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Interior insulation of solid brick walls in cold climates

Erik Brandt ¹, Tommy Bunch-Nielsen ², and Georg Christensen ³

¹ *Danish Building Research Institute, Aalborg University, Hørsholm, Denmark*

^{2,3} *Building- and Environment Technology Ltd, Ballerup, Denmark*

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ABSTRACT

In order to obtain substantial energy savings in old housing stock in Denmark a great number of old solid brick walls are in need of additional insulation. Although all technical aspects call for the use of external insulation interior insulation may be necessary for aesthetic reasons. An insulation method using mineral wool placed in a stud wall construction has actually been used during a couple of decades with very different results as mould on the old surface occurred in some cases and not in others. In the paper a number of stud walls with mineral wool insulation have been analyzed in order to study the conditions for mould growth. Based on the analysis the paper describes the conditions necessary to minimize the risk of mould growth in such walls. Since a certain risk cannot be avoided, it is proposed to use interior insulation based on an inorganic material with high capillary action. This solution may however not be quite as effective an insulation wise since a part of the material will lose some insulating capacity due to a so called "critical moisture content" caused by unavoidable condensation.

1. Introduction

It is well known that substantial energy savings within the building sector also calls for additional insulation of the building envelope. Here solid brick walls give special problems caused by moisture.

It is in general accepted that from a moisture point of view exterior insulation of solid brick walls is by far the best technical solution. Never the less interior insulation is for many reasons often preferred. However if insulation is placed on the interior side of the wall, this may cause such a low temperature and a high relative humidity on the interior side of the brick wall, that mould growth is likely to appear.

We often also - as a first priority - want to raise the interior surface temperature to a level where surface condensation or high relative humidity on the surface is avoided even if optimal insulation standard is not obtained. This is the case when the wish is to avoid mould growth on the surface or to avoid unpleasant thermal radiation from a cold wall.

However mainly architectural points of view often make it impossible to change the exterior surface appearance of our existing brick housing stock and consequently a certain risk must be accepted if additional insulation is placed on the interior side.

In the following the risk of interstitial condensation and mould growth using insulated stud walls are described and as an alternative it is explained how the use of a material with good capillary action may overcome this risk.

2. Interior insulation – as stud walls or as insulating panels

2.1 Moisture transport by diffusion - from the interior

Traditionally stud walls are constructed as seen in fig. 1a. A vapour barrier is placed on the warm side of the insulation material. In fig. 1b is shown the distribution of the water vapour pressure under winter conditions in the ideal situation if the vapour barrier has a high water vapour resistance as e.g. a 0,15mm PE-foil. Theoretically there is no risk of condensation on the old brick surface since the partial vapour

pressure is lower than the saturated vapour pressure at this place. The calculation of water vapour pressure through a multilayer wall has been explained by H. Glaser many years ago (Glaser 1958) and (Glaser 1959) and the theory behind will for this reason not be repeated here.

However, if the vapour barrier is not absolutely air tight especially at the top and the bottom indoor warm and humid air may circulate behind the insulation due to convective forces. In this case condensation is unavoidable. This is shown in fig. 1c. (For clarity the vapour barrier is omitted in the figure).

The same transport mechanisms may occur if an interior insulating panel is used.

2.2 Moisture transport by diffusion - from the exterior

A brick wall may under summer conditions be wet due to absorption of driving rain. In this case capillary action and thermal forces caused by sunshine may transport water from the exterior to the interior part of the wall. The moisture will condensate on the outside of the vapour barrier. This phenomenon is called "summer condensation". This is shown in fig. 1d. If a steel stud system is used this will in most cases not give any mould problems in the first place. However when the heat flow again goes outwards, moisture may condensate on the brick surface and a risk of mould growth will exist. It could be argued, that if no nutrient existed at this place mould growth would not occur. However practice has shown that complete absence of nutrient at this place is not possible – and mould will occur.

3. Interior insulation – material with good capillary action

During the last decade another principle for interior insulation has come into use. Here a material with high capillary action is glued (or placed in mortar) directly to the brick wall without any vapour barrier on the warm side. Since the material is not tight for diffusion, water vapour will penetrate into the wall and condensate in the wall near to the brick surface. However at a certain time the inwards diffusion will stop and due to capillary forces an equilibrium

situation will be established. This phenomenon B. Voss (Voss 1967) has been explained many years ago by. In fig. 1e is shown the zone which is partly saturated when an equilibrium situation is established. However the saturation only comes to a certain point called the “critical moisture content”. This is a situation when the meniscuses are just no longer connected which means, that moisture transport in the form of water is not possible. This is shown in fig. 2 where it can be seen how the meniscuses are just separated. In popular terms it could be stated that moisture transported into the wall by diffusion is transported away from the zone with critical moisture content by means of capillary forces as no vapour barrier is used.

This partly wetted zone has of course a smaller thermal resistance (may be one third) but even with a moderate insulation thickness the total thermal resistance is in most cases acceptable – especially if the problem mainly is to avoid condensation and mould growth on the surface.

The use of a material with good capillary action also eliminates the problem of summer condensation. Further the alkaline property of such materials prevents mould growth.

3.1 Practical examples

In a project sponsored by the Danish Ministry of Social Affairs a great number of houses with interior insulation with mineral wool in stud walls were investigated in order to study if mould could be found in walls insulated within approximately the previous five years. The walls were constructed with and without vapour barriers, had steel or wood studs, one or two layers of gypsum boards and some deviations from this general picture. The parameters and the results are shown in table 1.

It is not possible to find a clear answer to why mould occurs in some cases and not in other. However a further examination of the different investigated walls makes it possible to give some recommendations as to when interior insulated stud walls or insulating panels may be used with only a small risk of interstitial condensation and following mould growth.

4. Recommendations regarding stud walls

If exterior insulation as a first priority is not possible the following recommendations can be given regarding interior insulation of solid brick walls in a “mild” cold climate.

The recommendations regarding insulated stud walls are formulated so as to avoid mould growth on the surface of the brick wall causing bad smell and an unhealthy indoor climate. They also make it likely that temperatures on the new surface facing the room have a temperature high enough to avoid mould growth. Further the separation of the stud wall from the brick wall makes it likely that dust patterns (staining) are avoided.

1. The outside of the brick wall must be in good condition with tight joints and not highly absorbent bricks.
2. The inside of the brick wall must be cleaned from all wall paper, glue and paint.
3. The surface of the brick wall must be even so that convective airflow cannot pass between the existing wall and the new wall – or the insulation must be flexible enough to cover an unevenness of the wall and in this way obstruct air movement.

4. A vapour barrier including air tight joints and penetrations must be placed on the warm side of the stud wall or in the insulating panel.

Further it should be added that experience has shown that studs should be placed apart from the brick wall e.g. 50mm in order to avoid discoloration (dark areas) on the interior surface. Under Danish conditions a stud wall with 100mm of insulation is recommended. Dark dust patterns are more likely to occur with studs of steel rather than wood.

5. Recommendations regarding inorganic insulation boards

Regarding insulation materials with capillary action (e.g. calcium silicate boards) these must be glued to an even surface in order to avoid air pockets between the brick wall and the insulation boards. An insulation thickness of 80mm is recommended as a compromise between “optimal insulation” and the area in the wall with “critical moisture content”. The alkaline properties of the materials prevent mould growth on the brick wall. The surface should be open to water vapour diffusion which means that e.g. silicate paint is applicable.

6. Conclusion

Although external thermal insulation is by far the best technical method when insulating a solid brick wall an interior insulation may for many reasons come into play. The analysis of a number of cases with interior insulation from the past couple of decades has shown that minimizing the risk of mould growth on the interior surface of the brick wall is possible if certain precautions are taken. First of all, the solid wall must not have highly absorbent bricks and leaking joints. Further the interior surface must be free from organic materials (wallpaper, glue etc.) and the vapour barrier must be airtight in order to prevent room air from penetrating into the brick wall. If room air penetrates surface condensation and mould growth is unavoidable under winter conditions.

As an alternative to a construction with 100mm mineral wool insulation in a stud wall the use of a solid inorganic material with a good capillary action is proposed. Here a certain equilibrium condensation – the so called “critical moisture content” - is accepted since the thermal insulation of the material is only affected to a certain degree. However past experience has shown that an insulation thickness of only 80mm is recommended in order to reduce the amount of moisture accumulated in the wall. The alkaline properties of the glue, mortar and the material in itself prevents the growth of mould on the surface of the brick wall.

Further it should be mentioned that the proposed solutions do not meet the present Building Code requirement ($U \leq 0.20 \text{ W/m}^2 \text{ K}$) when refurbishing an external wall. Never the less the solutions proposed might be a realistic alternative due to economic and technical reasons.

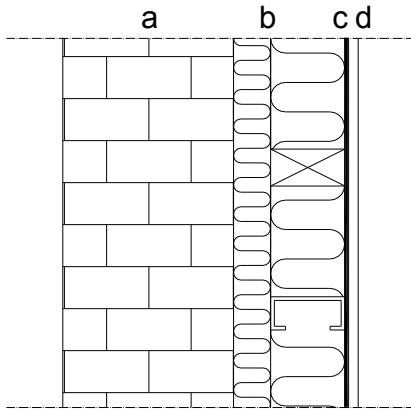


Fig. 1a. Interior insulated brick wall.
 a. Solid brick wall
 b. Insulated stud wall (or insulating panel)
 c. Vapour barrier
 d. 13 mm gypsum board

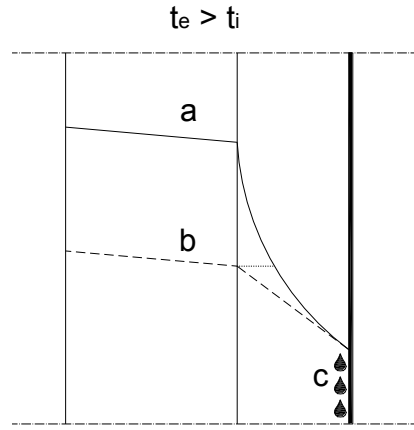


Fig. 1d. Vapour pressure distribution, sun.
 a. Saturated vapour pressure
 b. Actual vapour pressure
 c. Condensation

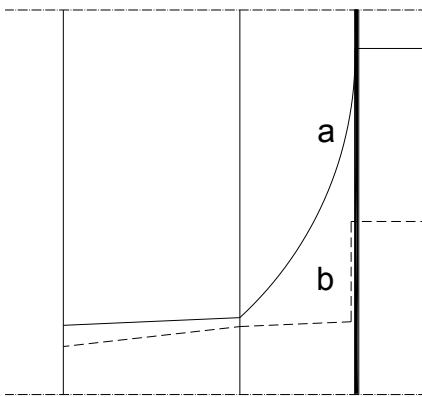


Fig. 1b. Vapour pressure distribution, PE-foil.
 a. Saturated vapour pressure
 b. Actual vapour pressure (no interstitial condensation)

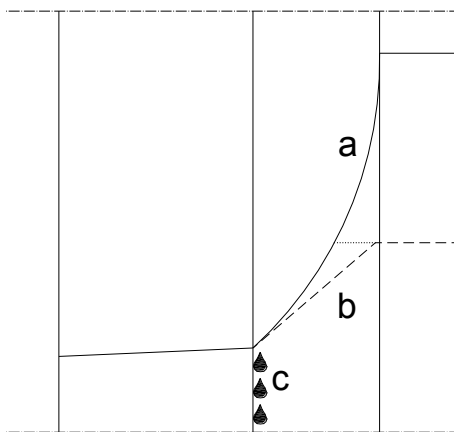


Fig. 1c. Vapour pressure distribution, air leakage
 a. Saturated vapour pressure
 b. Actual vapour pressure
 c. Interstitial condensation

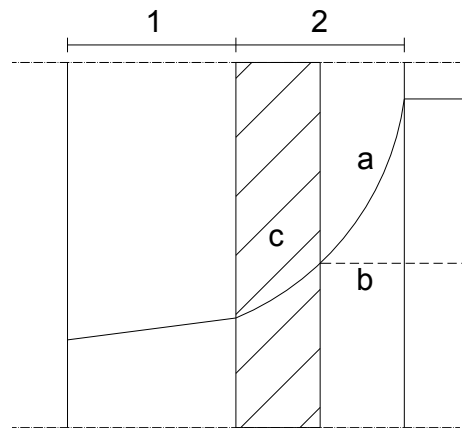


Fig. 1e. Zone with critical moisture content.
 1. Solid brick wall
 2. Calcium silicate boards
 a. Saturated vapour pressure
 b. Actual vapour pressure
 c. Area with critical moisture content

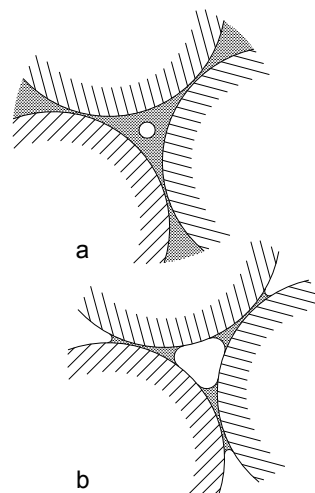


Fig. 2. Critical moisture content.
 a. Menisci filled, moisture transport possible
 b. Menisci not filled, moisture transport not possible

Table 1. Wall/Insulation systems investigated.

	Brick wall mm	Insulation mm	Stud wall	Layer of 13 mm GB	Paint	Vapour barrier	Mould
1a	340	100	Steel	2		+	Yes ¹⁾
1b	340	100	Steel	1 ²⁾	+	÷	Yes
2	230	100	Steel	1		÷	No
3	350	20 ³⁾		1	+	÷	No
4	110	100	Steel	2		+	Yes ⁴⁾
5	230 ⁵⁾	50	Wood	1	+	+	No
6	230	50	Wood	1		+ ⁶⁾	Yes
7	230	100	Wood	1		+	No ⁷⁾
8	230	125	Wood	1		+	No

¹⁾ Air leakage in vapour barrier

²⁾ Calcium silicate boards, 12 mm

³⁾ Mineral wool boards in bath rooms

⁴⁾ Only in corners

⁵⁾ Aerated concrete as facing wall

⁶⁾ Two vapour barriers

⁷⁾ In general OK – 10 % with mould in corners

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