7

DISCUSSION

The necessity of understanding natural processes in the man made environment

I have tried to convey in this thesis my fascination for natural processes in man made structures. Many engineers' attitude to the unwanted properties of the materials they have at their disposal is to ignore them, or deplore them. My view is that it is better to understand materials and use their properties fully, or choose another material for that particular purpose.

The key example which illustrates the consequences of ignoring the properties of materials is the turbulent microclimate in the roof of the Arts and Industries Museum. This story shows the intricacy of the interplay between permeability and water absorbency in materials that are put close together to provide that function described in constructor jargon as the building envelope.

Figure 7.1 One of the team of architects for the National Gallery of Art in Ottawa entertains some delegates from the conference of the International Institute for Conservation, while a bucket in the shadow (arrowed) collects the condensate from the well bringing light from the roof to the galleries

Attempts to control water vapour by denial of access are doomed. One cannot construct a building like an aircraft. The industry does not have a perfectionist tradition and it works mostly out of doors, often in weather that hampers precise work.

Designers have become wiser since the early eighties, when we were investigating the Arts and Industries Museum, and other building failures with similar causes. Greater care in the design does not necessarily show in the finished product. Figure 7.1 shows the interior of the National Gallery of Art in Ottawa, designed in a cold country that has put a lot of research into the control of condensation. In this building there are simply too many complicated details in the precautions against condensation.

Using absorptive properties of materials instead of combatting them

The alternative approach put forward in this thesis is to take the water absorption of materials, and their permeability, as fundamental properties that can be used to advantage, or that, in other parts of a design, are so disadvantageous that the material should not be used.

In the case of the Arts and Industries Museum one can propose, with hindsight, that the roof deck should have been unabsorbent, perhaps metal, while the surface directly supporting the glass fibre insulation should have been absorbent: wood, for example, rather than polyester membrane. The vapour barrier should have been laid separately, just over the ceiling panels instead of in discrete rectangles within the prefabricated boxes, which left regular gaps for air flow through the roof.

Testing the original design against this, or any other proposed alternative, by computer simulation is impossible in the present state of refinement of the models for heat and moisture flow through buildings. I have therefore used most of my time in designing and building a test chamber for studying experimentally the performance of porous, water absorbent materials.

The need for a climate chamber that allows the expression of material properties

The unique feature of this chamber is that it allows the material under test to influence its environment, in contrast to traditional experimental chambers which impose an environment and watch the material react to its instructions.

The chamber described here is a prototype of limited use. It can imitate the interaction of interior walls with the indoor environment. There are two important limitations to its usefulness in predicting the performance of outer walls: there is no temperature gradient and there is no air, or vapour pressure difference across the test wall.

The chamber was, however, designed to be part of an extendable system. The obvious next step would be to build two chambers which could bolt up to each side of a model of an outer wall, or a roof, sealed around the edges. The chamber representing the outdoor climate could be constructed in the traditional way: controlling the temperature and the relative humidity. This is how the outside weather is. We have no control over it, nor does any material which is less extensive than a million hectares of sea or rain forest.

The results obtained with the isothermal chamber show that the indoor climate can be substantially influenced by porous, absorbent walls. I use the double adjective 'porous, absorbent' deliberately, to distinguish the entirely different performance of porous unabsorbent materials.

The usefulness of water absorbent materials as short term buffers

The usefulness of water absorbent materials indoors is as a buffer against brief periods of human activity that threaten condensation: showering, cooking and partying. During these events an absorbent material can substitute for mechanical ventilation. The heat of evaporation is recovered by heat of absorption released at the wall surface, giving increased comfort in the shower and removing the risk from automatic ventilators which eventually stick, either on or off, with energy loss in the first case and mould growth in the second.

The behaviour of porous materials laid over porous, absorbent materials is interesting. Figure 4.35 shows how the combination of gypsum plaster over cellular concrete provides a sort of diode: allowing condensed water to penetrate but hindering its return. The gypsum plaster conducts liquid water, because it is wettable and has a system of large pores, if the spaces between fibres can be so described. The cellular concrete has the same structure on a finer scale and so hangs on to the water once it has reached it. Such a system seems worth investigating side by side with the two other systems for selective water transfer: the offset laminate (Hygrodiode) of Professor Korsgaard and the variable resistance polymer film from the team at the Fraunhofer-Institut für Bauphysik in Holzkirchen. The difference is that these last two are factory made foils, while the material laminates are a technique of building.

This use of gypsum or lime plaster reduces the efficiency of buffering at moderate RH, by screening the good absorber from the room air. The RH has to rise to 100% before the plaster becomes active, and then gypsum begins to dissolve, which is why lime plaster is recommended. The high RH at which stabilisation begins is maybe an advantage in a bathroom, where buffering to a lower RH will increase evaporation from the skin and so give a chilly sensation to the person in the shower.

Porous lime plaster in the upper parts of bathrooms, which direct spray cannot reach, was at one time required, or at least regarded as good practice, in Danish houses.

The process of slow diffusion through a porous, but unreactive material from a porous-absorbent material may be the mechanism behind the observed stability, and excess water content of church interiors.

Water absorbent insulation as a very short term buffer

Water absorbent insulation, in the form of wool, or paper insulation, may have a useful role to play in preventing condensation caused, as in the Arts and Industries Museum, by the cycle of intense solar heating followed by heat loss by radiation to the night sky. The water distilled from hot surfaces can be temporarily stored in absorbent insulation, without condensation, to be released again on the cooling part of the cycle when the bottom of the insulation is relatively warm.

A related subject has been briefly discussed: whether absorbent materials conduct moisture according to the gradient of the relative humidity or the vapour pressure. The isothermal experiments can shed no light on this matter but it is identified here as an important matter whose resolution is essential to a complete understanding of the behaviour of porous, absorbent materials.

The author's recommended material

The best buffer materials in this investigation were wood and clay. Neither is effective in its normal form. Wood in the form of planks has too small a permeability to give good buffering in a room with a normal ventilation rate. Clay is completely impermeable. To make an effective buffer the cross section of the wood must be exposed and the clay must be opened up by mixing it with a filler.

The material that comes out with the best all-round performance is bentonite clay mixed with perlite as both filler, stiffener and thermal insulator. This material can be formed into any shape and it has reasonable compressive strength, so that it can be used as a massive wall whose heat capacity also contributes to the stability of the indoor climate. When mixed with straw it can be given bending strength sufficient for built in bookshelves, or, if one dare, a TV or computer table.

The balance between water capacity and diffusion rate can be adjusted by altering the ratio of clay to filler, limited by the increasing drying shrinkage as the clay content is increased. The surface can be burnished to adjust its vapour permeability.

The disadvantage of clay is that it is very dusty and requires some surface treatment.

The performance of absorbent buffers over longer periods

Humidity buffering is always in competition with ventilation. Even a massive wall with a large water capacity cannot compete with rapid ventilation, because as the surface layers become depleted, diffusion from deeper down becomes slower and slower, while the ventilation rate is relatively constant, over the long term.

In a house with about half an air change per hour the buffer capacity is effective over a period of a few days at most.

Even the best buffer, the lightweight bentonite/perlite mixture, cannot long prevent the indoor dryness that comes with the onset of the heating season in cold and temperature climates. Low relative humidity has no disadvantage for human comfort but is not so good for the organic materials in houses: coins fall through cracks between the floorboards, pianos go out of tune and portraits of the ancestors wrinkle and crack.

Buildings which contain humidity sensitive objects but can have a low air exchange rate, such as archives, can moderate the climate with absorbent materials so well over the whole year that orthodox air conditioning is unnecessary. Museums require a suitable air exchange rate for people to breathe, but can also benefit from porous absorbent materials. They may well need mechanical air conditioning but the design can be simpler. An underdimensioned air conditioning system operating overnight would prepare the climate for human occupation during the day, during which time the climate would be stabilised by the absorbent construction. Indeed, an overdimensioned, fast reacting air conditioning system cannot work in a well buffered building, because of the risk of positive feedback in the control system, as described in the section on the Brede Museum Store in chapter 6.

The potential that lies in the combination of absorbent materials with air conditioning has lain dormant since MacIntyre's article describing lining the ducts in Hampton Court Palace with discarded fire hose (The fire hoses are clearly also a fire risk, but it was an old lady smoking in bed half a century later who actually burned part of the Palace).

The problem of chronically low RH in exhibition buildings during the winter can be, at least partly, ameliorated by massive, absorbent walls. These should, according to theory, pump water into the building against the concentration gradient of water vapour in air, if the computer model of moisture movement through porous absorbent materials in a temperature gradient is confirmed.

Surface treatment of porous building materials

Combinations, or rather laminates, of porous materials will be advantageous for indoor surfaces of walls. Mud is dusty, and porous materials generally collect dirt. Surface finishes have not been investigated in this thesis, but only through lack of time.

Decorated porous surfaces have been in eclipse since the extinction of the cheap post second world war distemper paints, made from oil emulsions with a low binder to pigment ratio. The best chance for aesthetically pleasing porous surfaces for buffer walls seems to lie in a revival of the north European tradition for porous lime painting, now confined to churches. Any research that offers alternatives to the current fashion for white plastic painted interiors cannot be entirely wasted.

Figure 7.2 A porous lime painting by Conny Hansen, 1996, after the early 16th. century original in Nibe Church, Jutland, Denmark.

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