Reduced service life due to common building failures in Denmark

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ABSTRACT

Durability is more than wear and tear in the sense that many problems occur that terminate the service life of building materials and components far too early. These problems are usually associated with big expenses for repairs or exchange of the involved materials and components. Moreover, additional expenses are very often needed for necessary repairs of adjacent materials/components and/or correction of the constructions in order to avoid that the problems reoccur.

Some of the most common failures in Denmark are associated with roofs including flat roofs and sloped roofs, bathrooms including watertight membranes and floor gullies, wooden floors and decay of buildings due to dry rot. In recent years big problems have also been encountered in constructions with high humidity levels associated with health problems and resulting in mould growth. Mould problems have lead to considerable expenses, e.g. due to lack of maintenance and/or incorrect refurbishment.

This paper gives an overview of a number of the most frequently occurring building failures and their reasons and gives examples of how they are dealt with. Finally the paper discusses how the different reasons for building failures might be attacked in order to reduce or even avoid failures in the future.

KEYWORDS

Building surveys, building failures, service life, roofs, bathrooms, floors, mould.
1 INTRODUCTION

Building failures have a significant effect on the service life of building materials and components and may in severe cases reduce the service life to almost nothing. Problems with materials and constructions can never be totally avoided. However, considering the nature of the failures seen in practice and not least the huge number of failures that occurs, it should be possible to gain great benefits just by reducing in the number of failures. It is believed that the situation can be improved by attacking the problems systematically, even though this should not be considered an easy task, as much effort has been put into this area for many years - apparently without great success.

The reasons for the failures are many but 3 of the most common are the following:

Many of the failures occur due to the fact that common knowledge is not used. For example the well-known fact that a vapour barrier should not only be made of a vapour retarding material, but it should also be mounted so that it is airtight in order to avoid humid indoor air from penetrating to colder parts of the construction. Nevertheless, in many cases the vapour barrier is not mounted correctly with the consequence that problems are encountered soon after the building is taken into use.

Another big problem is the use of well-known materials and constructions in new ways. For example the design of many floor constructions has been changed due to energy saving requirements in the building regulations (or energy saving measures made by the occupants). These changes may at first appear to be minor, but unfortunately the results could be major problems, e.g. with mould growth in the constructions.

The last problem to be mentioned is the introduction of new materials. The use of new materials always calls for precaution as no experience exists. Quite often it will be necessary to perform some sort of experiments – or at least an analysis – in order to assess the use potential. A number of the new products come without documentation for the most necessary performance properties, making it difficult – if not impossible – to use them correctly. Even worse, the test results for some products are misinterpreted by the supplier so that the users are mislead, e.g. claiming that a reflective foil has the same effect as a thick layer of insulation.

In the following a number of examples of common building failures will be given followed by a discussion about the reasons for these failures. Finally there is a discussion of how the problem of building failures might be reduced.

2 PROBLEMS WITH ROOFS

During the last 30 years many changes have occurred as regards roofs in Denmark. Some of these are due to ever-stricter energy saving measures now calling for the use of about 300 mm insulation in a roof construction. Besides, new building components and materials have been introduced in flat roofs as well as in sloped roofs resulting in a number of problems.

2.1 Sloped roofs

For sloped roofs 2 major problems are:

- Change of constructions with little or no insulation to energy efficient constructions have lead to failures due to insufficient ventilation after the change and/or failures in the vapour barrier.
- Change of constructions with roof tile underlay from ventilated to unventilated type.

The first issue is an example of a technical problem with an easy and well-known solution, namely the introduction of a decent vapour barrier, if necessary, and the use of existing directions on how to add
insulation to an existing construction without jeopardizing the ventilation and without introducing risks of condensation in colder parts of the construction.

The second issue is more difficult. Some 10 years ago a number of new thin membranes were introduced on the Danish market as alternatives to the existing roof tile underlays. The advantage of the new products was that not only were they watertight, but they were also vapour permeable. Consequently, the traditional ventilation between insulation and roof tile underlay could be omitted and the roof construction did not need to be as thick as before. Unfortunately the new products did not perform without problems, as some of them were only watertight for a short period of time. In such cases an investigation of the new products was launched especially to identify the necessary performance properties including the degradation mechanisms acting under the in-use conditions. One of the problems identified was the so called “tent effect”, i.e. water penetrated some of the products when these were lying directly on a substrate for example plywood – the effect of water penetration was similar to water running through an old fashioned tent when it was touched on the inside. A test method was elaborated due to these investigations and a number of products have been tested resulting in the withdrawal of quite a few products from the market. Another problem was the workmanship as there was a considerable lack of qualified information on how to make this new type of constructions. This problem was solved when new directions were sent out. Besides, in a new voluntary association all suppliers have to document how a number of commonly used details are made (by building them in a mock-up). However, there are still problems especially with products that are watertight only for a short period of time, but so far further reasons/degradation mechanisms have not been identified.

Figure 1. Deterioration of plywood in a sloped roof made with wood-based elements assembled in situ. Due to leaks in the joints between elements in the corners, humid air has penetrated into the construction, where it condensates on the cold surfaces above the insulation.

2.2 Flat roofs

For flat roofs 2 major problems are:

- Change of constructions from solutions made in situ to prefabricated solutions assembled on the building site.
- Change of constructions from ventilated to unventilated have led to a significant number of failures due to insufficient information/knowledge about a new type of vapour barrier.

The first subject is especially connected with leaks in the vapour barrier over the joints and lack of securing the joints between elements from penetration of precipitation immediately after assembling. The result of both is a high humidity level in the elements resulting in mould growth and in extreme cases in deterioration of the wood. Leaks in the vapour barrier are mainly due to the failure of recognising the importance of securing the joints from beneath and - to a much lesser extent - due to problems with the tolerances of the joints, which the present solution is unable to accommodate.
The second subject is connected with the large proportion of flat roofs that are made as prefabricated wooden elements with a special vapour barrier – Hygrodiode – that not only acts as a common vapour barrier but also allows humidity from the roof construction to penetrate back to the interior of the building in summer time. The major part of roofs of this type performs without problems but unfortunately the use is restricted as the performance is dependent on the sun to warm up the surface in order to force the humidity out of the construction, i.e. the construction is not functioning properly on parts of the roofs (and facades) lying in shadow. This has resulted in a fair number of failures as the restrictions in the field of use have only been common knowledge for a short period of time.

Figure 2. Leaks in the vapour barrier (as seen to the left) due to poor workmanship allow humid air to penetrate to this school roof, where it condensates and causes mould attack and dry rot.

3 BATHROOMS

Bathrooms have for a number of years been #1 as regards failures. In fact failures occur in all kinds of bathrooms whether traditional or more innovative.

3.1 Traditional bathrooms

Traditional bathrooms are made from concrete, masonry or lightweight concrete. All things considered, the performance is satisfying, as solutions of this type are rather tolerant to minor mistakes.

The most common failure in traditional bathrooms is old floors that are renovated by removing existing terrazzo and installing a new screed with ceramic tiles but without changing the floor gully to an adequate type or securing the joint between floor and walls, see Fig. 3. Failures show as water penetration between floor and floor gully (water often penetrates between the old and the new floor and from here to the room below) or through the joint between floor and walls. Failures of this type are examples of problems that occur as a result of not following legal requirements and existing knowledge.

3.2 Lightweight bathrooms

For the past 30+ years so-called lightweight bathrooms have been used quite extensively, because they are cheap, easy to install and without excess water. The major part of these constructions is made from board materials, e.g. gypsum boards, calcium silicate boards or plywood.

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Figure 3. Penetration of water through a floor constructed with a solid steel profile with concrete. The penetration is caused by water entering cracks between an old and a new floor, because the floor gully was not replaced. The steel corrodes and expands causing the cracks to grow bigger, thereby accelerating the deterioration.

Unfortunately the use of these lightweight bathrooms has lead to a rather large number of failures with water penetrating though walls and/or floors. Common failures are use of unsuited materials e.g. board materials with insufficient properties, watertight membrane missing or too thin and failures around details especially floor gullies, see Fig. 4. The failures have a number of different reasons but most of all it has proved to be difficult to teach the skilled labourer and the user the importance of strictly following the directions for use.

Figure 4. Deterioration of plywood wall and entire floor construction due to ceramic tiles applied directly on plywood - without watertight membrane. Besides the missing membrane the construction was too weak to resist dimensional changes in the plywood.

4 FLOORS

4.1 Crawl spaces

Crawl spaces have been used extensively in Denmark for many years and have been considered to be very safe constructions. However, new requirements facilitating the access of disabled persons to buildings have made the use of crawl space constructions very difficult not to say impossible. At the same time problems with old crawl spaces are increasingly due to mould growth etc.

Old crawl spaces are usually not well insulated and the users therefore like to apply additional insulation in order to save energy and to increase the thermal comfort. Additional insulation will
quite often block – totally or partly – the ventilation gaps to the crawl space leading to accumulation of moisture in the construction. As many crawl spaces rely on a delicate equilibrium between humidity supplied from the environment and humidity removed by ventilation, even small changes might affect the equilibrium in an unfavourable direction. Increased humidity leads almost inevitably to mould growth and in severe cases to deterioration of the wood. The failures are most often due to difficulties in analysing the complex changes in temperature and humidity that occur when a crawl space is insulated and/or the ventilation gaps are partly blocked. In a minority of cases the problems are simply due to not making changes in accordance with common knowledge.

4.2 Wooden floors

Even though wooden floors have been used for centuries, they still account for quite a few failures – even in old well-known constructions.

For traditional floors with wooden boards nailed or screwed to joists, the main failure mode is too big variations in the widths of the joints between boards and/or creaking.

For floating wooden floors a number of failures are seen. There are some examples of uneven floors – due to the substrates being uneven and this can not be taken up by the boards. Another major problem is big variations in the widths of the joints due to restrictions to the free movement of the assembled floor. Free movement is crucial for floating floors, as dimensional changes will inevitably occur in the floor due to changes of the relative humidity in the environment.

Also quite a number of floors experience swelling due to boards mounted too close (not in accordance with the “10-board measure” as given by the manufacturer). When such floors are exposed to the humid environment of the late summer, the dimensional changes in the boards result in swelling of the individual boards and when there is no room for further expansion the entire floor swells i.e. lifts up, see Fig. 5.

Lately problems have occurred with delamination of laminated boards typically consisting of 3 layers. When selling the boards, the board supplier usually put restrictions regarding their use normally restricting the humidity in the environment to 30-65 % RH. This in itself is hard to keep in Denmark as relative humidity in late summer often exceeds 65 % and in winter often goes below 30 % even in ordinary dwellings. Besides, the same boards are often claimed to be fit for use in constructions with floor heating, where the humidity under winter conditions are far below the restrictions set by the supplier. Anyway dimensional changes (shrinkage) under very dry conditions may result in breakage of the glue bonds between the layers in the laminated boards.

Figure 5. Swelling of wooden floor due to boards mounted without possibility for expansion in the humid season.

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The major part of the problems may be attributed to not having made the floors in accordance with common knowledge but a fair part can also be attributed to the materials (or rather the use of materials in places where they are not suitable).

5 MOULD GROWTH

In recent years mould growth has become a serious problem as it has been proven to have a significant effect on health. Problems are seen in many different constructions e.g. roofs, crawl spaces, bathrooms, walls with additional interior insulation, basements etc.

Mould growth is facilitated by humidity in the environment and is consequently often found where constructions are affected by problems with water penetration, rising damp, condensation etc.

A number of severe cases in Denmark have been caused by lack of maintenance especially in roofs. The consequences have often been very costly repairs e.g. renewing an entire roof construction.

Figure 6. Façade with mould growth on wind barrier made with gypsum boards. Often mould growth in facades is due to water penetrating behind the cladding without being drained out (fast enough).

In other cases problems have occurred during the building period due to missing protection of vulnerable parts from precipitation. Also these damages have been seen to be very costly. Other causes of mould growth are constructions that are changed/insulated without paying attention to the risks of jeopardizing the ventilation or to condensation in the constructions. Finally mould growth is seen after accidents, e.g. pipe breakage or fire, where constructions are soaked and, if not dried very fast, are vulnerable to attack.

6 HOW CAN FAILURES BE MINIMIZED?

The causes for failures are almost unending. The question to answer is how can this be changed and the number of failures reduced?

As can be seen from the above, the causes for failures fall in different categories including not least the 3 mentioned in the introduction.

Quite a few of the failures are caused by not using existing knowledge. Great benefits should be easy to gain, as there are no technical problems. The key is more relevant information addressed not only to specialists but to the persons performing the work on the building site. It sounds like an easy task, but actually it is assessed to be very difficult. In Denmark for example a fair number of publications TT8-177, Reduced service life due to common building failures in Denmark, Erik Brandt
have been issued regarding good practice. This includes 2-page information sheets about common failures, why they occur, how they can be avoided and how failures can be fixed. Unfortunately, even these short publications are mostly read by architects or engineers and not by the persons who need it most. The reason is believed to be that these persons are neither used to look for information nor used to read a lot and especially not in a very technical language. To overcome this problem it has been discussed in Denmark to write publications in everyday language and with many illustrative figures addressed directly to workers.

Another big problem is the use of well-known materials and constructions in new ways. Many changes that at first appear to be minor turns out to lead to quite different working conditions for the materials/constructions e.g. with reduced ventilation increasing the risk of humidification, or reduced temperature increasing the risk of condensation in the construction. In both cases the result might be mould growth or even deterioration of organic materials in the constructions. Changes in the use of materials should consequently always be assessed/analysed in order to verify that the working conditions are not affected in a negative way.

Finally the introduction of new materials is quite often associated with failures. Not because the products are of poor quality, but because their potential is overestimated – by marketing persons especially – or they are used in a wrong way. This is actually a very different matter as only one small mistake can lead to considerable failures. A prerequisite for the introduction of new materials, without experience of their use, is that the performance properties are documented and that the properties fit the performance requirements for their use. Ideally such information should be given by the manufacturer/supplier, but unfortunately information is often not available. It is proposed that manufacturers should not only give guidance on what the products can be used for but should also provide information on limitations in their use. Besides the supplier should provide the information necessary to assess whether a product is suited for the intended purpose or not. Finally, the users should be encouraged to ask for documentation – from independent institutes/bodies – and to make their own assessments prior to the use of unknown materials.

It appears obvious to provide information about materials, constructions and their proper use via the Internet. However, this should be done with care in order to avoid incorrect information to be spread and taking into account differences in building traditions between countries. Currently a lot of the information available on the Internet is unfortunately not correct, so precautions should be taken at use.

The tasks mentioned above are so big and difficult that they are best dealt with in cooperation between countries. Preferably such work should be financially supported – especially when taking the huge amounts of money used on building failures into account. If this is not possible, at least sharing knowledge on a voluntary basis would be worthwhile.