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THE EFFECT OF VAPOUR BARRIER THICKNESS ON AIR TIGHTNESS

JØRN T. BRUNSELL

Norwegian Building Research Institute
Forskningsveien 3 B
Postboks 123
0314 OSLO 3, NORWAY

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Abstract

Laboratory measurements have shown that when pressure differences are applied across wall and roof elements, the majority of the pressure drop takes place across the vapour barrier. Similarly, field measurements have shown that the majority of the leakage in Norwegian buildings occurs at the joints in the vapour barrier, at wall/floor joints, around penetrations of the vapour barrier and through holes in the vapour barrier. Prior to 1980, the standard vapour barrier in Norway was 0.06 mm thick polyethylene sheeting. However it was suggested that the use of thicker material could reduce the number of holes in the vapour barrier created during construction so in 1980 the use of 0.15 mm thick sheet was initiated and this is now the standard.

This paper reports on a comparative study of the air leakage performance of these two vapour barrier thicknesses. The study considered 10 identical single family houses, five of which were constructed using 0.06 mm polyethylene and five of which used 0.15 mm. Air infiltration measurements were carried out on completion of the houses and repeated four years after construction. The results show that the houses with 0.06 mm film were on average about 17% more leaky than the houses with the 0.15 mm film when they were new.

Background

90% of the people in Norway live in single family houses and 95% of these are built of timber frame construction. In order to make the houses more energy efficient we have looked at different ways of making the envelope more airtight so that the ventilation rate can be controlled by the occupants. Laboratory measurements have shown that when pressure differences are applied across wall and roof elements, the majority of the pressure drop takes place across the vapour barrier. Field measurements of air tightness accompanied by thermography measurements have shown that the majority of the leakage takes place at the joints in the vapour barrier, especially at the wall/ceiling joints. Leaks are also often seen around penetrations of the vapour barrier and through holes in the vapour barrier.

Norwegian housebuilders used to use 0.04 mm or 0.06 mm thick polyethylene film as the vapour barrier in timber frame constructions. However about 1980 0.15 mm thick polyethylene film was introduced to the building market with the aim of reducing the number of holes made in the vapour barrier during construction. It was also expected that the joints in the polyethylene should be tighter with a thicker film.

Method

To verify these predictions 10 identical single family houses were built. They each have 1 1/2 storeys and a basement giving a total floor area of 260 m^2, are heated by electricity using individually thermostated, wall mounted panel heaters and have mechanical ventilation using a balanced system with heat recovery, see figures 1a - 1d. The normal ventilation rate is 100 m^3/h but can be varied up to a maximum of 250 m^3/h. In 5 of the houses 0.06 mm polyethylene film was used and in the other 5, 0.15 mm film was used. All the building details were discussed with the architect, the developer and the carpenters before construction started, in order to find out how the building details which affect air tightness were planned. The final solutions were chosen by the architect and the developer with the aim that the construction details should be similar for all the houses.

Meetings were arranged with all the carpenters before construction started where they were informed about the project, why and how to build airtight houses, the building regulations and about how to measure airtightness.

During the construction we visited the building site several times both to see how the vapour barrier was installed and to interview the carpenters about the installation of the film.

After construction we measured the airtightness of the houses using fan pressurization in conjunction with thermography measurements.

After 4 years the measurements were repeated. At the same time we interviewed the occupants and questioned them about draughts, the ventilation system and whether they had carried out any alterations to the house since the last measurements which could affect the airtightness. In addition we read the electricity meters.

Results

During the construction period no difference could be seen in the number of holes or other damage which could be attributed to the difference in the thickness of the polyethylene film.

The carpenters said that one disadvantage of the thick film was that it was heavier, however, they thought that the greater strength was an advantage.

The airtightness measurements which were carried out on completion showed that the average n_{50} value for the houses with the thick film was 2.9 ach compared with 3.4 ach for the houses with thin film, see figure 2. After 4 years the numbers were 3.2 ach and 3.6 ach respectively, see figure 3.

Thermography measurements showed many different leaks in each of the 10 houses. We were, however, not able to discover any difference in the leakage distribution between the two groups of houses. We found leaks in the vapour barrier joints, e.g. between walls and roofs and in roofs, see figures 4 and 5, and also between different building components where one or both did not have a vapour barrier, e.g. between walls and windows and between walls and intermediate floors, see figures 6 and 7.

In the questionnaire only one occupant complained about draughts saying that there were draughts around the doors and windows. However 70% of the occupants were dissatisfied with the mechanical ventilation system complaining that it had insufficient capacity, that it was noisy and that the heat recovery system seemed inefficient.

The annual total electricity consumption for each house is shown plotted against its air tightness in figure 8. The average annual electricity consumption for the group of houses with 0.15 mm foil is 29800 kWh compared with 30800 kWh for the houses with 0.06 mm thick foil.

Discussion

The fan pressurization measurements carried out when the houses were new showed that the houses with the thin film were on average about 17 % more leaky than the houses with the thick film . After 4 years this difference had apparently decreased to 9 %. This reduction can be due partly to changes carried by the occupants which could have affected the airtightness. It may also be due to the effects of thermal movement.

The standard of building will, of course affect the results. The intention was to let each construction crew build one house with each of the two polyethylene film thicknesses but in practice this was only the case with 6 of the houses. The remaining 4 were built by other construction crews. However the variation in airtightness of houses built by the same crews appeared to be of the same order as the variation between different crews. There are however other factors that could influence the results e.g. which of the houses was built first, or the weather conditions during the construction of the vapour barrier.

The Norwegian building regulations require that the n_{50} value shall be equal to or less than 4.0 ach. This regulation was introduced in 1981. However air tightness measurements made on new single family houses before and after 1981 show significantly higher values than 4.0 ach on average. The low average of the n_{50} value for the houses in this project, 3.2 ach, may thus indicate that the results are influenced by the purpose of the project. The construction of the houses in this study is no less complex than that for the other houses measured so this cannot explain the low leakage.

There appears to be poor correlation between the total electricity consumption in the houses and their airtightness. The spread in individual consumptions is also large but this is to be expected because the total electricity consumption, which includes not only space heating but also water heating, cooking, lighting and power is greatly dependent on the occupants. Part of the spread may also be due to the fact that some of the houses used wood for space heating in addition to electricity, but there was insufficient information to include this in the calculation of the total energy consumption. The group of houses with 0.06 mm thick foil does have a slightly higher average total electricity consumption (3% higher) than the group of houses with 0.15 mm thick foil.

In order to access the cost effectivness of using 0.15 mm thick foil rather than 0.06 mm thick foil the average air infiltration rates for the two groups of houses need to be known. Work carried out previously at NBI (see ref.1) used a computer programme called ENCORE to calculate a relationship between the airtightness and the annual energy consumption for ventilation of dwellings. Using meteorological data for a standard year (1964) for Oslo the predicted energy loss over the heating season due to infiltration for an average dwelling with different values of airtightness is shown in figure 9. From this graph it can be seen that the use of 0.15 mm foil rather than the 0.06 mm foil results in a reduction in the calculated infiltration heat loss for the heating season of about 300 kWh/100m^2. Thus for the test house (floor area 260 m^2) the saving is about 760 kWh. At a current cost of 0.35 NoK/kWh the energy costs are thus reduced by about 270 NoK/yr. Current prices for the 0.15 mm and the 0.06 mm foil are 2 NoK/m^2 and 5 NoK/m^2 respectively. This means that the additional cost of using 0.15 mm thick foil on a test house (300 m^2 total foil) is about 900 NoK . The additional cost for the 0.15 mm thick foil is thus recovered in approximately 3.5 years.

Conclusions

The results from our study show that the 5 houses with 0.06 mm polyethylene as the vapour barrier are on average 17 % more leaky than the 5 houses built with 0.15 mm film. The n_{50} values are 2.9 ach and 3.4 ach respectively

After four years the majority of the houses were less airtight with the houses with 0.15 mm film showing an increase in n_{50} value of about 10% compared with an increase of about 7% for the houses with thin film. The houses with thick foil are thus now, on average, only 10% more airtight than those with thin foil.

Direct comparison of the 2 sets of results is however difficult because some of the owners have made changes to their houses which could affect the airtightness. Increased leakage may also be due to thermal movement.

The current Norwegian Building Regulations require an n_{50} value of not more than 4 ach. The average for the houses in the study at 3.2 ach was well within the regulations. This leakage is actually low compared with other measurements on new single family houses and this indicates that the nature of the project and the efforts to make all the participants aware of air tightness may have influenced the results.

The polyethylene sheet thickness did not affect the position of leaks in the houses as far as could be seen using thermography. It also had little effect on the building process and both thickness were equally acceptable to the construction workers.

Only the total annual electricity consumption of each of the houses was measured and this showed only poor correlation with airtightness. The average consumption for the two groups of houses was similar with the houses with thicker sheet having marginally lower consumption, but the individual consumptions showed considerable spread (±15%).

Using a theoretically calculated relationship between airtightness and energy consumption for infiltration, the direct payback period for the thicker polyethylene sheeting was calculated to be about 4 years, which is short compared with the lifetime of the building. The change to 0.15 mm thick polyethylene sheeting thus appears to be cost effective.

ACKNOWLEDGEMENTS

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REFERENCES

1. Brunsell, J.T.
   Teoretisk beregning av luftlekkasjenes betydning for energiforbruket og ventilation i småhus. Intern arbeidsrapport nr. 229, Norges Byggforskningsinstitutt Oslo 1981.

2. Norwegian Standard 8200. Air tightness of buildings. Test Method.

3. Bankvall, Claes G. Forced convection. Technical Report 1977:21, Revised April 1979. Swedish Testing Institute, Borås.

Figures 1 a and 1 b
Views of the test houses

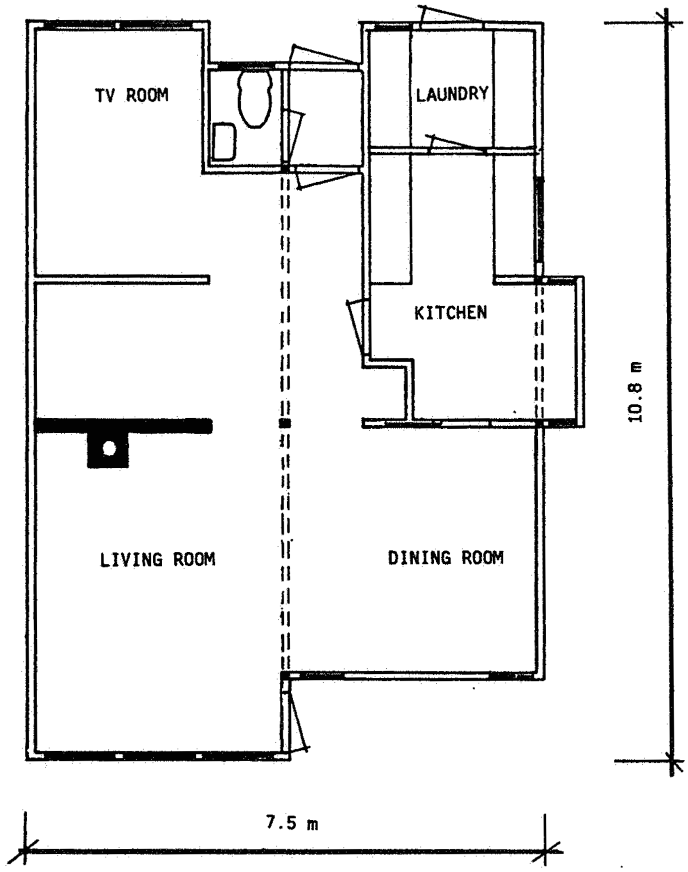

Figure 1 c
Ground floor plan

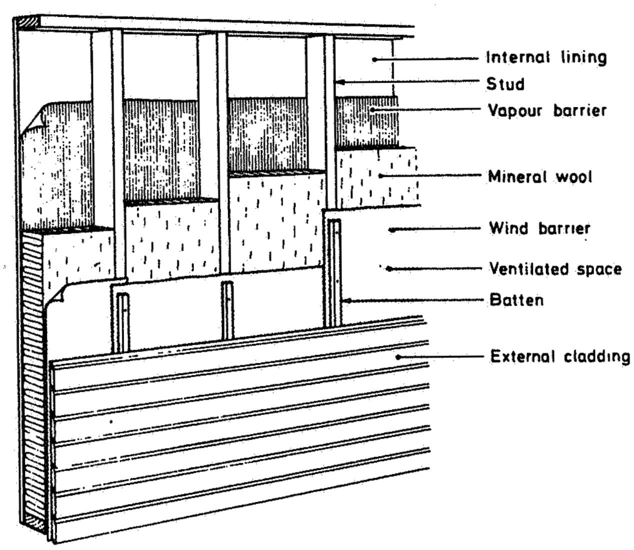

Figure 1 d
Section showing the timber frame wall construction

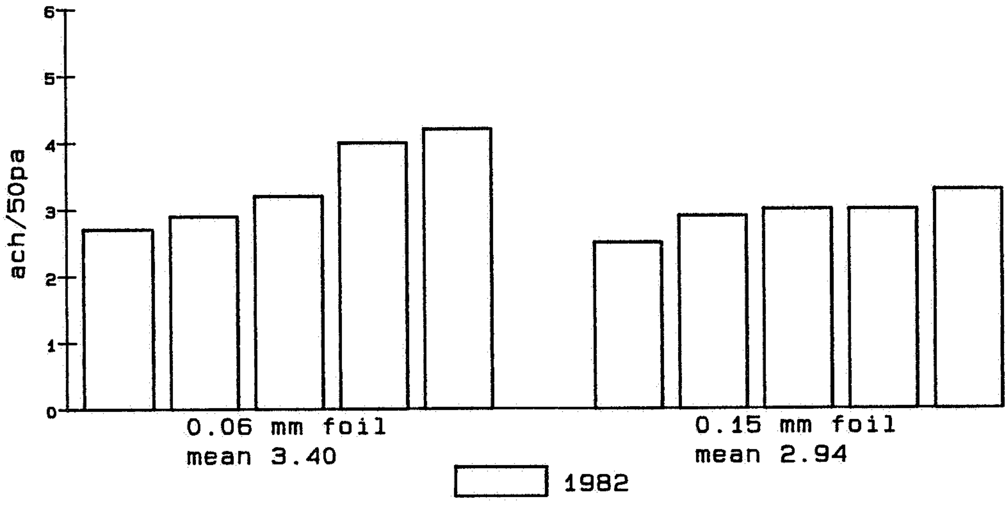

Figure 2
Effect of foil thickness on air tightness

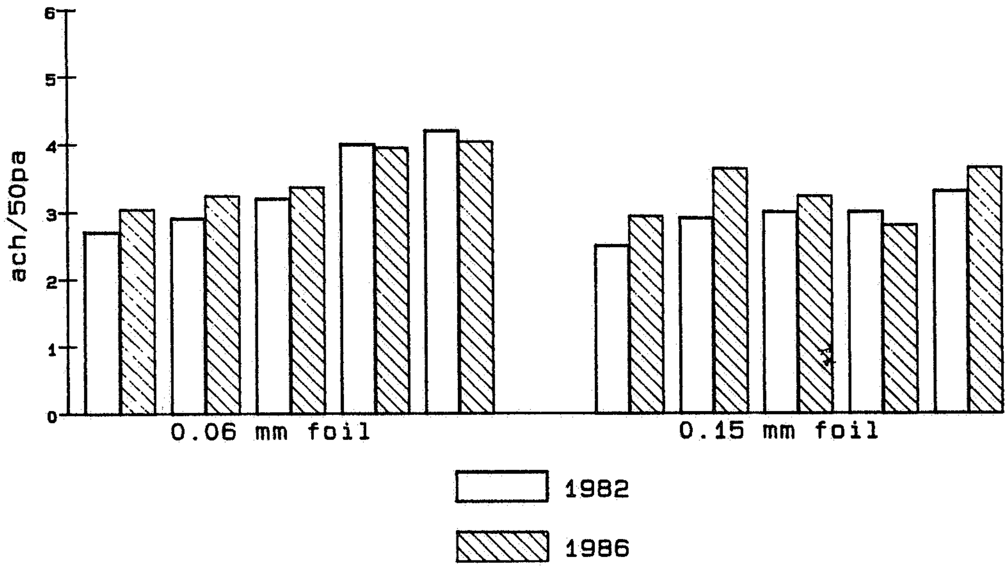

Figure 3
Effect of foil thickness on air tightness
comparison of 1982 and 1986 measurements

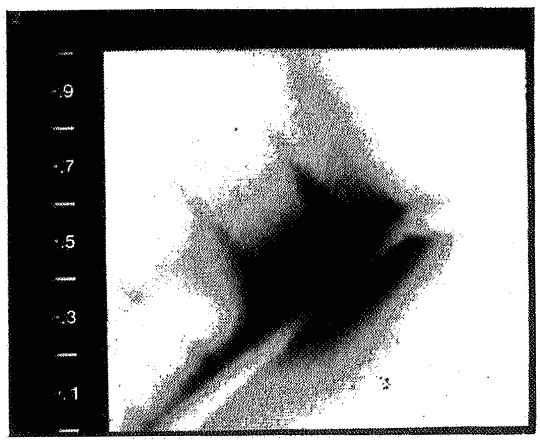

Figure 4
Leak at a vapour barrier joint between a wall and a sloping roof

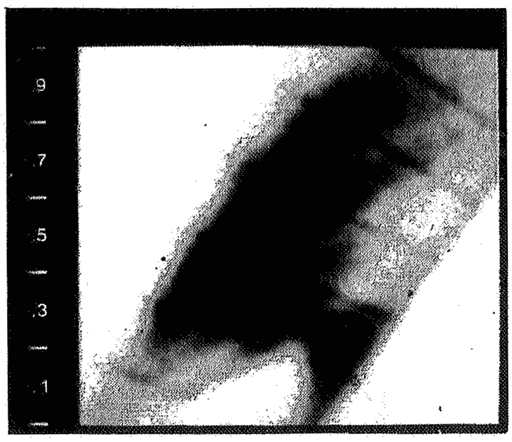

Figure 5
Leak at a vapour barrier joint in the roof

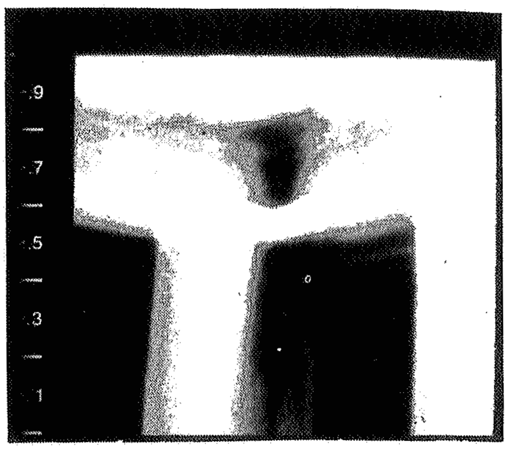

Figure 6
Leak between a window and a wall

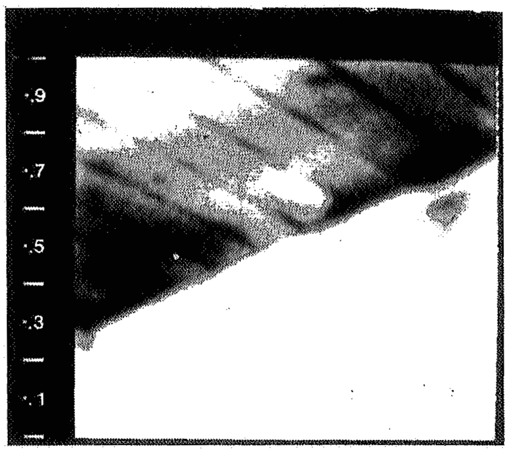

Figure 7
Leak between a wall and an intermediate floor

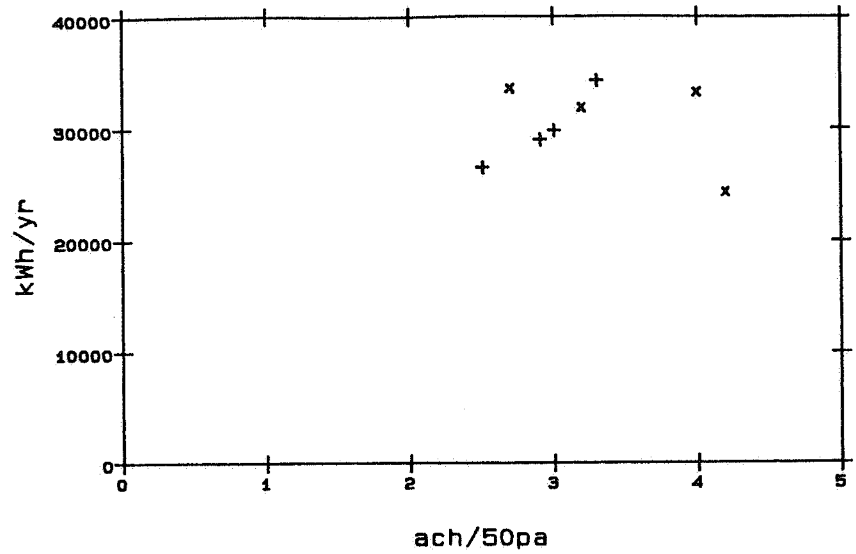

Figure 8
Total annual electricity consumption
vs. air tightness

x 0.06 mm
+ 0.15 mm

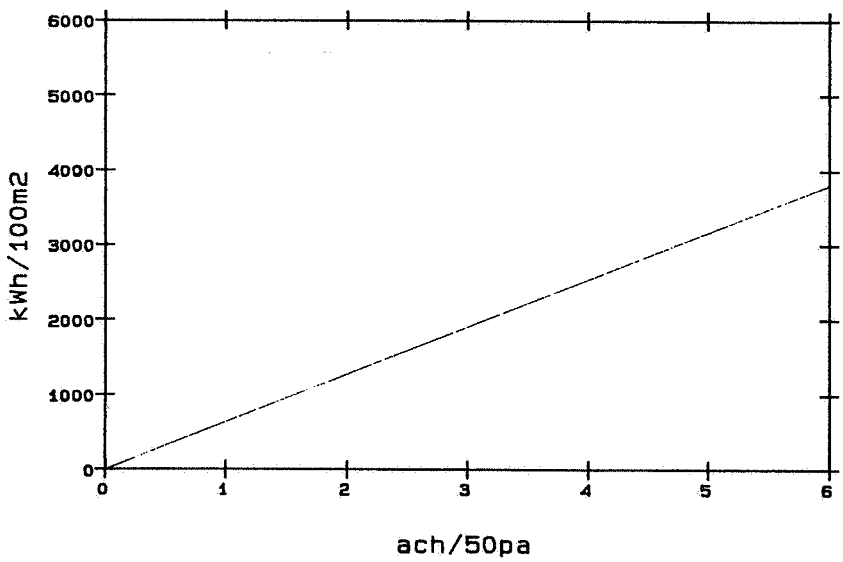

Figure 9
Average annual infiltration energy loss vs. air
tightness for housing in Oslo