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Airtight houses

Timber frames for thermal comfort

With all the controversy surrounding timber framed housing, it is all too easy to get the technical situation out of perspective. Claims and counter claims by both the timber frame and traditional housing lobbies have tended to obscure pioneering developments. This article hopes to redress the balance partly by looking at the work of timber frame experts Walker Timber in the construction of airtight houses.

Ever since the energy crisis of the early 1970's there has been an increasing awareness of the cost of maintaining a comfortable thermal environment. Walker Timber's approach to this problem was to look for ways to reduce heating costs without sacrificing comfort standards. Although well aware of the importance of building shape, orientation and layout, the company looked beyond these elements to the construction system itself.

The ultimate aim was to develop a housing construction system which, by improved insulation standards, would provide a high level of comfort but at no extra long-term cost to the occupier. In other words, any extra capital cost had to be balanced by a corresponding saving in running cost. It was clear from the outset that as the running cost, and therefore the heating system, determined the financial viability of the project, the heating system should ideally be considered as an integral element of the construction.

The need to be cost effective, considered alongside the cheapest fuel option then available, indicated an optimum insulation level of 150mm mineral wool giving 'U' values for ceiling and walls of approximately 0.2W/m²°C, together with high performance double-glazed windows and insulated doors. For various practical reasons, however, the actual system eventually used 140mm insulation and triple-glazed windows.

Thermal Comfort Levels

The selection of triple-glazing raised an important aspect of recent housing designs: the notion of thermal comfort. This is an extremely complex area but, even at a basic level, most of us recognise the negative side. Thermal discomfort elements include: cold draughts generated by convection currents around single or even double-glazed windows, as well as more obvious leakage around doors, windows and skirtings; thermal stratification leading to cold feet and hot heads; poor ventilation unable to remove moisture and smells and giving a general feeling of 'stuffiness'. Triple glazing was, therefore, selected for its contribution to 'comfort' rather than mere energy saving.

For larger, detached family houses of up to 180m², the company had, by these means, reduced calculated fabric-related heat losses from 10Kw (for a house to Building Regulation standards) to approximately 2Kw. However, ventilation losses, which at 4Kw had previously represented less than one third of the total heat loss, now represented two-thirds of the design load and it was to this area that Walker next devoted its energies.

Recovering Heat Loss

For reasons of improved comfort and in order to minimise the heating load, Walker Timber decided to install a whole-house ventilation and heat recovery system which, by recovering 75% of the heat from exhaust air, reduced the ventilation loss to 1Kw. The total heat loss has now been reduced from around 14Kw to only 3Kw. The performances of numerous houses built using this system has confirmed the benefits of high insulation levels combined with heat recovery. So why, only three years later, did the company abandon this system?

Simply because, whilst the 'Heatkeeper' system had proved a substantial improvement on current construction methods, staff could see areas that could be improved still further. Swedish experience had shown that besides the obvious benefits of draughtstripping in eliminating draughts, comfort could be further improved and the fabric-insulation values enhanced by constructing a virtually airtight house.

Up until that point, the designers had been interested in a modest degree of airtightness, provided by the polythene vapour barrier. There has been a great deal of concern regarding the possible degradation hazard resulting from interstitial condensation. Calculations, however, show that this condition is not even theoretically attainable where the ratio of vapour resistance of the vapour barrier to the sheathing exceeds 5:1. A recent report by the National House Building Council states that, in their tests, even with severely abused vapour barriers in the most adverse conditions, the moisture content of the structure never reached a critical level. To date, there has not been one case of damage due to interstitial condensation in the UK.

The ventilation and heat recovery system further reduced the possibility of interstitial and surface condensation. The slight negative internal pressure designed into the ventilation system opposes vapour migration induced by the naturally higher vapour pressure at the higher indoor temperature. Because vapour is continuously extracted at source, the build-up of internal vapour pressure is reduced, as is the risk of surface condensation on walls and windows. It was, therefore, in order to improve airtightness rather than vapour resistance, that Walker set out to produce a continuous vapour-resistance membrane.

With regard to the insulation package, it was relatively simple to establish the cost-effective limit of specification. But the company was still faced with the problem of how to determine a realistically attainable level of airtightness. In order for the heat recovery and ventilation system to work at optimum efficiency, an involuntary leakage rate of approximately 0.1 air changes per hour (acph) is acceptable. The system is designed to extract 0.6 acph and supply 0.5 acph, giving rise to the slight negative internal pressure mentioned above: the supply deficit being made up by 0.1 acph leakage.

Swedish Building Standards stipulate a maximum leakage of n_{50} = 3 acph. Canadian Standards 4 acph 'n_{50}' is the number of air changes per hour at a pressure differential between inside and outside of 50 Pa. N_{50} = 3 acph corresponds to a leakage of around 0.6 acph at normal pressure differentials, assuming a linear relationship as Figure 1. Dependent upon the pattern of leakage, i.e. a large number of small penetrations or a fewer large penetrations, the relationship may be more closely represented by the curve in Figure 2. The value for n_{50} = 3 appears to give adequate thermal efficiencies and to be obtainable with conventional timber frame construction techniques provided the vapour barrier is carefully installed.

Figure 3, based on a recent B.R.E. survey of U.K. Housing, illustrates dramatically how most houses fall far short of this target at present.

In order to circumvent the potential pitfalls of poor site practice, the company sought to create a system which was virtually foolproof; a system in which the 'easy way out' was the right way.

In conventional timber-frame construction the vapour (and air) barrier is situated directly behind the plasterboard wall lining. Electrical, and other services located within the wall, therefore have to puncture the vapour barrier in order to reach the room (Figure 4). To prevent this problem, the vapour barrier was installed within the structure, making it much easier to install services, as these could now be surface mounted, in no way interfering with the integrity of the membrane.

Continued on page 14.

1. AIR TIGHTNESS BARRIER (C.R side of insulation)
2. under suspended floor insulation,
3. Aluminium Foil & air Gap Insulation.
4. Insulation products + techniques for internal insulation of solid wall houses.
5. Domestic air conditioning & hot air heating

Airtight houses continued

Factory Insulation

The decision to adopt factory insulation and sealing for quality control purposes allowed Walker to use 'large' panels with bitumen-impregnated sheathing externally and plywood sheathing directly behind the vapour barrier. In other words, the structural elements were arranged in the ideal order of higher vapour resistance towards the warm side of the construction (Figure 5). Furthermore, the plywood provided a firm fixing for services and the fibreboard provided additional insulation.

Because the insulation was located within a sealed 'cassette', the scouring effect of moving air was eliminated and the effective insulation value raised. It was therefore possible to reduce the thickness of insulation without any detriment to the shell performance.

One major problem remained. How to maintain structural integrity without destroying the membrane continuity? For example, how could the mid-floor joists of a house be built into the wall without penetrating the vapour barrier? Various optimistic solutions have been advocated, most of them depending on a high degree of on site control. Eventually, Walker Timber decided to continue the air-tightness barrier around the joists onto the cold side of the wall. Obviously this barrier was required to resist bulk air movement but not vapour movement. The material selected for this purpose is a double layer of kraft paper bonded with a 'breather layer' of bitumen. (Figure 6).

This paper is sealed at junctions to the walls with a paper-backed 'hot-melt' strip. The adhesive layer is absorbed by the vapour and wind barriers and becomes an integral part of the continuous membrane.

The ground floor construction, particularly for suspended floors, presents a further problem. A vapour barrier also resists the passage of water. Therefore, if a vapour barrier is placed in the floor construction, any water spilled on the floor will be permanently trapped within it, creating a potential hazard of rot. This is avoided by using an extension of the logic applied to the wall construction. Walker fixed a secondary floor above the vapour barrier and used the space so formed both for service runs and to distribute ventilation and heating air (Figure 7).

Warm Feet Effect

Besides continuously removing any excess moisture, this layout also provides a warm floor which is psychologically more comfortable. Air outlets are provided around the perimeter of the floor so that thermal comfort is assured. By using this construction system, infiltration rates as low as n_{50} = 0.1 acph have been achieved. In practice, leakage of this order is difficult to measure accurately and simply so that a target level of n_{50} = 0.4 acph is set. At this level, total air control provides an extremely high level of comfort by eliminating draughts (even high velocity warm air is perceived as a draught) and by supplying precise amounts of fresh air where required. The company did not simply assume that this system performs as designed. Measurements are taken at a stage in the construction process where remedial action is both simple and effective. It is not feasible to go into the precise nature of the tests here, but they were based on practices adopted by Sweden's Building Regulatory Authorities.

It has been theoretically possible for some time to design a house with such low fabric losses that the design heating load was minimal. Now it is practically feasible to construct airtight houses with controlled ventilation and heat recovery. It is, at least on a seasonal basis, quite straightforward to reduce the total heating load below the level of internal gains. Naturally, peak internal gains do not always coincide with the peak design load, but apart from a minimal 'top-up' element, it is now possible to construct houses which require virtually no heating at all.

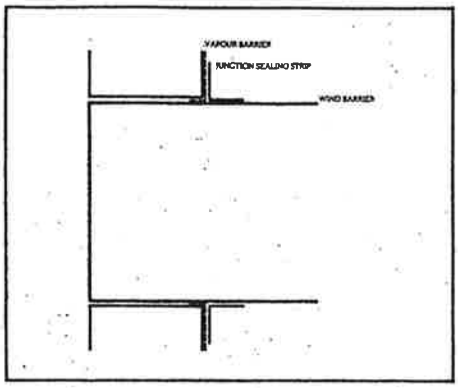


FIGURE 6
Continuity of the airtight membrane is achieved at mid-floor by use of a breather-type wind barrier.

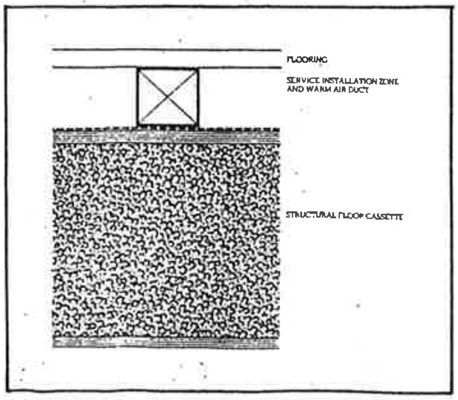


FIGURE 7
Provision of air calculation zone permits continuity of vapour barrier around complete shell.

FIGURE 1

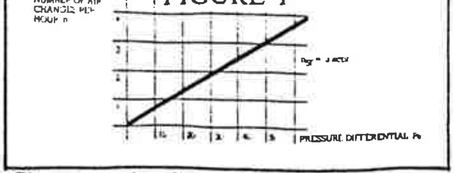
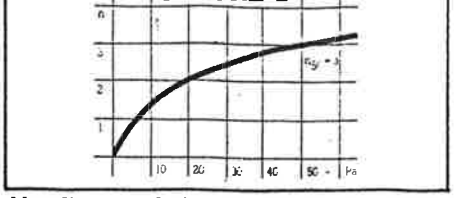


Chart showing linear relationship between differential pressure and infiltration rate. Working pressures for most houses are below 10 Pa. There is a risk in extrapolating at this level and the chart below shows a more realistic indication of performance. (n_{10} = 0.6)

FIGURE 2



Non-linear relationship illustrates higher actual leakage at lower differential pressures. (n_{10} = 1.3)

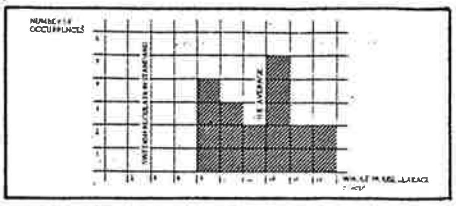
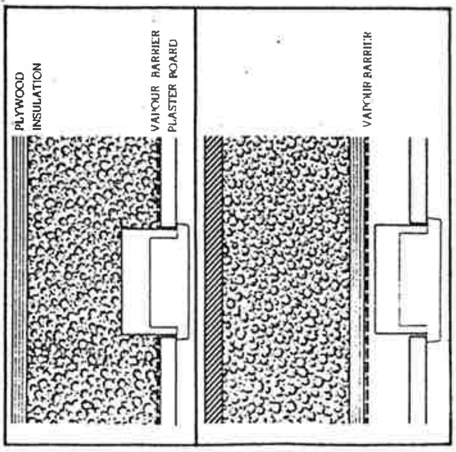


FIGURE 3
Although based on small sample size, 19 houses, this chart illustrates the dramatic deficiency in infiltration rates between UK and Sweden. Best UK performance gave n_{50} = 8. Average UK value n_{50} = 13.9acph.



FIGURES 4 & 5
Vapour barrier punctured at electrical power point. Although resealing around such service entries is adequate for vapour control, it is impossible to achieve airtightness by this method (left).
Services can be more easily installed. Here, the wiring is surface fixed on vapour barrier with plywood backing and the vapour barrier remains intact (right).

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