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Healthy and Energy-efficient Living in Traditional Rural Houses

Biodegradation of structures and materials

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Healthy and Energy-efficient Living in Traditional Rural Houses

Contents

1 General

Biodegradation in traditional and historical rural houses – barn dwellings was carried to reveal main threats to the materials used in these types of buildings. The basic building materials used in traditional rural houses are softwood in combination with limestone. There are certain problems arising with usage of timber adjacent to limestone in damp conditions. In Estonia natural limestone has been widely used in facades and basements over many centuries. Raising damp and faults in constructions lead to the elevated moisture content both in stone and wood and caused numerous problems in renovation of historical buildings. Wood decaying fungi produce during their life-cycle organic acids which are very destructive to the carbonate-based stone. The choice between the constructive means and chemical treatment to stop the physical decomposition of stone and biodegradation of wood is restricted to the technical possibilities and/or knowledge of the background of the process.

There are many particular reasons for the evidence of biodeterioration in rural houses:

- Seasonal occupation
- Moisture accumulation at winter-time
- Surrounding nature (close to the forest) is a an endless source of intruders
- Lack of knowledge
- Houses are designed for LIVING but actually used seasonally.

Many of rural houses have new owners coming back to the countryside from cities. They are not familiar with traditional “living customs” (or ignore it) and intend to use new materials with diverse properties. The lack of knowledge in the co-usage of different materials in historical building is widely spread and the expert opinion of constructive engineers is hardly used. This is an obvious evidence of the missing link between urban and rural people and in some rare cases, even a lack of respect to traditional building methods. The lack of resources has also an important influence upon the decisions of house owners.

The main aim of this research is get an overview about the conditions and main problems of traditional rural houses from the aspect of biodeterioration of traditional rural houses in Estonia.

2 Methods

2.1 Studied houses

Current project covers a study of 24 threshing barn houses in Estonia. Houses originate from years 1810 until 1924.

Threshing barn house is a traditional rural house in Estonia. Houses are usually one-storey buildings with attic. Houses have high roof with roof angle 45°.

Stone and wooden logs have been used for bearing structures. Roof was originally covered by thatch. Major or minor renovations have been done in all of the houses. Latest renovation from 1997 to 2011. One of the studied houses had 3-storeys. Other houses were traditional one-storey houses. Examples of the typical threshing barn houses are shown in Figure 2.1.

Half of the studied houses are used periodically today, mostly in summer time. Half of the studied houses are in everyday use all year around.

Figure 2.1 Samples of studied threshing barn houses.

2.2 Main building materials

Limestone is a natural resource of Estonia and has been used as a constructive material since the lime mortar was invented in the 13th century. It was publicly declared to be Estonian national stone at 1992. The usage of limestone depends on first hand from its building, thereafter technical and decorative qualities. In constructions it was used everywhere – foundation, floor, facades, walls, etc. There are many different types of limestone deposits differing in structure, clay content, calcium/magnesium ratio, texture and properties. The stone used in building depended in a great extend from the local resources and the chemical composition was not in the focus of interest. Due to its inhomogeneous structure and variable density, limestone is very affected by the environment. Another important feature is that historical rural houses have very shallow foundation and built on soil floors.

Timber is also a national resource of Estonia, as 47% of the area is covered by forest. From the wood biomass 39% constitutes pine, 25% spruce, and 27% birch. The most fascinating properties of timber are high strength/weight ratio, elasticity and aesthetic exterior. Wood is used in walls, floors, ceilings, roofing, and frames, everywhere. In dry conditions timber is considered as a long-lasting constructive material. In past the average tree age used in constructions was higher than today. Consequently the trunk had higher proportion of heartwood and was less attractive to different kinds of biological attack. There is a big difference in the quality of the used timber. Traditionally the timber was cut only on wintertime and dried seasonally over quite a long time. That made the wood matter more sustainable against the attack of biological organisms. Today for the commercial reasons timber comes from immature trees and is more susceptible for decay. The additional negative effect originates from the usage of rapid kiln seasoned wood in damp conditions. The phenomenon of degradation is evident regardless the presence of wide scale of wood preservatives.

Inevitably these two basic constructive materials existed side by side. In favoured conditions when the moisture content in wood stayed below 20% the accordance of these materials was very good. In damp conditions accompanied with inadequate maintenance the combination of these two constructive materials generates numerous problems what are in the focus of this study.

2.3 Samples

The investigation of biodeterioration of materials was carried out by taking wood samples for the determination of degradative agent and tape lift samples to identify the possible mould damage.

The fungal species and degradation rate of wood was established by the light (LM) microscopy. Light microscope is an essential tool to reveal changes in the wood structure. Samples for LM were cut out from the freshly taken sample of wood and stained with the cotton blue. After that they were examined by the NIKON MICROPHOT FX microscope in the transmission light. The fungal species were detected according to (Bech-Andersen, J. 1995). The wood structure degradation was examined on the cut slices of wood. This detection method is very suitable in the presence of soft rot, as the cavities made by the fungus in the wood cell wall are clearly visible. Mould species were identified according to (Microorganisms in home and indoor work environments. Ed. B. Flannigan et al. 2001). The number of samples and the appearance of biodeterioration are presented in Table 2.1.

Table 2.1 Samples, appearance of biodeterioration

	No.	%
Houses	25	
Total no of samples, incl.:	73	
Materials samples	41	56
Tape lift samples	28	38
Rot appearance, incl.:	14	34
Brown rot	7	50
White rot	2	14
Soft rot	5	36
Wood borers, incl.	21	51
Active damage	8	38

3 Results

3.1 Rot types and biodegradation

In this research particular attention was paid to the survey of degradation of wood, which was connected to the stone. For that purpose the following wood decay types were examined: wet rot (brown and white), soft rot and dry rot.

Naturally each group of rot involves the biodegradation of wood by a large number of different fungi. In this study the differentiation of rots was made by the primary needs of fungus after nutrients, moisture and chemical elements.

Different types of rots reveal variant patterns, which indicate the depth of cellulose and lignin depolymerisation inside the wood cell wall. Cellulose as a natural polymer is responsible for the wood strength. Decrease in the wood cell wall density indicates directly the deterioration of timber quality.

The most palatable places for wet rot causing fungi are immediate surroundings of moisture sources like leaking water pipes, beam ends within the stone wall, vegetable storing boxes in cellar, the back of wallboards in bathrooms, staircases.

Common rot in buildings is a **brown rot** what can attack virtually any part of the construction. Brown rot prefers softwoods and attacks mainly the cellulose part of the wood cell wall and makes the wood brittle and dark in colour. Wood cracks like glass and after drying disintegrates into small cubes. Brown rot can advance very slowly and is natural in old buildings but in favourites temperature and moisture conditions the breakdown occur fast.

White rot producing fungi are more water dependent than brown rot and therefore they occupy timber in facades, window joineries, and roof constructions, pile foundations – where the water is abundant. Nearly always it is connected to the leakage in buildings. White rot causing fungi break down both cellulose and lignin, leaving the wood with pale, fibrous structure. White rot attack preferably hardwoods but also softwoods. Commonly white rot fungi decompose wood more slowly than brown rot. The attack speed increases with high oxygen content in water.

It is important to know that most of timbers destroying fungi die when the wood humidity exceeds 90% due to the lack of oxygen and below 20% due to the lack of necessary water. The lower limit 20% is somewhat confusing as many wood rotting fungi turn impassive and may be revived even after several years, when water is supplied once again. For example cellar fungus (*Coniophora puteana*) can survive up to seven and half years in dry timber at 20 °C (Riba, A.E.1994).

After the water leakage is eliminated the surroundings should be dried rapidly. The decay stops shortly after the timber moisture drops and the problem ends with that. There is now need to take special actions unless the mechanical strength of the construction has weakened or new moistening is not provisioned.

From the preservation point of view it is important to know that brown rot attack starts from the cell lumen side. Preservatives should cover insides of cells against fungal hyphen growth. Also the action of the enzymatic system of white rot is restricted to the immediate surroundings of the hyphae and preservative must halt the spread of hyphae on the inside surface of the cell lumen.

Soft rot appearance inside of the constructions is a direct indicator of poor maintenance. Outdoors it appears only in places where water is excessively available – fences, transmission poles, bridges, steps, etc. It is common decay type in pressure-impregnated wood contacted with soil. Soft rot fungi produce cellulose and the harm is shaded inside the wood cell wall. After starting to use of CCA-type (copper-chromium-arsenic) preservatives suddenly extensive soft rot appears due to the restricted action of preservative only to the cell lumen surface. Preservative against soft rot should impregnate the entire cell wall.

It is important to distinguish between *true dry rot* and the *wet rots.* While the number of wet rot producing fungi is large then dry rot is represented only by one species – *Serpula lacrymans*. In fact this fungus belongs also to the group of brown rot forms but by the spreading activity, damage range and eradication complication it is rather different from other species. Particular qualities of dry rot include following:

- vigorous strand former;
- cannot colonize very damp wood;
- dies eventually under the moisture content of timber 20%;
- needs very stable conditions for development;
- is dominantly found in contact with damp stone or brickwork;
- excretes large quantities of oxalic acid in metabolism;
- very rarely is found outdoors;
- survives for about 12 months in dry timber at 20 °C;
- growth stops at –2 °C, bears freezing;

- mycelium dies at temperatures higher 35 °C and spores die at 70 °C;
- the spore powder and mycelium dust causes allergic eye and respiratory disturbances (Bech-Andersen, J. 1995, Riba, A.E.1994).

Therefore identification and eradication of dry rot needs special knowledge and very accurate constructional solutions.

As all houses under investigation were long time in use, the active rot species were hardly identifiable, therefore the main types of rot – brown, white and soft rots were detected.

3.1.1 Brown rot

Brown rot can appear everywhere in a house. In typical brown rot appearances are presented in Figure 3. 1. The main amount of water comes from the non-insulated foundation (in this case the rock is not limestone but granite pieces) or from the rainwater what pours onto the beam surface. The distance of the first row of beams is about 10-30 cm from the ground. Frequently in rarely used houses the grass grows higher than the level of the first row of beams and promotes the collection of water in this area. Frequently brown rot is accompanied by insect damage. If in the course of restoration the lower beams are left inside concrete floors, different kinds of rot may appear, but mostly in these cases the brown (dry) rot appears.

Figure 3. 1 Evidence of brown rot outside and inside of beams.

3.1.2 White rot

White rot indicates the water leakage spots in the house. In Figure 3. 2 typical white rot attacks are presented.

Figure 3. 2 White rot appearance in different constructional sites.

White rot can appear also in all sites, depending only from the availability of water. Because of that the distribution area of white rot is tightly connected to the water source and can be used as an indication of leaking spots. When the inserted sealing between the ground floor and attic is in direct contact of massive stonewall the water condensation causes appearance of the white rot. Also when the floor beards are too close to the ground or in direct contact with it the growth of white rot is promoted.

3.1.3 Soft rot

Soft rot requires permanent contact with water. Therefore it could be found mostly in external facade elements. Typical evidences of the soft rot are shown in Figure 3. 3. Soft rot is always an indicator of a poor maintenance.

Figure 3. 3 Evidence of soft rot.

3.2 Mould

Moulds are microorganisms that produce thousands of tiny particles called spores as part of their reproductive cycle. Actively growing mould colonies are usually visible as colourful "woolly" or "slimy" growths. They can be virtually any colour—red, blue, brown, green, white, or black. Moulds grow on the surface of all kind of materials but need for the vital activity organic material. This could be a material itself or precipitated organic matter from the air. Therefore it is said that the appearance of mould growth depend mostly on the water content around the growth region. Favourable temperature range is enough wide from 0˚C up to 45˚or even higher.

When disturbed by air movement or contact, moulds release their spores into the air. Given the right environmental conditions, these spores can go on to form other mould colonies.

Mould becomes inactive or dormant if moisture is not present. Inactive mould is often dry and powdery or crusty and, like actively growing mould, can be readily disturbed by air movement or contact, causing mould particles and spores to become airborne. Mould can remain inactive for many years but will grow once moisture returns.

There is also a numerous quantity of mould in outdoor air. Important is that the number of fungal spore indoors should be less than outdoors.

Besides the fact that moulds spoil the outlook of many materials, it can produce toxic substances known as mycotoxins. Some mycotoxins adhere to the mould spores while others can be found within the spore itself. Air movement and the handling of contaminated material can release spores containing mycotoxins into the atmosphere. Once released, spores must contact the skin or be inhaled before symptoms can develop. Therefore it is vital to know what kind of mould is present. Moulds like *Alternaria, Aspergillus, Cladosporium,* and *Penicillium* are known as allergy causers of respiratory system (Singh J. 2000).

There a number of moulds what appearance evidences moisture problems in houses and they are called indicator moulds: *Aspergillus versicolor, Aspergillus fumigatus, Trichoderma, Stachybotrys atra,Phialophora, Fusarium, Ulocladium, Exophila, Rhodotorula, Chaetomium, Eurotium, Wallemia (*Sanna Lappalainen et.al. 2008).

In this survey, following mould species were identified:

- *Cladosporium*
- *Aureobasidium*
- *Phoma*
- *Chaetomium*
- *Penicillium*
- *Stachybotrys.*

In the appearance of moulds on different materials is shown. Textiles in rarely used summerhouse type rural houses are the most vulnerable to the mould. In storerooms where air is not moving but a quantity of organic food and materials are present, the mould is a common visitor. Wallpaper is the first victim of the moist indoor climate and will be covered extensively with mould.

Figure 3. 4 Mould appearance on different materials.

The short descriptions on discovered mould species is presented as following (http://www.isct.com/mold_glossary.pdf):

Cladosporium

Most commonly identified outdoor fungus. Common cause of extrinsic asthma (immediate-type hypersensitivity: type I).

Aureobasidium

Relatively rare agent of Phaeohyphomycosis; reported cases include corneal, peritoneal, cutaneous, pulmonary, and systemic infections. May also be encountered as a contaminant in clinical specimens. This is a yeast like fungi which is commonly found on the silicon caulk used in bathrooms and kitchens, on damp window frames and in shower tracks. It starts out as a pale pink growth maturing to black in colour, staining the material on which it is growing. It is seldom the cause of infections but can be allergenic.

Phoma

Phoma is a dematiaceous filamentous fungus that inhabits the soil and plant material. Phoma species are cosmopolitan in nature and are common plant pathogens. While they are commonly considered as contaminants, Phoma species may rarely cause infections in humans.

Chaetomium

Commonly considered a contaminant, occasionally allergenic.

Penicillium

Identification of this species can be difficult. Often found in aerosol samples. Commonly found in soil, food, cellulose, and grains. Some species can produce mycotoxins. Common cause of extrinsic asthma (immediate-type hypersensitivity: type 1).

Stachybotrys

Several strains of this fungus (S. atra, S. chartarum and S. alternans are synonymous) may produce a trichothecene mycotoxin- Satratoxin H - which is a poisonous by inhalation. The toxins are present on the fungal spores. This is a slow growing fungus on media. It does not compete well with other rapidly growing fungi. The dark coloured fungi grow on building material with high cellulose content and low nitrogen content. Areas with relative humidity above 55% and are subject to temperature fluctuations are ideal for toxin production.

Individuals with chronic exposure to the toxin produced by this fungus reported cold and flu symptoms, sore throats, diarrhoea, headaches, fatigue, dermatitis, intermittent local hair loss and generalized malaise. The toxins produced by this fungus will suppress the immune system affecting the lymphoid tissue and the bone marrow. Animals injected with the toxin from this fungus exhibited the following symptoms, necrosis and haemorrhage within the brain, thymus, spleen, intestine, lung, heart, lymph node, liver, and kidney. Affects by absorption of the toxin in the human lung are known as pneumomycosis.

This organism is rarely found in outdoor samples. It is usually difficult to find in indoor air samples unless it is physically disturbed or if there is (speculation- a drop in the relative humidity). The spores are in a gelatinous mass. Appropriate media for the growth of this organism will have high cellulose content and low nitrogen content. The spores will die readily after release. The dead spores are still allergenic and toxigenic. Percutaneous absorption has caused mild symptoms.

It is evident that appearance of mould is closely connected to the quality of indoor climate. Therefore before building up the sequence for the eradication of mould from the surface of materials, a survey on the relative humidity, temperature and air movement in indoor atmosphere should be conducted to obtain productive results of the cleaning.

3.3 Wood borerers

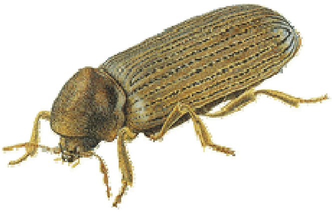
Frequently insect damage is associated with wood rot. But this is not an absolute criterion. Depending on the species of insect dry or wet wood, damages with fungus or not, could be attacked. Additionally, distribution of wood borers depends also on the region (costal, inland), the appearance of the forest, the age of the timber etc.

In this survey the main findings were damages by *Anobium* and *Hylotrupes* insects as it is shown in following Figure 3. 5 .

Figure 3. 5 Insect damage of wood.

Wood boring insects affect mainly the sapwood part of the wood stem. In beams used in old wooden houses the share of sapwood in the cross-section area of the stem is minor and therefore the mass and volume loss relatively small. It is visible on beam ends and floor boards as well. Finishing old beams with varnish or paint enhances drastically the activity of the insect. As the finish on the wood surface keeps moisture locked inside the beams, the life cycle of insect turns shorter and more exit holes appear on the surface of wood.

3.3.1 Common House Borer



ANOBIUM PUNCTATUM is a pest of major economic importance. The significance of which is not adequately recognized. 3 - 5mm long, dark-brown/black in colour, it is clearly identifiable with the hooded prothorax which covers the head 2 - 3 years spending tunnelling away inside the wood as a larvae the adult beetles will exit via a round hole 1 - 2mm in diameter.

Cutting out this trapdoor is their final wood-destroying act. They emerge in order to breed, will not eat any more timber and will die within 3 - 4 weeks. Attacks only soft sapwoods. Larvae-pupae 2-3 years in wood.

Anobium larvae are seldom, if ever, found in fresh milled timbers. Larvae require some condition for their development, which is not present in wood until it has aged, or in some other way differs from new timber. Eggs are laid ONLY in starch rich wood Larvae eat and absorb cellulose only when it is rendered digestible by fungi and micro-organisms present in the wood itself Humidity plays a very important part in the incidence of timber infestations Damp, humid areas create ideal conditions for borer attacks (Figure 3. 6). Costal humid climate in Estonia provides the perfect climate for borer. Eggs are always laid in cracks, crevices, end-grain timbers, often into old flight holes, never onto sealed, painted or varnished surfaces. The exiting urge is of such magnitude that they frequently gnaw out through paints, wallpapers, varnishes, linoleums, wallboards and plasters. They have also been known to exit through sheet lead and formica (http://en.wikipedia.org/wiki/Common_furniture_beetle).

Figure 3. 6 Anobium damage in the wood.

3.3.2 The old-house borer or longhorn beetle

HYLOTRUPES BAJULUS
Contrary to its name, it is more often found in new houses. This is in part because new home construction may use wood infected with the beetle's eggs.

Old-house borers prefer seasoned softwoods, and particularly pine. Infestation starts from the trees, but it can also be found in treated wood.

Larva can live in wood from 3 to 10 years, depending on the moisture content of the wood Larvae reaching 200mg in weight and causing extended damage. Preferring sapwood.

Boring dust is pushed out of holes in the wood and is good evidence of their activity. Large oval holes (6x9 mm) are also a sign of the infestation (http://en.wikipedia.org/wiki/Old-house_borer).

In this study exiting holes with fresh wood powder were found in several cases, particularly in houses recently repaired. The eradication of insects was usually not performed in studied houses (Figure 3. 7).

Figure 3. 7 Evidence of HYLOTRUPES BAJULUS attack.

3.4 Moisture damage

Long before wood rot appears the evidence of „moisture damage“ show up in the form of changes in materials outlook and physical properties. Moisture signs (Figure 3. 8) or construction faults are visible what lead to the moisture problems in the future. When moisture signs appear on internal walls, a real damage is hidden behind the surface. Moisture problems prepare the infestation of biological organisms. Frequent reasons of the moisture damages are maintenance problems and seasonal usage of houses.

Figure 3. 8 Signs of moisture damage in buildings.

3.5 Other damages

With time a physical ageing of wood in environment occurs. Rural houses were commonly not painted and environmental influences – temperature, wind, light – had strong influence onto the wood surface. It caused volume degradation, extraction of wood tar to the surface etc. (Figure 3. 9). Creeping plants are not right solution for the decoration walls in Northern climate. Also planting too close to the foundation of the house could lead towards degradation of foundation.

Figure 3. 9 Different kinds of problems causing damage which could lead finally to the moisture problems.

4 Conclusions and further assumptions

From investigated 25 houses 73 samples were collected and analysed towards rot and insect damage evidence. Rot damages were mostly not active, even though the moisture of timber in some places was high (this could be the reason why the rot was not active any more).

Main problem arose with insect damage what gained power in almost all of investigated houses. Especially noticeably was the insect damage in newly restored houses. One reason could be that the eradication of biodegradation damages was not commonly performed.

Damages have certain relation to indoor climate conditions, technical condition and habits of residents. On the basis of results of the investigation suggestions for the eradication of damaging organisms and suggestions for the renovation were handed over to the owners of the rural houses.

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