Risk assessment on interior insulation

Where do we need more knowledge?

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Risk assessment of interior insulation – Where do we need more knowledge?

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ABSTRACT. Building investigators often find moisture and mould growth behind interior insulation, and as a result many practitioners hesitate to recommend interior insulation. This hesitation might be appropriate; however, it might be based on biased information. A systematic in-situ investigation is needed, including assessment of the moisture conditions behind interior insulation, the quality of the building envelope, the quality of the vapour barrier and type and thickness of the insulation material. On this basis, experiments in climate simulators must be conducted. In the experiments, the three parameters must be varied to determine what the risk is of high relative humidity behind interior insulation with given parameters. As a result, it will be possible to make a better and more specific risk assessment of interior insulation. The ultimate goal is to quantify the risk; a true risk assessment.

Keywords: Risk assessment, in-situ investigation, climate simulator, building envelope

1 Introduction

This paper addresses moisture problems characteristic of traditional interior insulation. Traditional interior insulation is here defined by using traditional insulation material, in contrast to less traditional systems with capillary active insulation material. The traditional interior insulation system must include insulation material (e.g. mineral wool or EPS), a tight vapour barrier and a protective backing e.g. gypsum board.

In principle, moisture problems related to traditional interior insulation can be limited to either a faulty vapour barrier or a building envelope that allows driving rain to pass. It seems to be easy to eliminate the problem by defining a rain-tight building envelope and a tight vapour barrier as prerequisites for interior insulation to be installed. This has been known for a long time, but still examples of moisture occur behind new interior insulation. Some guidelines therefore describe traditional interior insulation as a risky way to apply additional insulation material. Consequently, many practitioners hesitate to recommend this solution.

This hesitation might be appropriate, however, it might be based on biased information. Moisture experts are only involved when there is a problem; accordingly they see mainly cases where the interior insulation has caused problems. Moisture experts with experience from practice might therefore overestimate the problems with interior insulation. Interior insulation may be deselected just to be on the safe side. The consequences could be that:

- The building envelope may be insulated on the exterior. In some cases this will be inappropriate from an aesthetic point of view.
- Only cavities are insulated. Cavities are often small and filling them with a conventional insulation material is seldom enough to meet modern standards for U-values.
- No insulation materials are added to the building envelope.

The last two options would counteract the wish for highly energy efficient building envelopes.

Having said that, insulation can cause moisture problems in practice, so it must be emphasised that the number of cases is unknown, where traditional interior insulation works without moisture problems. Likewise, the number of cases is unknown, where traditional interior insulation has caused undetected moisture problems, e.g. mould growth which nobody has reacted on yet.

Instead of judging traditional interior insulation to be too risky to use, a proper risk assessment is called for. Until then, more knowledge is needed on how often moisture problems occur, why they occur and how the risk can be reduced most effectively.

2 What is behind the interior insulation?

A major problem in determining the condition of a wall with traditional interior insulation is that moisture and mould growth is hidden by the insulation. Often this is only detected because the building users experience indoor climate problems.

A defective vapour barrier is often suspected of causing moisture problems behind interior insulation. To check whether there is a moisture problem, the vapour barrier must be broken. If no moisture problem is found, hopefully, the new vapour barrier will be placed just as carefully as the original, as the inspection itself might otherwise cause a moisture problem.

2.1 Experience from practice

An inspection of whether internal insulation has caused moisture or mould problems will always be destructive. Therefore, inspections are generally only undertaken if the internal insulation is suspected of being the cause of a problem or if the insulation is to be removed for some reason.

2.1.1 Buildings with indoor air problems

When building users complain about health problems that might indicate exposure to mould growth or dampness in buildings e.g. respiratory symptoms, respiratory infections and exacerbation of asthma [1], moisture or mould experts will begin to look for visible signs of moisture or mould problems. Experience has shown that, if elimination of the visible problems does not help sufficiently, the problem is likely to be hidden by interior insulation.

Figure 1. Example of outer wall of 230 mm lightweight concrete where interior insulation has been removed; revealing areas with mould growth.

Figure 1 shows an example of what can be hidden by interior insulation and how removal of the entire interior insulation can help the investigator to understand the history of the moisture problems in the house. Figure 1 is from a building where the inhabitants had respiratory problems. There were no visible signs of moisture problems on the wall, but when the interior insulation was removed large areas with mould growth became visible. Bituminised paper (dark wallpaper) became visible under a layer of ordinary wallpaper. There seems to have been moisture problems before, which were interpreted as moisture from the outside or the ground. It has been tried to stop the problem by applying a tight barrier (bituminised paper) to the wall and cover it with ordinary wallpaper. Later the interior insulation with a vapour barrier was installed, without removing the old layers of wallpaper. Apparently the bituminised paper was not effective; when the interior insulation was removed, there were water droplets at the vapour barrier on the side facing the outer wall and embedded steel pipes for cables were heavily corroded.

In such a case, it is difficult to determine why there was mould growth; whether the moisture came from the outside, the ground or the inside. It could also be a combination. However interior insulation should not have been installed before the original moisture problem had been solved. Unfortunately, it is often impossible to find any records of why specific remedies to solve moisture problems have been chosen; insulated incidents with moisture are often treated ad hoc. Depending on the skills of the decision-maker or craftsman this sometimes becomes a question of trial and error. Applying interior insulation can hide the real problem for several years and the original decision-maker or craftsman may therefore never know that the solution did not work. On the contrary, as the problem has not resurfaced for several years, they may think this was a good solution.

Removing the entire interior insulation like in Figure 1 is the best way to determine whether mould or moisture problems are hidden behind the insulation. However, the costs for restoring the wall might be considerable, e.g. the whole room may have to be repainted or repapered to make all walls look the same. Therefore, a simpler method is often used; with a hole saw the interior insulation is removed at a spot where it may be less visible but still in an area where moisture problems are likely to occur. Areas behind sofas or cupboards in corners are often chosen. This means that approximately only 2 % of the wall area will be inspected

Unfortunately, there is no guaranty that the inspected area is representative of the whole wall; sometimes the outcome of a mould test would be totally different if the sample was taken 20 cm beside the chosen area, especially if the problem is very local, or not very massive. There is no effective way to e.g. scan the wall before the area is chosen. Consequently, the samples are often taken close to known thermal bridges or at joints.

2.1.2 Inspections in randomly chosen houses

It is difficult to find building owners who are willing to remove interior insulation in a building where it apparently does not cause any problems. Therefore, unbiased information on the percentage of cases with interior insulation where the internal insulation causes moisture problems is difficult to obtain. In Denmark Bygge- og Miljøteknik [2] have made a small study on nine cases with interior insulation where no moisture problems were reported, but the interior insulation was removed or investigated for other reasons. The results are shown in Table 1. Moisture measurements were only performed where timber constructions were used.

The study showed few cases with moisture or mould problems behind the interior insulation. Mould growth was only detected in cases with high moisture exposure like bathrooms (cases 2b and 6) or where the problem was rising damp (case 5a). Only in case 2a the mould growth is assumed to be due to a faulty vapour barrier, based on massive dust found in the insulation material. This is interpreted as air movements in the insulation as a result of a faulty vapour barrier.

Table 1. Investigation of moisture and mould conditions in nine randomly chosen buildings, based on [2]

Case	**Original wall**	**Interior insulation**	**Vap our bar rier**	**Raised moisture level**	**Mould growth**	**Test method**	**Remarks**
1a	110 mm brick	100 mm	Yes	No	No	1 x 200 mm opening	Ventilated space between original wall and insulation
1b	Timber framing	100 mm	No	No	No	1 x 200 mm opening	Ventilated space between original wall and insulation
2a	340 mm brick	100 mm	Yes	No	Little	Insulation removed	Air movement in insulation
2b	110 mm brick	100 mm	Yes	?	Yes	Insulation removed	Bathroom
3	70 mm concrete 50 mm insulation 150 mm concrete	50 mm	Yes	No	No	2 x 200 mm opening	Bathroom
4	230 mm brick	100 mm	No	No	No	Insulation removed	Low occupancy
5a	230 mm brick	20 mm	No	?	Yes	Insulation removed	Complaints, Rising damp
5b	230 mm brick	100 mm	No	?	No	Insulation removed	Complaints
6	Timber framing 110 mm brick	100 mm	Yes	?	Yes	Insulation removed	Bath room and exposed corner
7	Concrete 50 mm insulation concrete	100 mm	Yes	No	No	Insulation removed	Gable walls
8	230 mm lightweight concrete	50 mm	Yes	No	No	Insulation removed	
9	230 mm brick	50 mm	Yes	No	No*	Insulation removed	Also vapour barrier behind insulation.

* Mould growth on the outside of vapour barrier between brick wall and insulation

This very small study indicates that the condition of the vapour barrier may not be as critical as generally supposed unless there is a high internal moisture exposure. Other factors may be more decisive. To ensure that resources are used most effectively, this must be investigated.

2.2 New knowledge changing Danish guidelines

In Denmark, there are several guidelines to how internal insulation must be performed, e.g. [3], [4] and [5]. The recommendations have changed over time as knowledge has increased, more examples of mould problems related to interior insulation has been reported and new challenges e.g. higher demands on energy efficiency have been faced.

2.2.1 No old wallpaper

Theoretically, a tight vapour barrier and an existing wall without moisture problems should be enough to ensure interior insulation without moisture or mould problems. Before installing interior insulation older recommendations stated that to avoid an extra vapour barrier, which might even be in the wrong place, existing wallpaper and paint should be perforated by brushing the area with a steel brush.

However, experience has shown that if vapour reaches the original backside of the wall, organic material from e.g. old wallpaper or wallpaper glue will facilitate mould growth. Therefore, the problem is not only a question of risk of interstitial condensation but even more a question of reducing nutrients for moulds. Modern recommendations state, that the existing wall must be cleaned of any remains of former internal surface treatments.

2.2.2 Better insulation

As the demands for energy efficiency increases, insulation will have to be more efficient. Correspondingly, the original wall will be colder. This will increase the demand for a tight vapour barrier. Some of the cases in Table 1 without vapour barrier may have had moisture or mould problems if the insulation had been more effective.

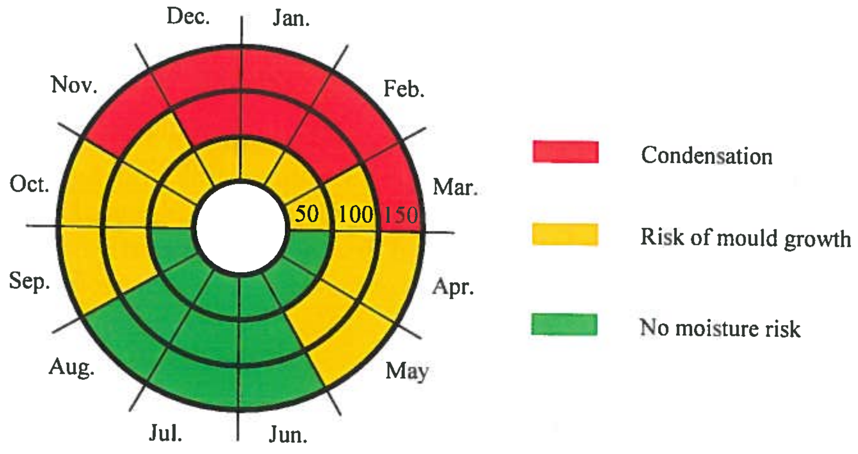

Figure 2. Risks behind interior insulation without vapour barrier with different thicknesses, over a whole year. Inner circle: 50 mm, middle circle: 100 mm, outer circle: 150 mm

Figure 2 illustrates how the risk of condensation and risk of mould growth increases as the thermal resistance increases. The example is of a cavity wall, i.e. two brick walls separated by a 70 mm cavity filled with mineral wool (λ-value: 0.044 W/m·K), internally insulated with mineral wool and battens (combined λ-value: 0.045 W/m·K), vapour retarder and a 2 x 13 mm gypsum board. The calculation was made by a simple Glaser calculation according to [6], based on outdoor climate according to the Danish Design Reference Year (DRY). Risk of mould growth is determined according to [7].

3 In-situ investigations

To gain sufficient knowledge of how often and why interior insulation cause mould or moisture problems, it is necessary to remove the interior insulation from many walls. The small investigation in [2] has only given indications, and nine buildings are not sufficient to draw any conclusions that might affect how we will insulate buildings in the years to come. A systematic, scientifically based in-situ investigation should be made. In this chapter a possible way to obtain this is sketched.

3.1 Choosing examples

The first step must be to define how many buildings should be inspected to get data that would ensure statistically significance. This is based on how many buildings already have interior insulation and a fraction of these must be investigated. Furthermore, the investigated examples must be chosen randomly.

As a consequence of the many examples of mould growth behind interior insulation several Danish housing societies have decided to remove interior insulation whenever a tenant moves out of a dwelling. Teaming up with these housing societies would make it possible to investigate random buildings, although the moisture load would all be in the humidity classes of dwellings according to [6]. These classes are also the most interesting; if humidity load is important, lower classes would be less prone to moisture problems than higher classes.

However, it will probably be necessary to investigate other examples as well, as the dwellings of the housing societies probably will have an age bias; most Danish housing societies only have dwellings built after 1900 and approximately 80 % of the dwellings in housing societies are built after 1957, while approx. 55 % of the total amount of dwellings are built after 1957.

The scientific value of the investigation would be greater if the investigation was international. In this way more building traditions would be investigated and local climatic factors could be taken into account. After all, driving rain is an important factor of the weather load of all Danish buildings; while this factor is more diversified in e.g. Germany [8].

It will not be enough to investigate the original backside of the wall, as this shows only the result of the interior insulation; however, the reasons for the result are just as important. The investigation should therefore, if possible, include:

- Description of the whole wall including interior insulation (materials and dimensions)
- Humidity load (e.g. occupancy as persons per m^2, ventilation)
- Condition of vapour barrier
- Condition of original wall (e.g. condition of surface treatment or joints, moisture barrier toward the foundation)
- Moisture measurement at the backside of the original wall
- Mould measurements at the backside of the original wall
- Registration of any abnormalities (extra vapour barrier, air gaps, ventilation etc.)

3.2 Test method

A few holes through the interior insulation are insufficient to assess how the entire interior insulation has affected the moisture conditions of the wall. Only if there is access to the entire wall, it will be possible to make a proper assessment of whether interior insulation has resulted in moisture or mould problems or not. Therefore, the whole interior insulation must be removed.

When the entire wall is free of interior insulation it might be possible to recognise patterns of mould growth. Combined with knowledge of the construction of the original wall this can help the experienced investigator to decide whether water penetrations through the wall, defects in the vapour barrier or thermal bridges are the most likely to cause the mould growth.

3.3 Important parameters

In general interior insulation will decrease the drying potential of the original wall, as the wall will in general be colder in the winter. Theoretically, the most decisive parameters are known that cause moisture and mould problems behind interior insulation. However, it is unknown how often they are the cause of moisture and mould problems in practice. Quantification of the parameters can be difficult when the wall is inspected. To make quantification practical, simple scales can be necessary. The scales should be revised after a pilot testing of the scales.

The expected important parameters are:

1. *Quality of building envelope*. Internal insulation with an effective vapour barrier will prevent drying out toward the inside of the building, therefore, the existing wall must be tight against driving rain and must be protected against rising damp. Quantification of the quality of the building envelope could be a 3 step scale: 1. Building envelope not tight toward driving rain, 2. Rising damp, and 3. No moisture from the outside
2. *Quality of vapour barrier*. If the vapour barrier is faulty, moist warm indoor air will reach the inside of the original wall where there is a risk of condensation or mould growth. Quantification of the quality of the vapour barrier could be a 4 step scale: 1. No vapour barrier, 2. Not tightened vapour barrier, 3. Vapour barrier with perforations, and 4. Tight vapour barrier
3. *Indoor humidity*. Measurements of the indoor humidity are the most precise way to determine this parameter. Unfortunately, these are rare. Instead the indoor humidity could be quantified according to the humidity classes in [7], based on occupancy and ventilation.
4. *Insulation thickness*. The important factor is the thermal resistance, R, which is most easily described in-situ by the type and thickness of the insulation. The quantification would be the R-value.

The outcome of the in-situ investigation is supposed to be a description of how often interior insulation in practice result in moisture and mould problems combined with the most decisive parameters for its failure, including how often each of the parameters have a value that have resulted in failure.

4 Experiments in climate simulator

When the in-situ investigation has been finished and the results are known, the scientific approach is to recreate reality in the laboratory by means of experiments in a climate simulator. The results of the in-situ investigation will be used to determine the set-up of the tests. This paper describes the set-up based only on the state-of-the art.

Each test should be performed with at least three replications and the hygrothermal conditions behind the interior insulation should be recorded in each test specimen. Mould growth will not be determined.

4.1 Test subjects

The number of test subjects depends on the capacity of the climate simulator, available time and number of decisive factors. Massive brick walls could be the basic test subject, but cavity walls or lightweight concrete walls may also be relevant. A gap between the wall and the interior insulation could also be an interesting variation. Beside these basic specimens of walls, possible variations on the test subject could be:

- *Joints* with and without faults
- *Vapour barrier* perforated or tight
- *Insulation thickness* of e.g. 100 mm and 200 mm

4.2 Climate conditions

The outdoor climate could be varied in different ways, simulating outdoor conditions at different locations. Driving rain should possibly be varied. At least two indoor climates should be simulated e.g. humidity classes 2 and 3 according to [6].

However, a setup like this would be very time consuming. The climate conditions could simulate only one month e.g. by using the mean values of inside and outside temperature and humidity of the coldest month. Nevertheless, tests with 50 mm lightweight concrete (without driving rain) have shown that it takes more than one month to get equilibrium in the construction. The specimens in this project will probably need longer. It is therefore not realistic that experiments should be performed by one single institution. Several laboratories with climate simulators should therefore make a collaboration to ensure that the experiment can be finished within a reasonable timeframe.

The results of the experiments must be compared with the results of the in-situ investigation; they may not always compile as the experiments are more controlled than reality.

5 Computational simulations

To predict moisture conditions in future constructions, the results of the experiments should be integrated into computer programs allowing computational simulations of different situations as interpolations between the tested scenarios. There will be an uncertainty as to how reality compares with the experiments and this uncertainty can be used to take a probabilistic approach to how interior insulation performs.

6 Risk assessment

The main goal is to be able to make a risk assessment of a specific case i.e. to predict the likelihood that interior insulation will cause moisture or mould problems. The outcome of the experiments in the climate simulator will only be the hygrothermal conditions in the construction. However, these results may be further converted to risk of mould growth e.g. according to [7], although this will involve further uncertainties.

The risk assessment should be a part of the developed computational simulation. Here the comparison of the in-situ investigation with the experiments should be used, and it would probably be necessary to go back to the in-situ investigation to evaluate how e.g. buildability and craftsmanship (and thereby quality assurance) can be taken into account. When these parameters are low, the outcome of the experiments with perfect specimens is presumably different from what was seen in the in-situ test. The specimens with faults will only be the extremes, reality has more distinctions.

Supposedly important factors for the risk assessment will be:

- Material properties, some materials are more susceptible to moisture than others, depending on moisture buffering capacity, capillary suction etc.
- Moisture load
- Level of quality assurance, both in the design and on site

The result will probably not be moisture risk as a percentage, as this would purport to be a certainty, which there is very little justification for until the system has been validated for several years. Instead the result could be a ranking in a moisture risk class. The system would make it possible for the building owner to compare the moisture safety class for different solutions and thereby decide how to reduce the moisture risk to a level he can accept. For example, it would be possible to decide what is more cost-effective: to demand more quality assurance or change the construction.

7 Conclusion

There is theoretical knowledge of how interior insulation works hygrothermically and reasons for moisture or mould problems behind the interior insulation are understood. However, in practise there are numerous examples where moisture or mould problems occur behind interior insulation even in recently installed insulation. As a result many practitioners hesitate to recommend interior insulation. There is too little knowledge of how many cases of existing traditional interior insulation result in moisture or mould problems in practice. Without this information there is a risk that many buildings will not be additionally insulated or exterior insulation will be used also in cases where the façade was worth preserving.

Instead of judging traditional interior insulation to be too risky to use, a proper risk assessment is needed. Therefore more research is called for on this subject. A possible project is sketched in Figure 3. The project is only realistic if several institutions collaborate.

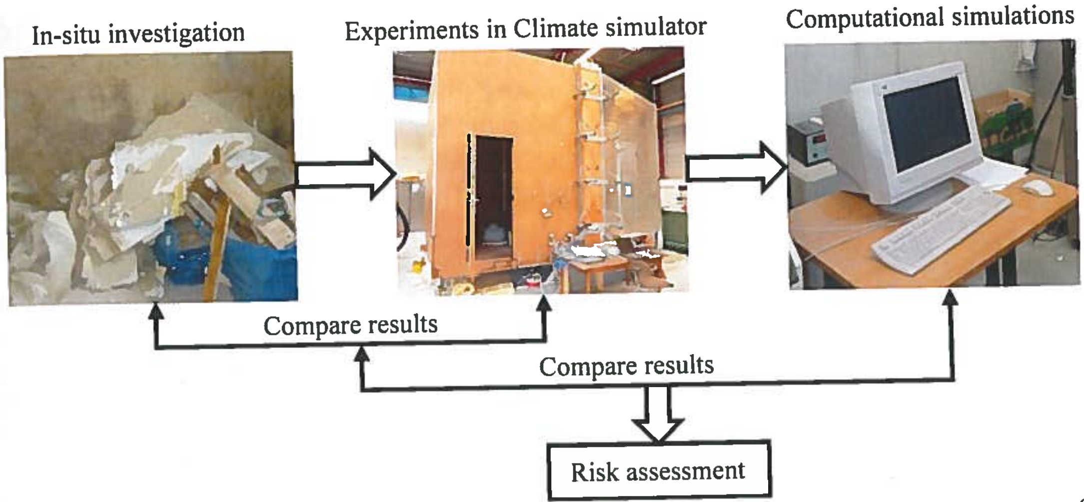

Figure 3. Principle of a project to gain more knowledge of how to make risk assessment of traditional interior insulation based on practice (in-situ investigation), experiments and simulations.

As a result it will be possible to make a better, more specific risk assessment of interior insulation. The ultimate goal is to be able to quantify the risk; a true risk assessment. If the risk assessment would result in a ranking of different solutions in different moisture safety classes, the building owner can decide what solution would be the most cost-effective with the lowest acceptable moisture risk.

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