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LOAD-BEARING STRUCTURE MODELLING OF HISTORIC BUILDINGS

Abstract

In the contribution the analysis and subsequent reconstruction of two religious building`s roof structure is presented. In the first case, the towers of the monastery church in Jasov are described. Second the Chapel in Bratislava is introduced. Through these structures the modelling problems and methods by historic buildings are presented. For each object the diagnostic inspection, structural analysis and recommendation for reconstruction is mentioned.

Keywords

Historic monument, timber load-bearing structure, structural analysis, wind load, structural protection, wood-destroying fungi and insects.

1 INTRODUCTION

Conservation and restoration of monuments is a field that requires cooperation with all the science and technology, able to assist in research and maintenance of the architectural heritage.

A restoration is the act, which should have a character of exceptionality. Its purpose is to preserve and reveal the aesthetic and historical values of the monuments. It is based on the respect for the original building materials and joints of load-bearing elements. The original idea of structure`s operation influences the modelling of load-bearing structure. It is necessary to take into account also the changes that occurred due to the time [1].

2 THE TOWERS OF PREMOSTRATESIAN MONASTERY

Thanks to the harmony of the monastery with the nature, its position opposite the Jasovska Rock, north-south orientation and valuable garden belong the Monastery of Premonstratensian's abbey in Jasov to the most famous sacral buildings in Slovakia. Because of its urban, architectural, and artistic qualities is a national monument since 1970.

The first church and monastery in Jasov was built in 1228. The monument had been destroyed and rebuilt many times during the 13th and 15th century. The monastery was completely razed in the 18th century and a new late-baroque monastery was built in its place.

The monastery includes two symmetrically positioned two-storied buildings, located on the sides of the central single-nave church with two towers in its facade.

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Fig. 1: Northern view at the Monastery

The reconstruction of the monastery has been carried out for several years. After the reparation of the roofs and renewal of cladding, the reconstruction of the towers has started. The wooden structure of the tower is 15m high. Towers are anchored to the bottom brick building with steel draw-bars. The structure has an octagon floor plan. The tower contains eight main columns placed in the edges of octagon. Columns are supported with a system of pitched supports. The columns are placed on the horizontal cross beams of the base. At a height of 9,5m there is the bearing cross of the tower's helmet. Both crosses are made of oak wood. The other timber elements were made of red spruce and spruce [2].

The investor's intention was the complete replacement of the cover plates, which were damaged in several places. This was caused by degradation of the decking and some bearing elements. The aim of the diagnostic survey was to determine the extent of damage in wooden elements by biotic and abiotic cankers.

According the findings from the survey the structural analysis of load-bearing elements and their joints were carried out.

2.1 Structural analysis

The first step in the reconstruction of historic buildings is a geodetic survey. After the survey, the detailed diagnostic inspection follows, which focuses on the biotic and mechanical damage of the bearing structural elements and connections.

During the diagnostic survey it was found out that the structure of the towers are not reinforced sufficiently. In one of the towers the spatial reinforcement lacked, which prevents twisting the tower structure. This tower was slightly twisted around its vertical axis in the time of inspection.

Due to the shape of the towers, the wind load is the main load. By structural analysis three cases were verified. First: the state before the reconstruction, when the anchorage was not sufficient. Second: the state during the reconstruction, when the cover plates were removed and third the state after reconstruction, when all the deficiencies were removed.

The cross sections of elements and their joints predetermine the way of loading. Some elements can carry only tensile force, other only compressive. Most of carpentry joints are designed to compressive forces. They are not able to carry significant tensile forces.

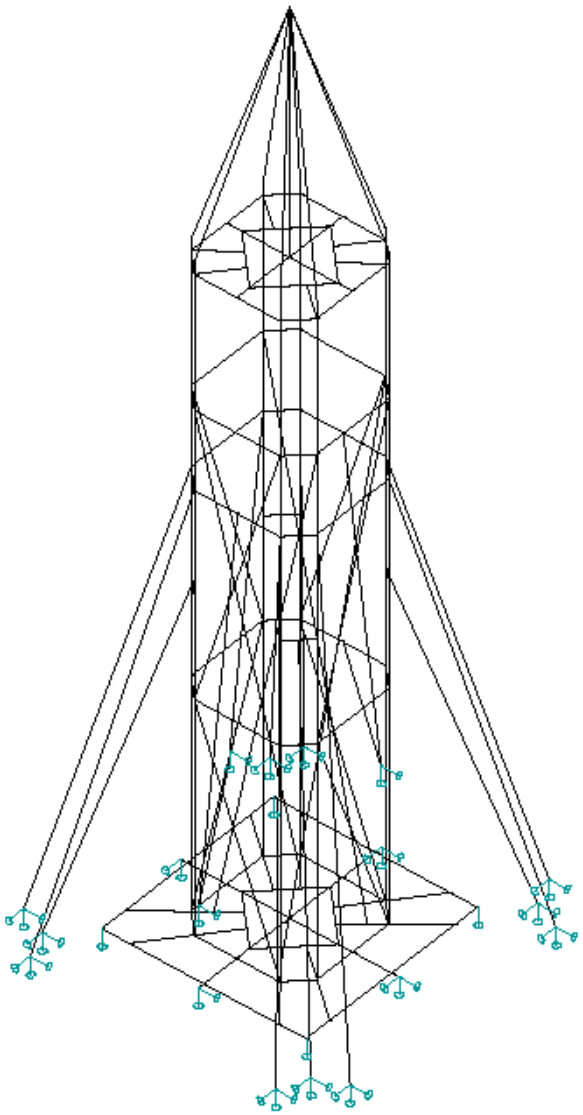

Fig. 2: 3D FEM model of the original structure

2.2 Refurbishment

On the base of the diagnostic inspection and structural analysis, the design of reconstruction has been carried out. First it was necessary to strengthen the tower base (fig. 3, 4), because of biotic damage by the supporting walls. Furthermore it was necessary to completely replace the elements of onion rings and decking. The new additional steel bracing system with a circle cross section was designed, located between the main supporting columns. The main columns were additionally supported by timber elements, providing better load distribution on the base of the tower. For the case of future inspections, the system of ladders and landings were proposed providing safe access to the highest positions of the towers. Besides the safe access, the landings are increasing the spatial rigidity of the structure.

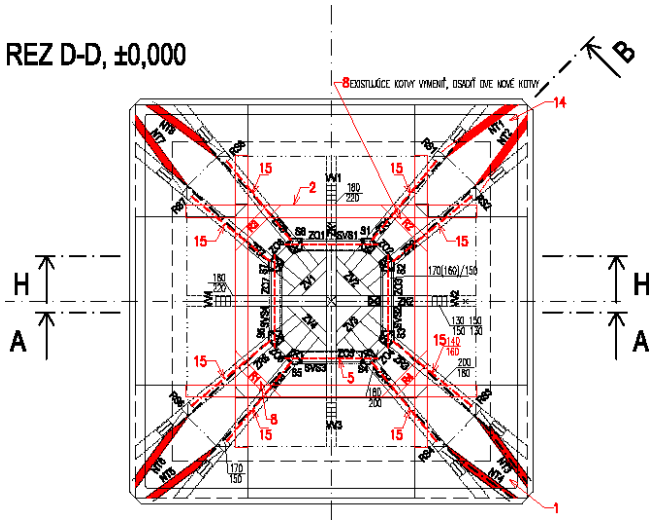

Fig. 3: The design of refurbishment – the lower base

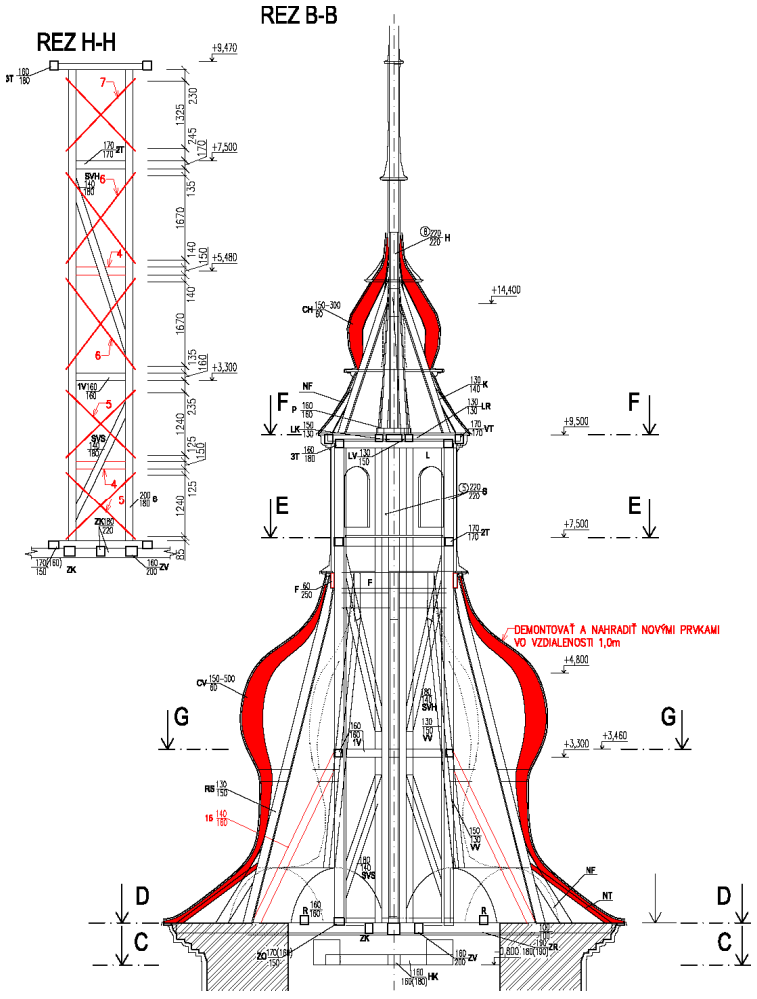

Fig. 4: The design of refurbishment – Cross section

3 THE CHAPEL IN BRATISLAVA

According to the available historical sources, the chapel dates from around 1780 and probably is the rest of an unbuilt baroque church. In 1870s within the extension of the chapel by a timber construction, some modifications on main nave`s roof was carried out. The chapel`s tower was built additionally. The change of covering and also the last reconstruction was in 1970.

Fig. 5: The chapel of Madonna Mary

The reconstruction of the baroque chapel began to at the "last" moment. The serious condition of the chapel can also evaluate an observant passerby. The tower of chapel was inclined toward the altar. The geodetic survey obtained the horizontal deformation of the tower about 0,5m at its highest point. During the diagnostic inspection serious defects of principals and other beams was detected, causing the inclination of the tower. The moisture of wooden components was measured with a portable moisture-meter. By many elements an absolute moisture content above 35% was detected, which was not corresponding to the equilibrium moisture content of wood for the climatic conditions in the attic in the time of inspection. This state was measured also in places where the direct leakage of rainwater could not appear. According to the measured values of wood's moisture content it is likely that the covering of the church does not fulfil its function in terms of tightness and in terms of vapour impermeability [3].

The last renovation of the wooden structure was inexpert, because the original structure was repaired by amateur way by adding various additional elements, which had very little static efficiency. The structural elements were not protected against the progressive decay. The intervention to the load-bearing structure in such a degree was very insensitive and induced further rapidly degradation of the wooden components. As the supporting points the vault was used, what is unacceptable in terms of load bearing system and did not match to the original idea of the load-bearing system.

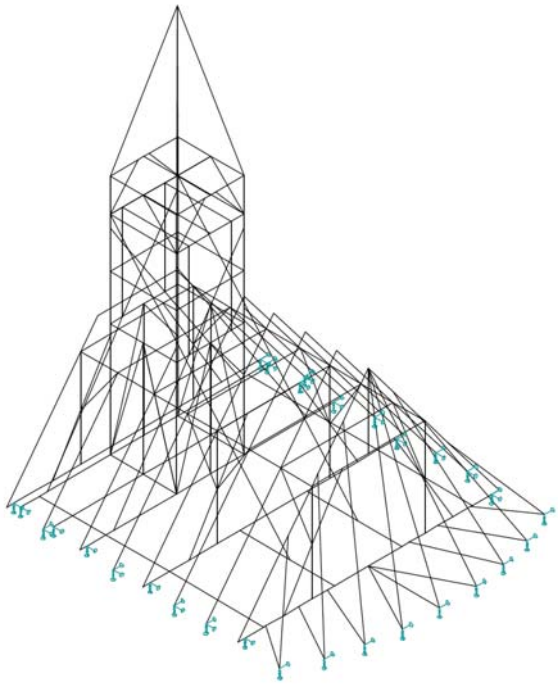

Fig. 6: 3D FEM model of the structure

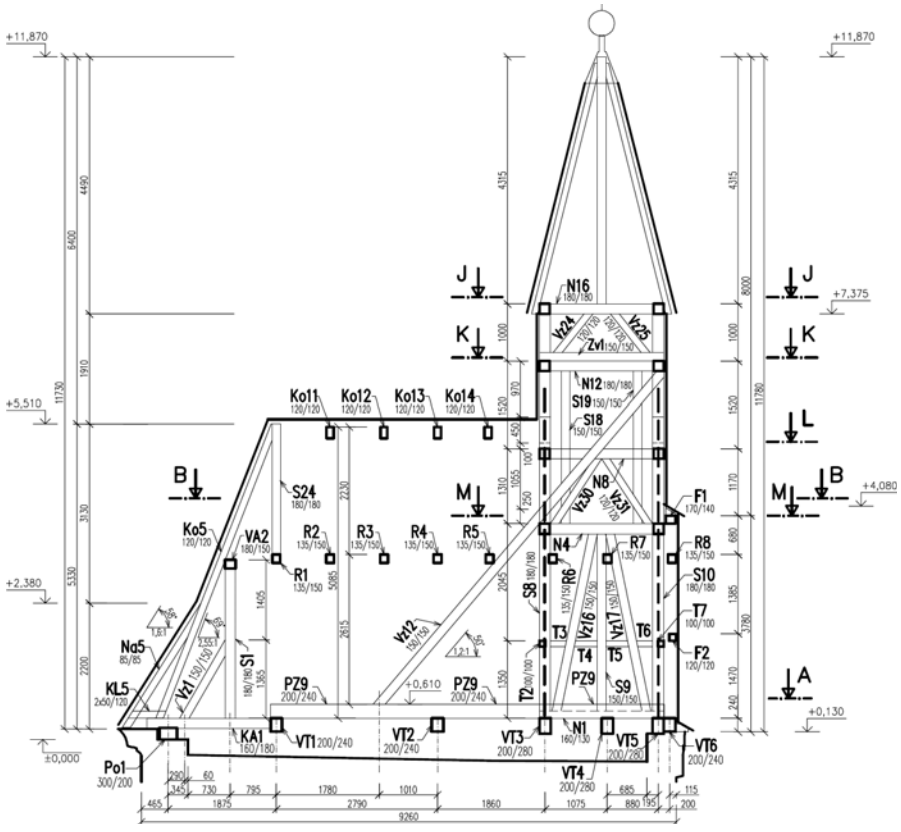

Fig. 7: Longitudinal section

Based on the diagnostic inspection the emergency condition was announced. Consequently the project of reconstruction was worked out, with the aim to maintain the original structure. It was necessary to cooperate with the Regional Monuments Board during the design works, seeing that the most of the original elements could not be saved. That's why the new structure was worked out as a real copy of the original roof structure, using the material of the same plants and using the same covering. In terms of indoor climate of the attic space, it was necessary to create effective ventilation. The air supply was designed near the wall beams and air will be led away through the tower of the chapel.

4 CONCLUSION

A renovation of load-bearing structures of the historic monuments is a very specific field, where the requirements to keep the monument in the most origin state and the demands for the safety and reliability of the structure meat each other. In the process of reconstruction of historical monuments, it is necessary to take into account several factors, which influence the activities of a designer. It is necessary to harmonize the demands of Monument Boards, investors, architects, structural engineers and contractors. A timber structure requires a cooperation of experts with knowledge of the wooden material and experts who are aware of the function of various elements in the structure. Knowing the functions of the elements, many of them could be saved in accordance to the requirements of the monument, because in spite of the defects, the dimensions of the cross sections are usually sufficient for bearing the loads. It is always in favour, if the designer works with an experienced contractor during the design and communicates with each other. After the reconstruction the regular inspections by an authorized person are important to save the monument as much as possible for the next generations.

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