Defects of roofing and roof structure – Apartment house Kaplice

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Abstract. The aim of this paper is to provide information on the defects of roofing and roof structure on the Apartment house Kaplice. The roof cover is Beronit fiber-cement template cover and the roof template is 400 x 400 mm (square with corrugated corners). The roof was laid according to the design documentation and documented invoices 10 years ago. The roof as a whole, as a result of very serious defects, does not fulfill its function (protection of the object from weathering). The rainwater penetrates into the attic and affects the wooden elements of the roof structure. Wooden elements of truss construction, in particular, formwork and rafters, in the ridge area, are infested with mold. The Czech Mycological Society confirmed the attack of wood mold elements, testing the samples taken. One sample from the inside face of the roof formwork has higher mold values, and the other sample has even high mold values. The attic space can only be ventilated through the opening windows and the roofing is designed as unpaved. During the ten-year lifetime of the roofing, one repair was carried out, which further aggravated the condition. The detected state of the roof is an emergency and the implemented measure in the form of capturing penetrated water into plastic containers is not enough to stop the deepening of destructive roof processes. Temporary repairs to roof roofing did not benefit, and on the contrary, it is one of the main factors causing cracking and shading of the roofing patterns and thus the penetration of rainwater into the soil.

1. Introduction

The aim of the paper was to assess the condition, causes and possible other defects of the roofing and roof structure, to determine the need for repair in the event that the survey concluded that the roof is severely damaged. Furthermore, we assess the consequences for constriction of the roof and other parts of the building if the roof covering requires urgent repair and this repair will not be performed. In conclusion, we recommend a technological procedure for the repair of detected roof defects.

It was found during the construction-technical survey that the roof covering was laid about 10 years ago, which does not correspond to its current bad condition. The roofing was still maintenance free. Last year, the roof was repaired, but the roof condition was even worse.

When investigating the roof covering, it was found out that the roofing is fiber-cemented Beronit (formerly Beronit, which was now manufactured by Cembrit a.s.). The roofing is in a catastrophic state and is now beyond its lifetime.[1] Roof templates are largely cracked and run down the roof plane into the roof trough. The ridge is cracked, sliding down the roof to the roof trough, and missing...
in some places on the ridge. When examining the roof structure in the attic space, it was found that it was leaking into a roof in a number of places. On the timber elements of the roof structure and the supporting structure of the roofing (formwork), there are visible moisture maps from rainwater leakage and mold. On the floor of the attic space, there are plastic containers to catch the penetrating rainwater and there are damp traces and penetrating rainwater directly on the floor. At the moment when there is darkness in the attic space, light penetrating through the openings in the roof cladding can be seen in the attic space. The attic space can only be ventilated through the exit windows and the roofing is designed as non-ventilated.

2. Structural engineering survey
The roofing is a fiber cement stencil covering Beronit (formerly Beronit, which was bought by the production name Cembrit as today), templates 400 x 400 mm (square with bevelled corners), the way of laying the roofing is a simple covering with elements placed in horizontal rows, the roofing is anchored using nails and windbreaks, the roofing was laid about 10 years ago, which does not correspond to its current poor condition and condition. The roofing is anchored to the formwork, the roof and the attic space are not ventilated. The roof covering is in a state of disrepair beyond its service life. The roof fiber cement templates are cracked in many places and in some places they are completely cracked and descend on the roof plane into the roof trough, the templates are crimped and do not lie against each other in the entire roof plane. The ridge is in a catastrophic state, is cracked and in some places missing from the roof ridge, some ridge is broken anchoring to the ridge lath and is folded away from the roof ridge and threaten to slip on the roof plane into the roof trough. Plumbing elements are made of galvanized sheet metal, they were painted when changing the covering about 10 years ago. Plumbing elements are poorly made for fiber-cement roofing. The roof waterproofing is made of asphalt board. The cardboard is fused to the roofing support structure (formwork) of the roof boards. Asphalt board is degraded due to natural (aging), biological and physical degradation, does not perform the function of waterproofing. Asphalt cardboard dissolves under the constant influence of water and moisture, the dissolved mixture manifests itself in black tar spots on the formwork and elements of the roof structure. On the roof formwork, there are local black tar stains from melting asphalt board, as well as moisture maps, especially in the place of the roof ridge and mold is located on the bottom surface of the formwork. Moisture maps are found on the wooden elements of the roof structure, especially in the places of the roof ridge, and are affected by mold. On the floor of the attic space, there are containers for catching rainwater penetrations and further on the floor, there are damp traces of already penetrating rainwater. [2]

3. Results and discussions
Roof coverings (figure 1), tinsmiths, roofing support structures (shuttering) and safety hydro-isolation being in a defective condition and replacement of these structures is necessary.

The roof as a whole does not fulfill its function due to very serious defects (protection of the object from the weather). Rainwater penetrates into the attic and acts on the wooden elements of the roof structure. In the attic space, there are visible traces of leakage and accumulation of rain water. Wooden elements of the roof structure, in particular, formwork and rafters in the ridge area, show moisture maps from rainwater (figure 2). On the soil floor, there are plastic containers to trap penetrating rainwater and wet tracks from dripping penetrating rainwater. The wooden elements of the truss construction, especially formwork and rafters in the ridge area, are attacked by mold. An infestation of wooden mold elements confirmed mycological laboratory test. Another reason for starting the destructive processes of wood elements is the surface condensation of water vapor on the formwork and timber elements. Condensation is the result of increased humidity in the attic, which cannot be ventilated because the roofing is designed as non-ventilated. Soil ceiling design does not yet show any signs of destructive processes.
Figure 1. Damaged roofing

The detected state of the roof is an emergency and the implemented measure in the form of trapping penetrated water into plastic containers is not enough to stop the deepening of the destructive processes of the roof. Provisional repairs to the roof covering have failed and, on the contrary, it is one of the main factors causing cracking and sliding of roof patterns and thus the penetration of rainwater into the soil space. Cracking caused an unprofessional movement on the roof (roofer?), Which after the roofing, moved alone without the auxiliary roof ladder and the footwear treaded on the roof templates. Such a roofing movement is not exclusively recommended by fiber cement flooring manufacturers and is prescribed by roofing auxiliary roof ladders for roof movement.

The roof covering has the following defects:
- Roof fiber cement templates are cracked in many places (figure 1)
- In some places on the roof plane, the fiber-cement templates are completely cracked and slid along the roof plane into the roof gutter (figure 1)
- In some places, the roof plane of the fiber-cement template is missing (figure 1)
- In the entire roof plane, the roof fiber cement templates are corrugated and do not lie against each other
- The ridge is in a catastrophic state, cracked and missing in some places on the roof ridge
- For some ridge, the anchorage to the ridge lath is broken and is folded away from the roof ridge, therefore there is a risk of sliding along the roof plane into the roof gutter
- Poorly performed ridge anchor detail along with ridge battens

In a given situation, it is not advisable for the roof deck to be designed as non-ventilated

These defects prevent roofs from being used properly. Furthermore, these defects cause penetration of rainwater into the soil space. These defects are removable when replacing the existing coverage with a new one, but a new support structure for the battens, which will be ventilated together with the waterproofing, must be provided. In addition, plumbing elements will be newly made. Replacing the covering itself while maintaining the existing waterproofing and the existing formwork will not result in the roof being used as a non-defective item or as required by the manufacturer's technical requirements.
Tinsmiths have the following defects:
- The execution of plumbing elements does not comply with the regulations of fiber cement producers and is technologically poorly executed.
- Plumbing elements do not prevent water penetration into the roof structure.
- Gutters are not properly sloping and damaged in many places.

These defects prevent roofs from being used properly and allow rainwater to penetrate the soil. These defects are removable when replacing the plumbing elements, but at the same time a new roofing material and support structure of battens, which will be ventilated together with the safety waterproofing, must be carried out. The replacement of plumbing elements while maintaining the existing roofing, shuttering and waterproofing will not result in so that the roof can be used as a non-defective thing.

The roofing support structure (formwork) has the following defects:
- the bottom surface of the formwork is attacked by mold (figure 2)
- moisture maps are formed on the formwork (figure 2)
- on the formwork, there are black tar stains from melting asphalt board (figure 2)
- formwork is not suitable as supporting structure of fiber-cement covering, it does not allow ventilation of roof and attic space according to modern regulations and recommendations of manufacturers of fiber-cement roofing.

Figure 2. Damaged roofing structure

These defects prevent the roof from being used properly. Formwork does not allow ventilation of the roof deck and the attic space. The lack of air exchange results in increased air humidity. This results in an increase in the dew point of the indoor air. If the dew point of the indoor air rises above the surface temperature of the timber formwork or other elements of the roof structure, condensation occurs on their surface. The surface condensation of water vapor on the timber formwork or other wood elements results in an increase in the moisture content of the wood. As a result, wood-destroying processes may develop. These defects are removable when replacing the formwork behind the lattice ventilated support structure of the roof covering and at the same time replacing the waterproofing, roofing and tinsmith elements. Replacing the supporting structure itself while maintaining the existing...
roofing, waterproofing and tinsmithing elements will not result in the roof being used as a non-defective item.

The safety waterproofing has the following defects:
• asphalt board is degraded due to natural (aging), biological and physical degradation
• the result of degradation is the failure and dysfunction of waterproofing and the permeation of rainwater into the attic space
• asphalt cardboard dissolves under the constant influence of water and moisture, the dissolved mixture manifests itself by black tar spots on the formwork and elements of the roof structure
• Unsuitable for the last laying of the roof covering.

These defects prevent roofs from being used properly and allow rainwater to penetrate the soil. These defects are removable when replacing the waterproofing and replacing the roofing, supporting roofing and plumbing elements.

As the roofing material is severely damaged, the waterproofing membrane, the tinsmith elements are poorly made together with the formwork bonded non-ventilated roof cladding is unsuitably designed in this situation, not only the replacement of roofing and plumbing elements for proper roof use is sufficient.

We recommend removing the entire existing roofing, ie. existing roofing, tinsmithing, waterproofing and shuttering. The attacked wooden elements of the roof truss structure of the mold. Perform a new ventilated roofing on the existing restored rafter. I design the new roofing material as ventilated with diffusion-open safety waterproofing, supporting roofing structures ventilated from laths and counter battens, roofing material folded for example plastic roofing template or fiber-cement templates. It is important that the ventilation details of the ridge and roof gutters are properly resolved. Ventilation aperture sizes must be determined by professional calculation and the roofing must be equipped with an adequate number of ventilation fittings depending on the manufacturer's technical regulation. The roof covering must be carried out in accordance with the applicable technological regulations and technical regulations of the manufacturers. All plumbing elements must be made according to ČSN 73 3610 [3], generally technical regulations for plumbing elements and technical regulations of the roof covering manufacturer.

Roof repair is necessary and inadequate, as it does not protect the building from rainwater and moisture in the current state.

The roof as a whole due to very serious defects does not fulfill its basic purpose and function. (together with other perimeter structures protects the interior of the building against external influences - water, humidity, temperature, wind, solar radiation, noise, etc.

In the current state, the roof requires urgent comprehensive repair. If this complex repair is not carried out, there is a risk of significant expansion and deepening of wood-destroying processes in the roof deck and in the timber elements of the roof structure, which can have two serious consequences:
• Rainwater will penetrate the 2nd floor apartments and will not allow proper housing. Flowing water into the ceiling structure above the 2nd floor will start destructive processes, threaten its stability and lead to its collapse.
• The wood-destroying destructive processes by which the wooden elements of the truss structure are attacked will deepen and expand due to the detected defects. This expansion and deepening of wood-destroying processes on timber elements will lead to a complete destruction of individual elements and the stability of the entire supporting structure of the roof will be
jeopardized. As a result of the destruction of the individual supporting elements of the roof truss, the entire structure of the truss is ruined.

4. Conclusions
Given the information available and the facts found on the spot during the local investigation and their evaluation, we are able to evaluate the expert opinion and answer the questions.

The roofing (roofing, roofing support structure - formwork, safety waterproofing, tinsmith elements) shows serious defects and does not allow proper use of the roof. The roof cladding in this state does not fulfill its weather protection function and allows for massive penetration of rainwater into the building. Penetrated water threatens the wooden supporting elements of the truss construction, the 2nd floor ceiling and the 2nd floor apartments.

The detected defects and facts are the result of unsuitable design of the roof cladding, unprofessional execution of roof covering and plumbing elements. People who have carried out the roof cladding did not comply with ČSN [3], general technical regulations, and technical regulations of building material manufacturers. The defects were exacerbated by neglected roof maintenance and improper repairs.

New renovation of the roof cladding and the elements of the roof wooden supporting structure are recommended as a complex building activity, which will be preceded by the right decisions in the order: assignment, investment balance sheet, eventual project or technical solution, selection of the control mechanism (technical supervision of the investor), remediation.

In order to ensure perfect use of the roof of an apartment building, the following modifications must be made:

- Based on the current state of the roof cladding and the roof structure of the apartment building, it would be advisable to stabilize the leakage state by immediately removing the current roof fiber cement covering and making a temporary roof covering from the PE covering sheet. After this measure, documentation for the redevelopment of the roof structure and the roof deck must be drawn up without delay.
- Partial repairs will not lead to proper use of the roof and restoration of its function. This means that replacing, for example, only a roof covering will not be sufficient for its perfect function.
- We recommend solving the remediation comprehensively by replacing the entire roof cladding and repairing the attacked elements of the roof truss supporting structure.
- Development project implementation documentation for roof remediation that sets out corrective actions and identifies clear solution points. Probably, there will be more systemic solutions for the new supplier of remediation works. Therefore, the new project documentation will include a consistent comprehensive solution before the actual renovation of the apartment building's roof.

References
[1] H. Islam, M. Jollands, S. Setunge, N. Haque and M. A. Bhuiyan, “Life cycle assessment and life cycle cost implications for roofing and floor designs in residential buildings,” Energy and Buildings., pp. 250–263, 2015.
[2] A. Felo and J. S. Machando, “In-situ assessment of timber structural members: Combining information from visual strength grading and NDT/SDT methods,” Construction and Building Materials., vol. 101, pp. 1157–1165, 2015.
[3] ČSN 73 3610 Designing plumbing structures, 2008 (in Czech).