Construction-Technical Survey of a Historical Building in Loket

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Abstract. The main objective of the article is to inform about the construction-technical survey, which focuses on the existing historical building from the first half of the 19th century, in Loket city, Czech Republic. In the past, the building was hit by floods, which affected its technical condition, the deterioration of which also affected the subsequent abandonment of the building, and neglect of maintenance. The main research issues stem from the building-technical survey focused on the condition of structures, especially the load-bearing wall structures, the ceiling structures, and the roof structures. After detecting the faults and other possible damage, we look for their causes and find out which of them are fatal to the building and which can easily remove. Of the evaluated structures, we focus mainly on their damage due to moisture, excessive structures loading, and changes in foundation conditions caused by previous floods. Furthermore, we assess the impact of failures on the structure and operation of the building. In conclusion, we propose measures based on the structure’s found failures and possibilities for their repair.

1. Introduction
The task was to determine the technical condition and extent of failures in structures affected by previous floods, i.e. primarily the perimeter and internal load-bearing masonry, especially in the building basement. The survey focused on the damage extent and overall technical condition of the truss structure degraded due to neglected maintenance. The main goal of the construction-technical survey is to locate faults and other possible damage, to determine their extent and determine their cause, as well as to assess the possibilities of eliminating these faults and damage.

The solved object is composed of three rectangular tracts (1x 6.7 * 11.85 m, 2x 4.75 * 9.90 m), while the larger central part (risalit) is three-story and the smaller outer parts are two-story. The building is also partially basement from the imaginary longitudinal half of the building in its western, southwestern, and northwestern parts. The built-up area of the building is 175 m\textsuperscript{2}, the maximum height of the building from the adjacent terrain is up to 15 m, the depth of the basement is up to 2.0 m below the level of the adjacent terrain. The ground floor of the building is located above the level of the adjacent terrain. The construction system of the building is walled, made of bricks or stone. Ceiling structures are concrete or wooden formed by a semi-combustible beamed ceiling. The individual tracts are covered by a hip roof with roofing made of profiled sheet metal, under which is located the hydro isolation foil. The trusses are wooden, with massive purlins and joists. The historic
façade is characterized by a massive plastered plinth, strip bossage to the height of the second floor, profiled shutters of windows and doors, window ledges, parapet cornices, strip (cordon) cornice, and main crown (drip) cornice. The initial use of the building was living in a family house (villa). In history, the building has changed its purpose several times and served as a school canteen and then as a police station. Subsequently, the building was abandoned for a long time and these days it is not used. In 2009, the town of Loket was hit by a flood, which flooded the basement of the building. [1]

2. Construction-technical survey
We have carried out two local surveys as part of the solved building construction and technical survey (local survey dated to 21st of May 2020 and local survey dated to 14th of July 2020), during which a survey of the building and the surrounding area was carried out, including photo documentation. On selected structures were also performed Non-destructive perceptual tests. Based on the found obvious faults, probes were performed in selected places of the building to verify the existing structures and determine their technical condition.

2.1. Cracks in the joints of perimeter masonry:
During the local survey, visual inspection revealed cracks in the internal and external plasters at both two-story outer parts of the building, on both floors, at the windowsill, lining, and lintel of the window, leading through the windowsills and window edging. Cracks are located in the basement and non-basement parts of the building. Inside the building, at the point of the window sill, cracks are visible at the point of contact between the sill and the window lining. Based on the survey a probe was performed (removal of the internal plaster of the lintel and parapet and discovery of the supporting structure) at one of the affected places. After removing the surface layer a crack was found in the place of the window sill in the vertical and horizontal joints of cross-walled brickwork, characterized by chipped mortar up to 3 cm deep. In the case of the window lintel, no crack was found in the joints of the masonry vault, or through the brickwork. After removing the plaster of the window lintel, the degraded condition of the original masonry mortar was also revealed, which crumbled at the edge of the bricks. The cracks on the façade and inside the building are shown in Figure 1 and Figure 2.

![Figure 1](image1.png)  
*Figure 1. The western and eastern facades of the building with the marked places and direction of the cracks.*
2.2. **Humidity in the basement:**

In 2009, the town of Loket was affected by floods, which, due to the location of the solved building, caused the flooding of its basement in its entirety. The flooding of the basement caused an increase in humidity in the foundation structures, in the perimeter and interior walls, and in the ceiling structures. Due to the long-term effects of moisture, there was a gradual degradation of the internal plaster walls and ceilings, and partial disintegration of the brickwork, incl. connecting mortars, in exposed places without plaster (especially at corners and lintels of openings). Insufficient drying of wet structures subsequently caused the formation of mold and salt blooms. However, the perimeter and interior walls, including the vaulted ceiling structures, do not show signs of mechanical damage in the form of statically severe cracks, greater disintegration of the material, etc., which would disrupt the stability of the building or limit its use. The extent of basement damage due to long-term exposure to moisture is shown in Figure 3.

![Figure 2. The probe in the windowsill and lintel on the 2nd floor of the building east wing.](image1)

![Figure 3. The extent of basement damage due to long-term exposure to moisture.](image2)
2.3. Rotten and damaged wooden truss elements:
During the local survey, a visual inspection revealed a neglected condition of truss parts, containing deposits of bird droppings, remnants of plaster and building material, places with rot on the truss foundation and adjacent wooden structures (tie beams, wall beam, rafters), including different coloring of elements. At the same time, rotten heads of a part of wooden tie beams were found, especially in the place of the perimeter wall. A sound test in the form of tapping the individual wooden elements of the truss revealed dull and hollow sounds emanating from some elements, which may indicate biological damage by wood-destroying insects. Visual inspection confirmed traces of deep scratch caused by wood-destroying insects (especially in the rafters of the truss in the central building part). [2] The extent of wooden truss elements damage is shown in Figure 4.

![Figure 4. The extent of wooden truss elements damage.](image)

2.4. Verification of ceiling structures
Verification of the real state of the existing wooden ceilings above the 1st and 2nd floors, which is shown in Figure 5, arises due to the cracks on the façade and due to the layout changes proposed by the investor, considering the future construction of new brick partitions.

![Figure 5. The technical condition verification of the ceiling structure.](image)

3. Results and discussions
3.1. Cracks in the joints of perimeter masonry:
Cracks in the joints of the perimeter masonry in the area around the window openings (lintel, lining, window sill) at both extreme parts of the building can be caused by two possible causes.

a) The building foundation
The first possibility is a change in the soil conditions in the basement of the building, caused by the mentioned floods in 2009. As these are old cracks in the vertical and horizontal joints of the masonry, these cracks indicate a gradual decline of the structure (foundation), see figure below.
b) Structure overload
The second possibility, due to cracks in the place of the window lintel, is the overload of the lintel by the wooden ceiling, or the ceiling beam placed in the place above the window lintel. Due to the fact that the building has changed the purpose of use many times in the past (housing, civic amenities), there were changes in the values of the live load, while increasing these live load values could lead to the overloading of the ceiling structure. Due to the subsequent distribution of forces, it decreased in the weakened place of the lintel, which caused cracks in the brick vault, which were reflected in the plaster at the junction of the lintel and the window lining. With a slight decrease in the window lintel, the ceiling structure in the place where the beam was placed probably also decreased, which also caused a decrease in the window sill above the ceiling structure due to the occurrence of deformations.

3.2. Humidity in the basement:
Due to the flooding of the basement in the past (floods in 2009), the current situation is most likely caused by insufficient drying of the premises after water depletion. According to the previous operators of the building, there was no waterlogging of the foundation/basement structures due to ground moisture. Whether the building has a waterproofing layer (original or additional) is not known.

3.3. Rotten and damaged wooden truss elements:
In the past, the roof most likely underwent a partial reconstruction, during which the roof covering (currently profiled sheet metal) was replaced and a waterproofing under-roof layer - foil - was additionally used in the truss of the building south wing. The attacked wooden truss elements are located in the parts of the north wing and the central part, without the hydro insulating foil. For this reason, the cause of the disintegration of the tops of wooden tie beams is mainly moisture in the structure due to leakage into it, which in long-term action, together with suitable temperature conditions and truss maintenance, causes wood-destroying rot, wood-destroying fungi and wood-destroying insects. As some wooden elements have deep surface scratches of a specific form, these may be ingestions caused by beetles "Corymbia Rubra" or "Lyctus brunneus".

3.4. Verification of ceiling structures
The technical condition verification of the ceiling structure of the wooden semi-combustion ceiling with the wooden flap and embankment was based on the values measured from the performed probe during the local survey. However, there were no defects or damage at the probe site. Also, frequent changes in the use of the building and thus changes in the live load could affect the reduction of the mechanical properties of wooden elements or could cause their local damage.

4. Conclusions
4.1. Cracks in the joints of perimeter masonry:
In the case of cracks in the structures, it is necessary to measure them and find out whether the cracks are active or passive. On the crack, we monitor its age, shape, and direction, the degree of opening, and the change of the crack over time. For this reason, we recommend the detection of all cracks on the internal and external plaster, in the presumed cracks, and subsequent observation of crack activity by applying a mortar/plaster target, which in case of failure indicates that the cracks are active and the process still continues.

Passive cracks can be sealed or injected using cement mortar, cement laitance and concrete mix, or modern technologies based on the principle of synthetic substances. Repair of Local and active wide cracks can be by stitching using steel clips, or sheathing (shotcrete). At the same time, it is possible to fix local cracks and additional reinforcement of structures by gluing steel reinforcement into the prepared grooves in the joints of the structures / drilled holes or their combination (HELIFIX system). This method can also be considered in the case of loose bricks, separated layers, etc. (e.g. in the case of lintels of windows and doors).
4.2. Humidity in the basement:
Residual moisture in the cellar, if it is not rising/seeping ground moisture, can be removed by sufficient drying of the premises and subsequently proposed remediation. Drying of unwanted moisture can be done in several ways, and construction interventions are very limited here, so remediation is limited primarily to the principles of physical and chemical.

In the case of Physico-chemical principles, it is possible to consider grouting masonry by a professional company, which will choose the most suitable solution (method of design and material) based on the actual condition. However, this type of measure is costly. The most available effective measures appear to be physical principles, such as intensive ventilation of cellars and the use of electric dehumidifiers (ideally on a condensing basis). If the impact of cellars with moisture is extensive to fatal, without long-term measures (e.g. after flooding), invasive measures in the form of installation of intensive heat sources together with effective dehumidifiers should be considered. This is a one-off measure, but it is also costly in terms of energy consumption. Other physical measures in the form of microwave wall heating and electroosmosis can also be considered.

4.3. Rotten and damaged wooden truss elements:
Excess moisture in the affected wooden truss elements can be additionally removed by thorough drying or complete replacement of the elements, depending on the extent of the damage. The rotten head of the tie beams must be replaced. Depending on the extent of the damage, wooden elements infested with fungi / wood-destroying insects can also be rehabilitated by impregnation methods of the infested wood (in the case of a greater extent of damage, efficiency decreases), as well as microwave remediation, hot air remediation or grouting of wood elements. However, these are costly methods. For a larger extent of damage to more elements of the recommendation, we recommend replacing all elements in the truss.

4.4. Verification of ceiling structures
Reinforcement of the existing wooden ceiling structure can be done with the help of additional support of the existing beams, in the place of the assumption of increased static load, with the enclosed steel profiles. The dimensions of individual additional elements must be chosen on the basis of detailed verification of the technical condition of existing structures and subsequently a detailed static calculation.

4.5. Recommendations for further survey activities
Due to the age of the building, its long-term non-use, and due to the occurrence of several types of defects and structural failures, we recommend performing:

- Removal of plasters in the entire extent of the basement space in order to determine the extent of damage due to moisture, or due to static load action (settlement of subfloors, loading, etc.).
- Carry out humidity measurements of the affected wall and ceiling structures in the cellars.
- In the place of cracks on the facade of the building, perform a complete removal of the plaster inside the building, in the affected places around the window openings, and finding out the actual extent of damage by static load cracks.
- Carry out crack measurements using a plaster target.
- Carry out a diagnosis of wooden elements in the truss, find out the actual extent of damage to elements exposed to moisture / wood-destroying insects, fungi, and rot.
- Revealing the ceiling structures in place of the designed partitions in order to determine the actual condition of the ceiling beams as part of the verification of their load-bearing capacity.
- Creating a digital model of a building using a 3D scanner or digital photogrammetry for accurate measurement of failures in one time period. It is important to choose the right LOD before starting work [3,4,5].
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References
[1] M. Dědič, “Analysis of Historical Residence on Terms of the Current State,” *IOP Conference Series: Material Science and Engineering*, vol. 471, 2019.
[2] M. Dědič, “Defects of roofing and roof structure – Apartment house Kaplice,” *IOP Conference Series: Material Science and Engineering*, vol. 603, 2019.
[3] K. Prušková, M. Dědič, and J. Kaiser, “Possibilities of Using Modern Technologies and Creation of the Current Project Documentation Leading to the Optimal Management of the Building for Sustainable Development,” *Central Europe towards Sustainable Building (CESB19)*, 2019.
[4] K. Prušková, “Building information management: Knowledge management principles used in the whole building lifecycle within the building information modeling technology”, *SGEM 2018*, Albena, Bulgaria, vol. 18, Issue 2.1, pp 209-215, 2018.
[5] M. Dědič, “Evaluation of the processes of creating a project documentation of an existing building using a 3D scanner”, *SGEM 2019*, Albena, Bulgaria, vol. 19, Issue 2.2, pp 127-132, 2019.