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A method for status determination and risk assessment of energy measures in historic buildings

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Abstract. Implementing energy efficiency measures in historic buildings is a challenging task and require knowledge in a number of different disciplines. The measures to reduce energy use must create a good indoor environment without jeopardizing the loss of important cultural historical values or entailing damages to building materials or load-bearing structures. Building antiquarian-, building biological- and building physical aspects are central, and must be taken into account in the entire process, from planning to implementation of energy update measures in historic buildings. This paper presents a methodology for status determination and risk assessment of energy measures in historic buildings. The method (KuReRA) has been developed in collaboration between curators, building biologists and building physicists.

Keywords – Building Physics, Building Biology, Building Antiquarian, Historic buildings

1. Introduction

1.1. Background

There is currently a strong focus on both how use and maintenance and how climate affects the life of the material in historic buildings. Less well known is the problem of how other changes can significantly affect construction physics and any consequential damage due to this [1]. Most of Scandinavia's historic buildings have undergone changes in design and use at various times. Older buildings have been renovated with new construction solutions and materials. Changing requirements for indoor climate and energy use have led to the installation of new heating and ventilation systems. The results of these changes have not always been satisfactory and sometimes resulted in damages of various kinds or an unacceptable indoor climate. These mistakes have led to high costs for repairing damage. In addition, in many cases important historical values have been lost during the restoration work.

Building a new energy-efficient house requires great expertise in a number of areas. Implementing energy-saving measures in existing buildings often requires even more. Changes in the form of thicker thermal insulation, intermittent heating, new types of building materials and reduced or modified ventilation affect the thermal and hygroscopic properties of the building. These changes increase the risk of moisture and mould damage [2]. Unfortunately, it is usually the case that the sensitivity and thus the risk of, for example, moisture damage, has increased with these measures. A number of structures, which we know are critical of moisture, will become even more sensitive and new parts of the building, which previously worked well, will be at risk.

We have many examples of this in buildings with crawl space or with cold attics that are remedied after the energy crisis in the 1970s. When poorly thermal insulated building envelope have been remedied by increasing the insulation thickness, the temperature in the crawl space, attic and parts of the outer wall will be lower than before during the colder period of the year.

If warm humid air can be transported from the heated space in the building up to the attic in winter, it cools down and the relative humidity increases. Even during cold winter evenings, the inside of the roof sometimes becomes so cold that the outdoor air, through ventilation, can condense on the inside of the attic. The inside of the roof is damaged, but also the attic floor due to the condensation that forms on the inside of the outer surface drips into the construction and causes moisture and mould damage [3]. Until 1994-95, heat-insulated basement walls were heat-insulated on the inside, normally in combination with a windbreak against the foundation wall and a vapor barrier on the warm side of the insulation. Such a construction is a high-risk construction with regard to moisture, and in old buildings where there may be some leakage of water through the wall, the risk of both mould and rot fungi is extremely high [4].

If we look at crawl spaces, it is a different season that becomes dangerous moisture. In winter, the crawl space cools down and then when spring and summer arrive, warm and humid outdoor air enters the crawl space through ventilation openings. The crawl space is still cold and when warm moist outdoor air enters the crawl space, it cools down and the relative humidity of the air increases. When moist air comes in contact with sufficiently cold surfaces, condensation and free water occur. This increases both the risk of moisture and mould damage [5] and rot damage [6]. The use of modern building materials, such as plasterboard and fibreboard instead of traditional wood materials, also increases the risk of mould damage due to poor mould resistance in modern materials [3], [4].

In modern constructions, there are a number of measures to reduce the risk of moisture damage in crawl spaces. However, these should be adapted to be used in historic buildings. In buildings in city environments, heating systems can be changed from a local system to district heating that can provide warmer conditions in the crawl space, but this is not relevant for buildings outside the cities. Local systems for ground heating are often relevant, but this means that you do not get any extra heating of the crawl spaces.

A fireplace that was previously used provided a heating of living spaces both directly and via the chimney. This also gave a partial heating of the cold attic and to some extent also parts of the basement and crawl space. At the same time, the building received good air circulation thanks to the air that draws out via the chimney. The negative pressure created by the "chimney effect" and contributed to the ventilation. This effect disappears if you stop firing.

Sealing against air leakage is a common measure, both for larger measures and where you want to do only a few simple, cheap measures. The seal provides a more even indoor temperature and cold floor drafts are avoided. Since an important part of the fresh air supply to the house takes place via leaks, sealing air leaks means a significantly reduced air exchange if, for example, windows are replaced or at least sealed around them. Unfortunately, sealing air leaks in floors and walls also means a reduction in the supply of fresh air into the building. This applies to both wooden and stone buildings. The consequence of this is first noticeable in that neither odours, CO2 nor water vapor produced indoors are exhaled as desired. Condensation on windows and mould growth on cold surfaces are common signals that something is wrong. We also see that during the heating season, strong negative pressures can easily arise indoors, which pulls out any dust particles and mould spores from hidden damage inside the structures. Other consequences of negative pressure indoors can be that it smokes in from previously well-functioning fireplaces and that, for example, radon-containing air can be sucked up from the ground under the house.

The result can be a building that is energy efficient but has a high risk of moisture and mould damage, poor ventilation and thus a poor environment for both the building materials and people. An additional problem is the often elevated radon levels in these poorly ventilated buildings, especially in basements and ground floors. Replacing windows and more effective airtightness reduces the natural ventilation in old buildings. In a concrete building, this can be critical and a change from an air turnover of about 0.5 to less than 0.15 air changes / hour has been documented after replacing windows (Mycoteam, assignment report).

A method for managing renovation and energy updating of historic buildings is in demand by many actors in the process of being able to energy update historic buildings without causing damage.

1.2. Aim

The aim is to develop a method and to develop different types of tools that are necessary to ensure correct status determination and risk assessment of energy updating measures in historic buildings. The method should take into account the various aspects that are affected by renovation / energy updates of historic buildings.

1.3. Limitations

The work has been limited to Building conservation professional, Building biological and Building physical aspects. Fire safety has only been treated peripherally. The content is intended to apply to Swedish conditions regarding climate, buildings and legislation.

2. Methods

The work of developing a method for status determination and risk assessment of energy savings in historic buildings has been developed by various experts who worked together. In our case, it is limited to building physicists, building biologists and building curators. Other relevant disciplines can also be easily supplemented if needed.

A challenge has been to develop a method that can be used in a similar way for the different disciplines, which reflects the different aspects but ultimately creates a result of consensus for the proposed measures. Various existing methods have been investigated and parts of them have been adopted and compiled as the work has progressed. Through frequent meetings and discussions, with the goal of understanding more of each other's specific areas and ways of thinking, the method has grown and developed.

Different versions of the method have been tested in practice on real buildings during the process and the experience of the practical use of the method has caused changes and corrections to make the method better and easier to understand and use.

Now the method is ready to be tested by other actors, consultants and national bodies to get feedback and make necessary adjustments to find a working method for the community for future renovations and energy updates of historic buildings.

3. Result

The work has resulted in a method with the working name "KuReRA". The method includes Building conservation Professionals, Building Biological and Building Physical aspects in the existing building as well as risk assessment of planned measures and proposals for consultation regarding fire protection.

Each of the constituent disciplines has been treated in a similar way that makes it possible to manage them all within the same system. The systematics of the method is inspired by the ByggaF method [7], which is developed to assess the moisture safety of the buildings, throughout the construction process. A number of checklists have been developed to cover and evaluate various aspects of the building. A few lines from one of the developed checklists are presented in Table 1.

Table 1. A few lines from the Roof, attic checklist .

6. Roof, attic	Comment	OK
6.1 Roof construction	Enter the type of construction, the truss, nodes and materials. Indicate culturally and historically valuable wholes and/or details as well as status and any damage.	
6.2 Slope, shape	Note if the roof is flat or steep. Enter shape (saddle roof, pulpit roof, semi-vault, mansard roof, manor roof, pyramid roof, counter-roof, etc.).	
6.3 Material	Specify layers of materials and thicknesses. If possible, refer to drawings.	
6.4 Tight layers	Note tight layers/materials (construction cardboard, waterproofing compound, asphalt, canvas, plastic film, etc.).	

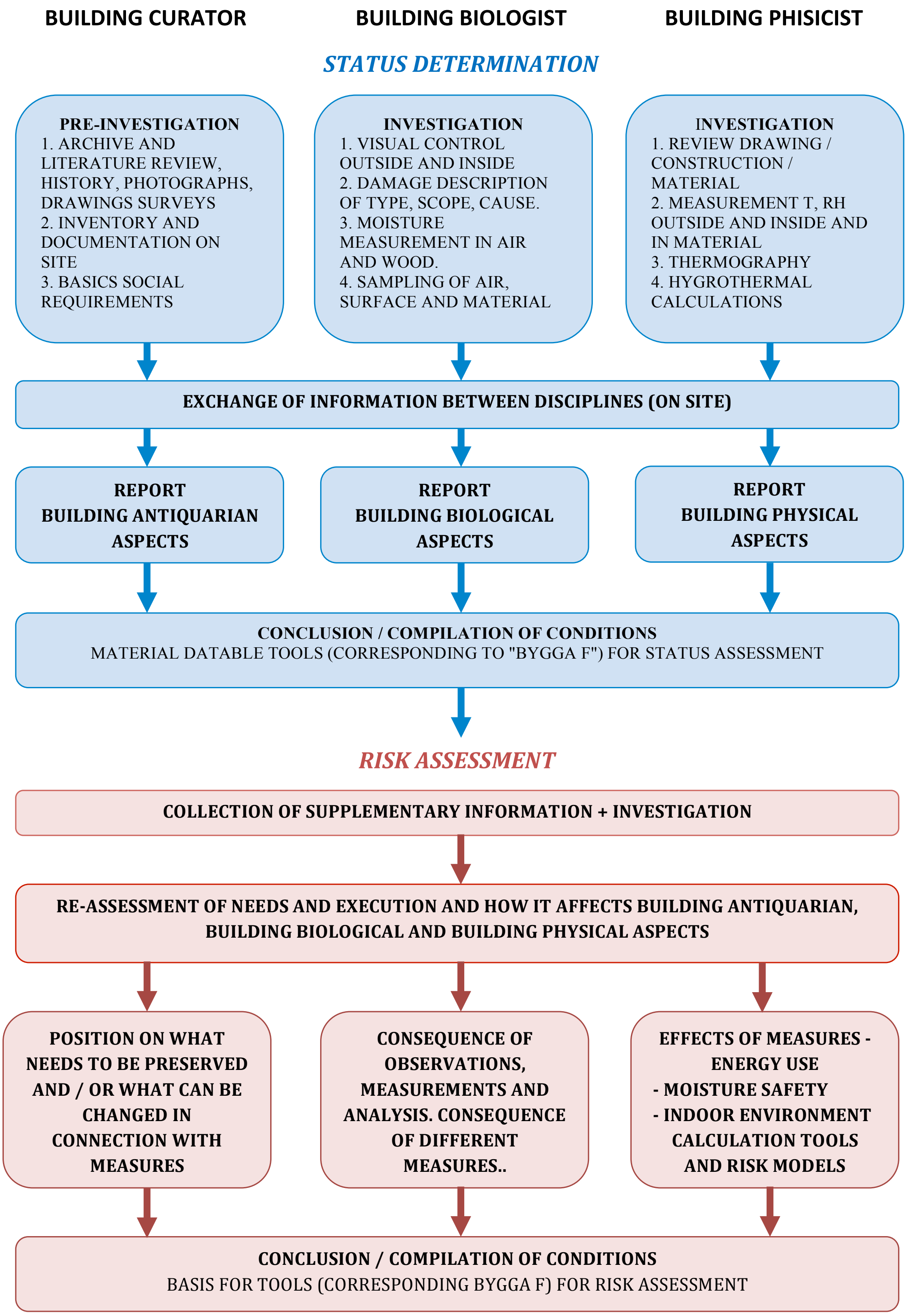

Figure 2. When examining historic buildings, several different aspects must be taken into account in order to achieve an optimal understanding and evaluation of the current situation. The picture summarizes the workflow in a developed method with the working name "KuReRA".

The building physics part is about energy efficiency, moisture safety, ventilation and indoor climate, but also construction technology.

The building biology part deals with the presence of different types of fungi and insects. Examples of checklists have been designed to facilitate the possibility of assessing the degree of infestation and how serious this is with regard to the consequences for the building. It also provides an opportunity to understand the cause of negative aspects of energy measures and the way to minimize future effects [2] [4]. It is important to distinguish between old, inactive and ongoing active attacks by different pests. It must also be possible to assess which organisms are present and the current building physics that creates suitable conditions for biological degradation. In addition, it is important to distinguish between species that can easily develop further at low moisture values and those that die out if the environment is kept within known moisture levels.

Both the occurrence and absence of fungal and insect damage is an important source of information for how the building's constructions, materials and use have worked in the past [2]. This knowledge and understanding is in fact the basis for being able to assess the consequences of different energy efficiency measures on building biological damage and reduced quality of the indoor climate in the building in question.

The building curator part is about building technology, traditional building materials and values. The care of the historically valuable buildings is governed by certain general principles and by special requirements and legislation, based on the individual cultural and technical characteristics of each building. Some general guidelines are; conservation nature, use minimally invasive procedures, prevent damage, use traditional materials and traditional techniques. This does not necessarily exclude modern technology as long as it preserves both the character and life of the house, both in its entirety and in detail.

The information is built up by various experts from "bottom up". All details are processed and assembled into larger and larger units and modules that are either approved or not. Figure 2 shows a schematic picture of the process.

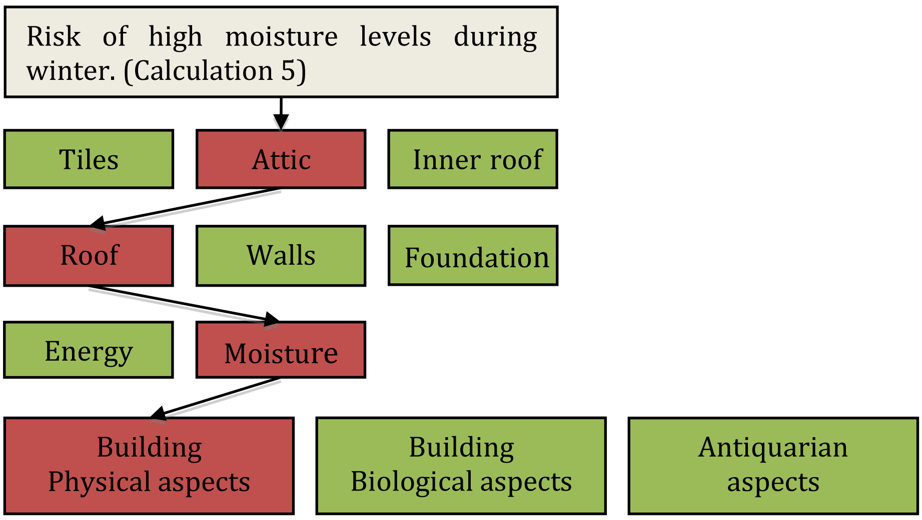

Figure 2. The "bottom-up" process. All information is gradually put together in larger and larger units. The purpose is to provide an easy-to-understand overview that can, for example, form a basis for decision-makers.

When the status determination is made, it is much easier to see what needs to be done and what is most important to take care of. Different measures and how they can affect other parts of the system must be assessed. A kind of risk assessment must be made, e.g. different mould models can be used.

Overall, the results of the method provide an overview of the building's current status and the possibilities for various measures. It provides a more holistic basis for decision-makers to be able to decide what to do and with what risk.

Now the method is used the other way around, "from top to bottom". If a module is not approved, it is possible to go down in the hierarchy and find in detail the reason why a particular part has failed. The reason can be found in one of the three most important three parts; Building physics, building biology or building antiquarian aspects, Figure 3.

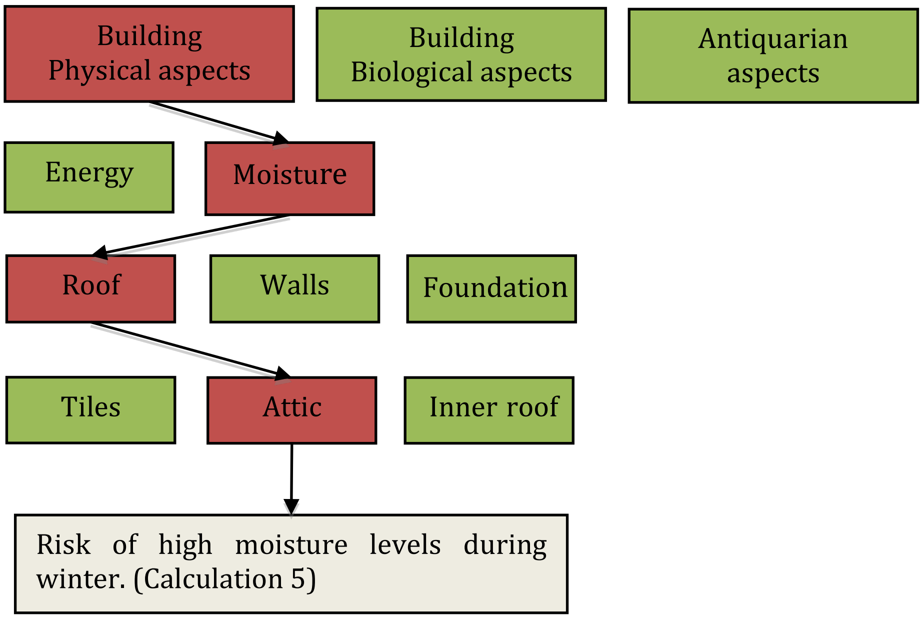

Figure 3. The overview of the status of the building is shown using colored boxes. For more detailed information, it is possible for decision makers or consultants to get more and more information about the background to various problems or injuries.

Understanding what constitutes the particular interest or significance of a historic building requires experience. Very often, technical, philosophical and aesthetic conflicts have to be resolved and sometimes very creative solutions may be required to solve problems. Under such circumstances, there is no compensation for the knowledge and skill of qualified and experienced professional advisers, such as architects or surveyors specializing in historic buildings. Such people have both the technical ability and broad knowledge of historic buildings so that accurate information regarding maintenance and adaptation can be prepared. Their advice can thus prevent damage and unnecessary costs, (English Heritage. 2012).

In order to be able to propose measures in an existing building, it is important to know the status of the building in its initial condition. One must get a clear picture of how the existing building works architecturally today (and perhaps also how it was intended to work from the beginning), given the heat, air and moisture transport in materials and structures and what influence different changes can have. The conditions for materials and structures must be determined with regard to moisture exposure, mould, rot fungi and wood-destroying insects. This is important both for the possible need for repair or replacement, and in the evaluation of the risk of a possible further development of already established damages, such as e.g. in cases of dry rot damage.

Due to the fact that damage caused by biological degradation in old buildings is a result of an accumulated damage development through buildings lifespan, it is important to clarify when and why the damage has been established and what the annual development has been [2]. Such knowledge of the damage often provides a detailed understanding of both the general risk of biological degradation in the building itself and the consequences of a possible further development. Even the lack of an expected attack provides information that must be considered and analysed. An accurate description of the original condition facilitates the choice of measures and reduces the risk of side effects such as humidity and poor indoor climate. In cases where there is a risk of reduced air circulation, appropriate measures can be planned and implemented before damage and complaints occur.

Fire protection aspects

The idea with the developed method (KuReRA) is that it should be possible to also connect or connect other processes and methods concerning disciplines outside the three that have been the focus of the project. In some areas, well-developed methods have already been developed, but the assessment is that these can be further improved or made more efficient through collaboration. A good example is fire protection aspects.

The fire protection aspects that are relevant with regard to historic buildings can be briefly summarized in the following points:

- Action - what to save?
- Evacuation - what are the requirements and what is something we should strive for.
- Property - there is a desire to install e.g. fire extinguishing system or fire cell boundary to protect the property?

In discussions with fire experts, the following proposals for work process have crystallized.

1. By implementing a status determination of the object using a developed method (KuReRA), an overall focus on measures can be prepared.
2. Information to the person responsible for fire protection. It is primarily the building antiquarian and the building physical aspects that must be highlighted.
    a. Building physics aspects → Fire: What measures will be needed and where?
    b. Building conservation aspects → Fire: What is particularly worthy of protection?
3. The fire protection manager makes an inventory according to his own prepared method.
    a. What are the requirements of the Protection and Accidents Act regarding personal protection?
    b. What is appropriate to do regarding personal protection (in addition to the legal requirements)?
    c. Is it appropriate to install additional protection to protect property? What?
    d. Action - What opportunities does the rescue service have to save parts / furnishings worthy of protection? Can it be improved through building technical measures or intervention support?
4. Building physicists and curators continue to work with solutions for energy efficiency, moisture safety, etc. taking into account requirements and wishes from the Fire Protection Officer. Any system for property protection is discussed if applicable.
5. When all drawings / descriptions of proposed measures have been prepared, the person responsible for fire protection carries out an inspection in accordance with established practice.
    a. Can planned measures be made more fireproof with small measures (e.g. swelling mass in air gaps)
    b. Have all legal requirements been taken into account?
    c. Can more evacuation requests be accommodated?
6. Construction
7. Fire inspection
    a. Have you done what you agreed on and is it done correctly?
    b. Emergency cards are produced in consultation with the rescue service and building curator.

4. Discussion and Conclusions

The developed method makes it possible to assess a building in a systematic and uniform way from a building antiquarian, building biology and building physics before an energy update. The condition of materials and structures must be determined. This is important both for the potential need for repair and for the assessment of risks in energy efficiency measures.

The hope is that the developed method will be used by actors in the field and that the method will be further developed gradually. The use of this methodology should lead to greater security in the choice of measures and thus to a larger number of our older buildings being energy updated. The energy saving potential in older buildings can in this way be used in a much safer and more efficient way.

Energy efficiency measures in old buildings are a challenging task. By using an interdisciplinary approach, it is possible to interpret how the building has functioned so far and what consequences different changes in use and construction can have. This provides an opportunity to optimize measures regarding energy efficiency while maintaining the values for cultural heritage and reducing the risk of fungal and insect damage and a bad climate for indoor air.

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