VENTILATION TECHNOLOGIES IN URBAN AREAS

19TH ANNUAL AIVC CONFERENCE
OSLO, NORWAY, 28-30 SEPTEMBER 1998

AIRTIGHTNESS OF TIMBER FRAME BUILDINGS NOT HAVING A PLASTIC FILM VAPOUR BARRIER

Eva Sikander and Agneta Olsson-Jonsson

SP Swedish National Testing and Research Institute
Borås
SWEDEN

Airtightness of timber frame buildings not having a plastic film vapour barrier

Eva Sikander
Agneta Olsson-Jonsson
SP Swedish National Testing and Research Institute, Borås, Sweden

Synopsis

Good airtightness of a building can be achieved by the incorporation of an inner sealing layer for the exterior walls and roofs in the form of a plastic film, which also serves as a vapour barrier. However, if it is not wished to use plastic film as an inner sealing layer, then airtightness must be effected through the use of other materials or in some other way. This project has been concerned with investigation of a number of alternatives. It has been found that the arrangement most commonly used in Sweden today comprises polymer-based fibre sheets (which permit diffusion) and gypsum board, as alternatives to plastic film on the inside of the structure.

The work of the project has shown that, provided that the materials are airtight in their own right, it is possible to achieve as good airtightness with alternative materials as can be achieved with plastic film. This has been demonstrated in the laboratory and in three of five houses in the field investigation. However, the airtightness performance of the finished building can be very poor unless care is taken both in the design and in construction, and this was also revealed in the field work.

General

Good airtightness is very important for resistance to moisture (in order to avoid damage by moisture convection), thermal comfort, indoor air quality, controlled ventilation and good energy husbandry. Airtightness is very dependent on both the design detailing and the quality of workmanship. It must be possible actually to construct the features that have been designed. All the materials/layers used in the structure contribute to the final airtightness performance.

Plastic film has been used for airtightness and as a vapour barrier in stud wall structures in traditional buildings in Sweden in recent decades. With it, it is often possible to achieve an airtightness performance of 0,8 litre/(sm^2) or about 2,9 $m^3/(m^2h)$ at a differential pressure of 50 Pa, as required for residential buildings by the Swedish Building Regulations [2]. If, however, the use of plastic film as an inner sealing layer is not wanted, then airtightness must be effected through the use of other materials or in some other way.

In addition to good air quality, it is also very important when selecting materials that the degree of diffusion protection is appropriate to the requirements of the building.

The objective of this project

The objective of this project [1] has been to:

- identify, in a field investigation, airtightness problems in wooden stud wall structures not having plastic film vapour barriers
- develop modified or alternative ways of providing airtightness, and
- evaluate the proposed solutions in the laboratory.

In the project, we have investigated the following alternatives to the use of plastic film for producing airtight layers in a wooden stud wall design:

- diffusion-permitting polymer-based fibre sheets (sometimes referred to as 'windproof' sheets)
- gypsum board panels
- wind barrier paper in some laboratory trials.

Diffusion aspects are not considered in this report.

The field study

The field study investigated six buildings in southern Sweden. Three of them were detached houses, and three were schools

When selecting the buildings to be investigated, it became apparent that diffusion-permitting polymer-based sheets are often used as an alternative to plastic film. Gypsum boards, without any further additional internal sealing layer, are also often used as an alternative to plastic film. The reason given for this is because plain paper sheets have been found to be more difficult to work with than 'windproof' diffusion-permitting polymer-based sheets. In addition, the polymer-based sheets are supplied in wide rolls, which reduces the number of joints needed.

For the field study, we therefore selected buildings having either an internal sealing layer of gypsum board alone or with a diffusion-permitting polymer-based sheet layer. Table 1 indicates the types of materials and designs employed.

The design details for ensuring good airtightness at connections, penetrations and joints are not shown on the drawings of the buildings. Many of these details are decided by the construction workers and/or by the site management.

We monitored the buildings during construction, looking at such aspects as detailing of joints at ceilings, floors, intermediate floor/ceiling structures, windows, doors and ground floor structures, as well as at the way in which joints and penetrations were made. After completion, the airtightness of the buildings was measured and leaks were traced.

Table 1. Materials and airtightness sealing principles in the field study buildings. Thermal insulation in all buildings has been provided by cellulose fibre (loose fill insulation).

Building no.	Type of building	Sealing layer	Sealing principle
1	Detached house, 1,5 storeys	EF Windproof, internal gypsum board	Stapling, taping
2	Detached house, 1,5 storeys	RW Windproof, internal wooden panels or gypsum board	Stapling overlapping
3	Detached house, single-storey	1 layer of gypsum board	Joints over studs and steel angles filler, mastic
4	School, single-storey	EF Windproof, internal gypsum board	Taping
5	School, single-storey	Ceiling: RW Windproof, internal gypsum board Walls: lightweight concrete	Stapling
6	School, single-storey	Walls: 2 layers of gypsum board Ceiling: RW Windproof, internal gypsum board and wood wool sheets	Stapling, taping

Our observations in the field trial buildings showed that there are several ways in which the same detail can be made: there are good ways and there are less good ways. The main areas in which there is scope for improvement are

- penetrations
- roof truss joist joints
- intermediate floor/ceiling structure joints
- ground floor joist joints (where the building has a wooden floor).

In addition, improvements could be made by developing designs that would enable penetrations to be avoided (e.g. by running unbroken sealing layers past internal walls, glulam beams, intermediate floor/ceiling structures etc.). In particular, it is the original design that is important in this respect.

The airtightness measurements were made in the spring and summer of 1997. Leaks were traced using a thermal imaging camera and air flow velocity meters. The results are shown in Table 2, from which it can be seen that two of five buildings have an air leakage that exceeds the permissible value in the Swedish Building Regulations. The other three buildings, of which one uses gypsum boards as its sealing layer, fulfil the requirements. However, it is not completely clear whether the buildings are sufficiently airtight to provide the necessary degree of resistance to moisture.

The airtightness measurements indicate that it is possible, using the same building materials, either to produce airtight structures or, equally, to have considerable air leakage, depending on the particular technical designs and on the quality of workmanship. Building no. 4, for example, has a low air leakage, while buildings nos. 1 and 2 have high air leakage.

The airtightness measurements of building no. 3 show that good airtightness can be achieved using only gypsum boards as the internal sealing layer. This is probably further underscored by the results from building no. 5, as our observations during construction revealed shortcomings in sealing of 'windproof' paper. However, the filling and painting work was carried out carefully, and so the relatively good airtightness performance may be due to the effect of this layer.

Table 2 Measured air leakage in some of the buildings in the investigation. The results shown are the air leakage through the building envelope at a differential pressure of 50 Pa between interior and exterior. The value is a mean value of air leakage at 50 Pa negative pressure and 50 Pa positive pressure.

Building no.	**Measured air leakage, $m^3/(m^2h)$**	**Building Reg. Requirements $m^3/(m^2h)$**	**No. of storeys**	**Sealing layer**
1	5.4	about 2.9	1.5	'windproof' + plywood
2	8.5	about 2.9	1.5	'windproof' + wood panel
3	2.4	about 2.9	1	gypsum board
4	1.7	about 5.8*	1	'windproof' + gypsum board
5	3.0	about 5.8*	1	'windproof' (lightweight concrete walls)

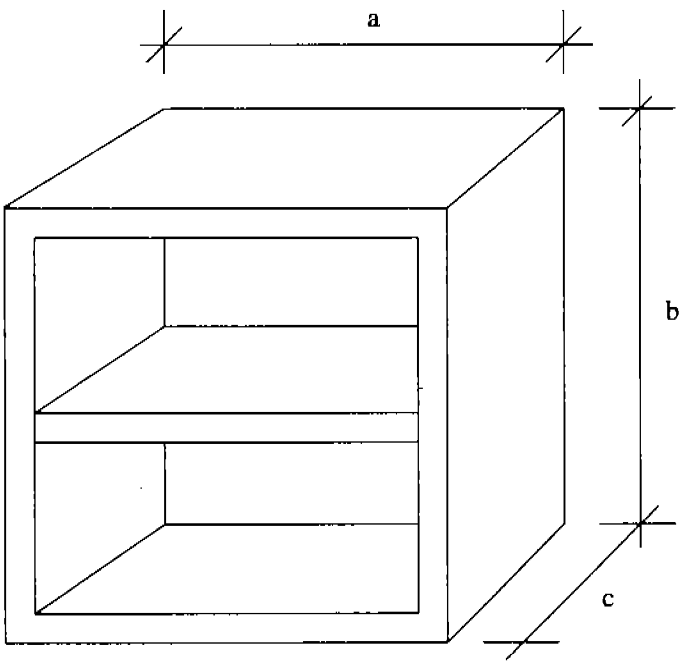
* The Building Regulations permit twice the rate of air leakage for other types of premises. The lower rate for residential buildings is in the interests of energy conservation.

Laboratory measurements

Working with a reference group, a number of proposals for design details for connections, joints and penetrations were developed. They were regarded as being capable of providing good airtightness, having a good likelihood of being properly made (i.e. good workmanship) and having benefits for production in general. They were tried out in the laboratory on large building elements consisting of walls, ground floor structu4res, intermediate floor/ceiling structures and roof truss joists (see Figure 1). The material combinations tested for internal sealing were:

- two layers of gypsum board with staggered joints, with fibre tape over the joints
- gypsum board + 'windproof'
- gypsum board + plastic film (to provide a comparison with a sealing layer that we know from experience is capable of providing sufficient airtightness).

The air leakage rate was measured for several different pressure differences, both positive and negative, across the building elements. Figure 2 and Table 3 show the measured values of air leakage for the three elements.



a ≅ 3.0 m
b ≅ 2.9 m
c ≅ 1.4 m

Figure 1. Test arrangement in the laboratory, consisting of walls, ground floor structure, intermediate floor/ceiling structure and a roof structure.

Table 3. Air leakage at 50 Pa differential pressure: mean values of positive and negative pressure. The upper figure indicates the measured leakage of the laboratory test elements, while the lower figure is the corresponding values for normal height walls, for comparison with the field measurements.

Material-combination	**Ground floor** Air leakage $m^3/(m^2h)$	**Intermediate** Air leakage $m^3/(m^2h)$	**Attic** Air leakage $m^3/(m^2h)$
Double gypsum boards	0.59 (0.35)	0.45 (0.26)	0.63 (0.37)
Gypsum board + 'windproof'	0.67 (0.40)	1.27 (0.75)	0.89 (0.53)
Gypsum board + plastic film	1.04 (0.62)	0.73 (0.43)	0.68 (0.40)

The measured values are quite low, and it does not seem to be particularly important as to which type of sealing layer - i.e. gypsum board, plastic film or 'windproof' - that is used. The values are also low in comparison with the field measurements, but it must be remembered that these laboratory elements contained no windows or penetrations, which could contribute to higher air leakage rates.

The table shows that it is possible to make joints with low air leakage, and that the proposed detail designs work well. Admittedly, there is some slight variation in air leakage from one to another of the different joints, but on the whole they are very similar. The element with the double gypsum boards provides the tightest connections when combined with a fibre tape stapled locally over the joints. The joints in the plastic film and 'windproof' elements are detailed in the same way. The differences noted can be due to variations in workmanship.

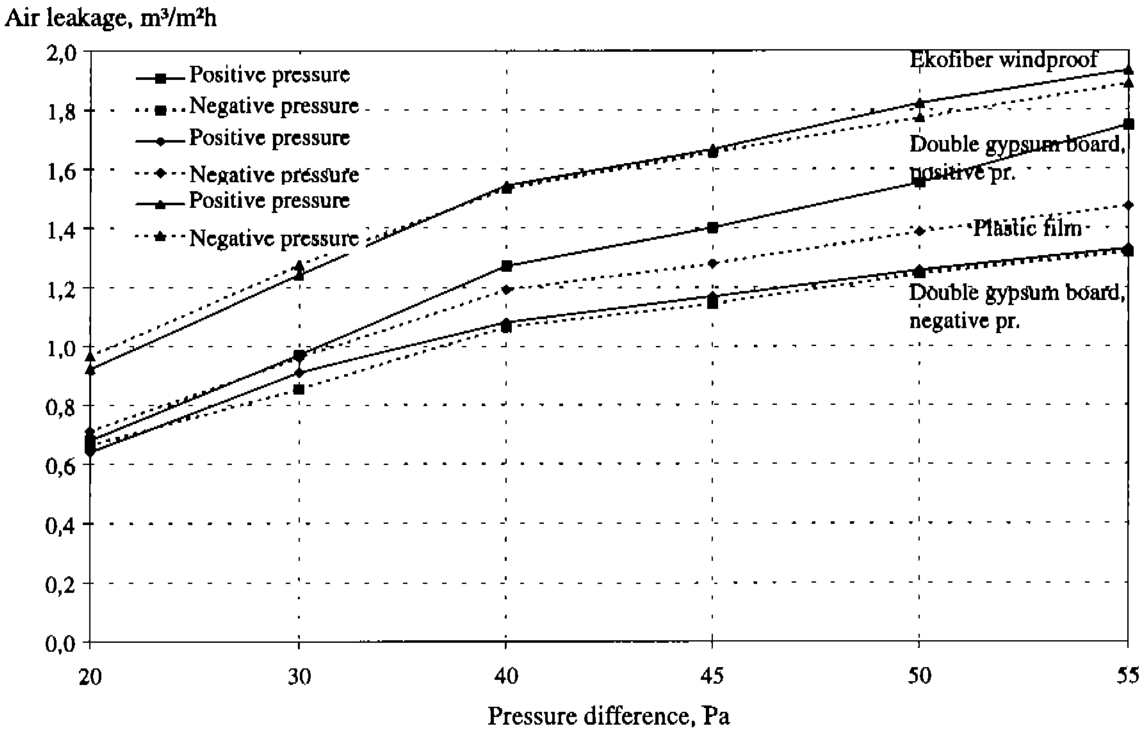


Figure 2. Example of measured results from the laboratory airtightness tests of elements having sealing layers of plastic film, fibre sheet and double gypsum boards with fibre-taped joints respectively. Test arrangement as shown in Figure 1.

The proposed connection designs consist of a number of variations of joints. These joint designs, together with a number of ordinary joints as used (for example) for joints in the middle of a wall, have been tested separately in a smaller test rig. These tests were also conducted using different types of sealing layers: plastic film, 'windproof' board in some cases and gypsum boards.

The comparisons of different materials in the same type of joint design show that, in principle, all the joints are equally airtight regardless of the material used. There are some differences, but they may be due to minor variations in the quality of workmanship. The windproof paper has the greatest leakage through the joints: this may be due to the fact that it is somewhat stiffer than the other materials, and so produces a poorer seal when overlapped.

The measurements also show that making an overlap joint, and then securing the overlap with a wood strip or gluing a sealing strip to it, produces a completely tight joint.

A single layer of gypsum board jointed over a stud produces a poorer joint than any of the other materials jointed with an overlap. However, if the gypsum board butt joint is then smoothed with filler, the seal is as good as that for the other materials. Double layers of gypsum board, with staggered joints, provide good sealing.

Comparison between the measured air leakage rates for the different types of joints and corresponding details in the large elements shown that the latter behave in approximately the same way.

Results and conclusions

The project shows that it is possible to achieve the same good airtightness with 'windproof' paper and gypsum boards as with plastic film. There is only slight air leakage through the two alternative materials ('windproof' paper and gypsum boards): this has been demonstrated in the laboratory and in three of the five buildings in the survey. However, poor design and poor workmanship can result in very poor airtightness in the finished building, as also shown in the field survey.

After interviews, investigation of the six buildings during construction and laboratory tests, the following conclusions can be drawn regarding the airtightness of buildings not having plastic film air and vapour barriers:

- If *the original design* is poor, then much of the sealing will have to be worked out and applied at the site, and the results will not always be good. However, it may be possible to work out how to deal with details, connections and joints at site planning meetings. This also applies if plastic film is used.

- *Work and time planning* (planning work at site) must recognise that good workmanship takes time.

- *Understanding of the need for airtightness* at building sites needs to be improved (although this is often properly understood when building using plastic film).

- *The airtightness should be measured, or be checked as the work progresses.* This would give greater awareness of the importance of good joint designs.

- In the buildings investigated, the main points where improvements were needed were found to be at penetrations, at ceiling joist joints, at intermediate floor/ceiling joints and at floor joints where there was a wooden floor. Good planning, with minimisation of the number of penetrations through the sealing layer, would improve airtightness.

- The laboratory measurements show that designs can be produced that, with proper workmanship, can reduce air leakage to essentially the same level as that produced by the use of plastic film. Plastic film provides satisfactory airtightness if properly applied. The materials that have been considered in this investigation as alternatives to plastic film are those that have good inherent airtightness, and so the work has been concentrated primarily on the design and quality of the joints. This conclusion cannot be applied if a material is used that permits air to permeate through it.

- Comparison of the laboratory results for designs based on plastic film, a plastic fibre fabric (having low permeability) and double gypsum boards as the airtightness layer shows that:
  - designs with a plastic fibre fabric give essentially the same results as those with plastic film. Minor differences are probably due to the quality of workmanship.
  - designs with double gypsum boards (combined with fibre tape over the joints) give approximately the same results as those with plastic film.
  - designs with single gypsum boards and with the joints sealed with filler give the same results as a similar design with plastic film.

- The long-term performance of buildings having gypsum board sealing layers needs to be investigated in a separate project, as should that of designs based on taping of joints etc. The project described in this paper has shown that alternative systems can provide good airtightness, but it is important also to show that this airtightness is long-lasting.

Acknowledgements

The work has been financed by the Swedish Council for Building Research, the Swedish Building Sector Development Fund and by companies in FoU-Väst (R&D - West).

References

(1) *SIKANDER, E. and OLSSON-JONSSON, A.*
"Lufttäthet i hus med träregelstomme och utan plastfolie" [Airtightness in buildings having wooden frame structures and without plastic film], SP, Swedish National Testing and Research Institute, SP Report no. 1997:34 (in Swedish).

(2) *ADALBERTH, K.*
"God lufttäthet - en guide för arkitekter, projektörer och entreprenörer" [Good airtightness - A guide for architects, developers and contractors], J&W, Swedish Council for Building Research report no. T5:1997 (in Swedish).