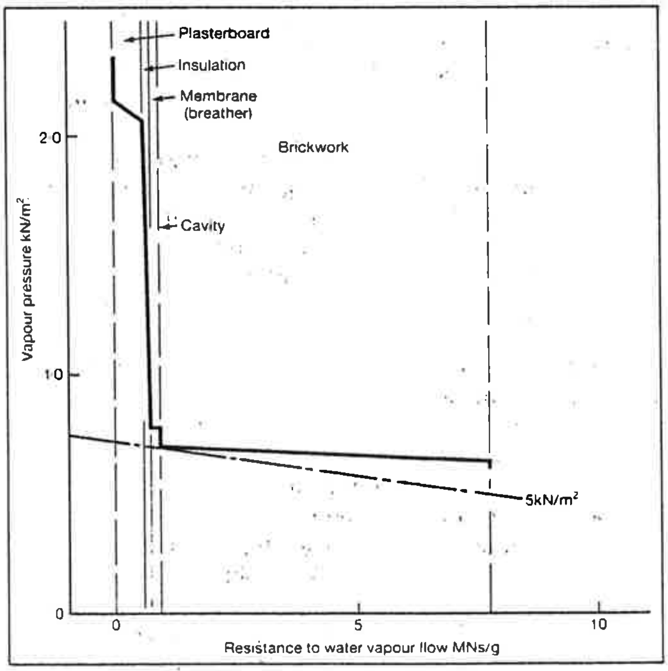

Fig 4: Condensation risk diagram — timber-frame - 1.

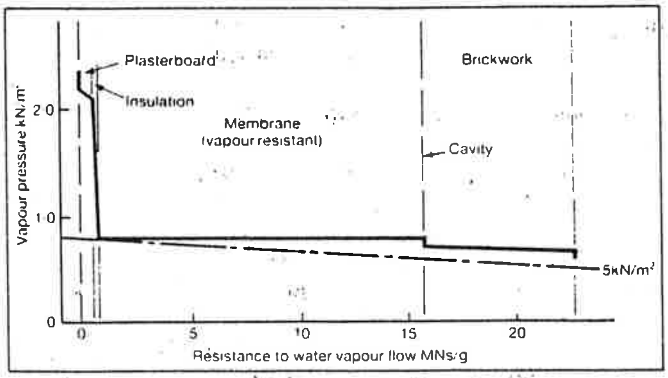

Fig 5: Condensation risk diagram — timber-frame - 2.

Effect of the position of the insulant in a brick/block cavity wall.
In all three cases illustrated in figs 6, 7 and 8, the condensation plane is the inside surface of the brickwork outer leaf. Whether the insulant is on the inside or outside of the inner leaf is immaterial, but by positioning it on the outside of the wall, the risk of condensate accumulating is somewhat reduced.

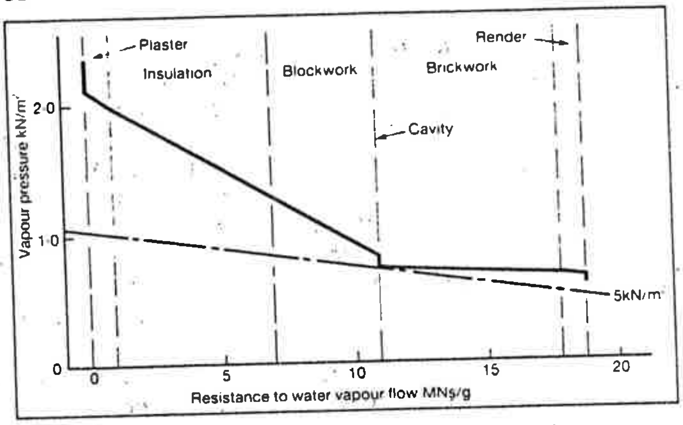

Fig 6: Condensation risk diagram - internal insulation.

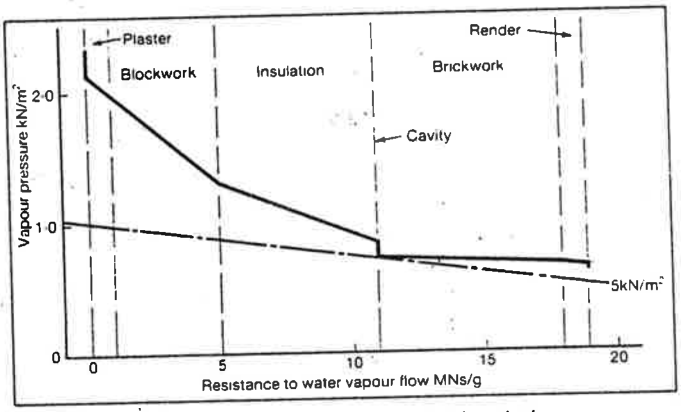

Fig 7: Condensation risk diagram - cavity insulation.

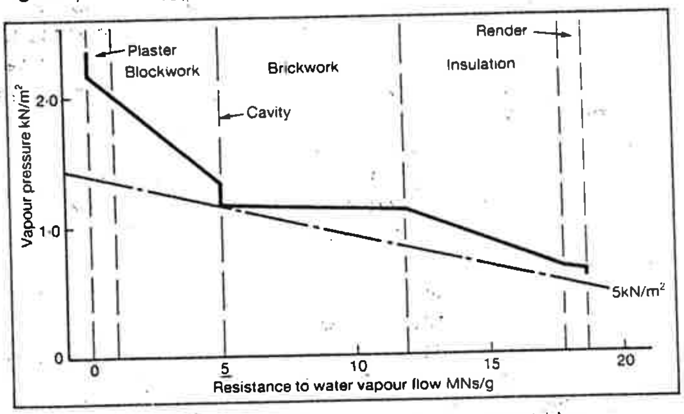

Fig 8: Condensation risk diagram - external insulation.

ADVICE
Advice on the topic of graphical methods of analysis of heat and water vapour flow may be obtained from J C D Twiston Davies (6016).