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Notre-Dame Cathedral Fire

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Short report

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Abstract

Of all the possible disasters that can damage monuments and installed exhibitions and collections, the most devastating are fires. Thus, even world-famous historical monuments have not escaped these catastrophes. The article deals with information about these fires. We describe in more detail the Notre-Dame de Paris fire and its subsequent recovery process. We have also created an overview of systemic preventive measures to protect historical and cultural monuments from fire.

Keywords: fire, fire prevention, historical building, Notre-Dame de Paris

1 Introduction

Of all the possible catastrophes that can damage monuments and buildings without monuments, and in their installed exhibitions and collections, fires are the most destructive ones. Thus, even world-famous monuments did not avoid these big and unpleasant events. Many owners as well as administrators of monuments mistakenly think that a fire cannot break out in their monument. Based on events, whether after the fire at Krásna Hôrka Castle, or in the Czech Republic after the fire at Pernštejn Castle, the all-wooden church in Guty or the wooden building Líbušín and the fires of cultural and historical buildings in other countries is paid more attention to this issue.

The Fire of the Castle of Krásna Hôrka in 2012 initiated the audit to secure the protection against fires all historical and cultural monuments in Slovakia. There are more than 12 thousand monuments that must go through this audit in our country.

The aim of this work is to point out the issue of fires in historic buildings, their subsequent ongoing renovation and overall renovation of the building, based on the example of the fire of the Notre-Dame Cathedral. This fire was also a stimulus for obtaining further information on the system of fire protection of historical and cultural monuments, as this issue is given little attention in the study of wooden buildings.

2 Analytical part

In this part of the work, we will use literary and Internet sources to analyze:

1) fires of selected historical and cultural buildings,

2) fires of Notre-Dame Cathedral in Paris

3) create an overview of systemic measures to protect historical and cultural monuments from fire.

3 Results and Discussion

3.1 Significant fires of historical objects

Fires do not avoid even the most important monuments. An overview of selected fires in historic buildings is given in Tab. 1.

Tab 1. Selected fires in historical buildings

Objects affected by fire	Date of fire	Damages caused by fire
Church of St. Michal in Prague – Czech Republic	10. 28. 2020	A large part of the church was destroyed.
Notre-Dame Cathedral in Paris – French Republic	04. 15. 2019	Destroyed roof, Sanctoid tower, damaged stained glass windows and arched ceilings.
National Museum in Rio de Janeiro – Federative Republic of Brazil	09. 02. 2018	Flames probably destroyed a collection containing more than 20 million objects, from archaeological findings after historical memorabilia.
Bank buildings in Belfast – The United Kingdom of Great Britain and Northern Ireland	08. 28. 2018	The building has suffered extensive damage at all levels, but the new wing of the building was relatively undamaged.
Church of the Assumption of the Blessed Virgin in Kondopoga – Russian Federation	08. 10. 2018	The whole church was destroyed.
Church of the Corpus Christi in Třinec-Guty – Czech Republic	08. 02. 2017	The whole church was destroyed.
Libušín at Pustevny – Czech Republic	03. 03. 2014	The fire destroyed its right part in which the artificially most valuable dining room was located.
Krásna Hôrka castle – Slovak Republic	03. 10. 2012	The shingled roofs, the exhibition in the upper Gothic palace and the bell tower burned down. The ceiling was broken in the congregation hall. Firefighters saved 90 percent of the exhibits, but the inner parts of the castle grounds remained smoky.
Industrial Palace in Prague – Holešovice – Czech Republic	10. 16. 2008	Burned the left wing of the building.
Pernštejn castle – Czech Republic	04. 15. 2005	About 700 objects burned in the depository in the former granary, including several rare paintings. A significant problem was that firefighters could not reach the third courtyard with fire with heavy equipment.
Lunéville castle – French Republic	01. 02. 2003	The entire roof and most of the chateau rooms, including the ministry halls and the chapel, burned down.
Church of St. Catherine's in Ostrava-Hrabové – Czech Republic	04. 02. 2002	The whole church was destroyed.
Chapel Bridge in Lucerne – Switzerland	08. 18. 1993	Two thirds of the wooden chapel bridge was destroyed.

3.2 Notre-Dame Cathedral fire in Paris

It is called the heart of Paris and is also the home cathedral of the Roman Catholic Archdiocese of Paris. Its name is also translated as Our Lady, or the Cathedral of the Virgin Mary or the Church of the mother of God. It was in this sacred place that the writer Victor Hugo planted the story of his world-famous novel The Temple of the mother of God in Paris. It is listed as a UNESCO World Heritage Site (Wikipedia, 2021).

The construction of the Gothic cathedral lasted from 1163 to 1345 and was started by Louis VII. At that time, Paris was only a diocese. During the Great French Revolution in 1793, the cathedral was destroyed and looted by revolutionaries, who also melted precious metals on altars. But by making it famous in Victor Hugo´s world-famous work, a voluntary collection was made, and the cathedral was saved again.

Fig 1. Notre-Dame Cathedral (before fire)

On April 15, 2019, for the first time in Paris Notre-Dame Cathedral, a fire alarm sounded on Monday at 6:20 p.m. At that time, even after a double procedure, they did not detect a fire. There were fire monitors in the cathedral, which checked the wooden structure under the roof three times a day. Notre-Dame did not have automatic sprinklers under the roof and its attic space was not divided into fire walls.

At 6:43 p.m. the alarm was activated again. The fire started in wooden beams under the roof, which is also nicknamed the forest. At that time there was a mass in the cathedral, people were subsequently evacuated. The fire then spread quickly. The temperature also reached 800 degrees Celsius and was fought by more than 400 firefighters. The fire was primarily fought from inside the structure, which was more dangerous for the staff, but reduced the potential damage to the cathedral, applying water from the outside risks draining flames and hot gases (at temperatures up to 800 ° C) to the inside. Flood cannons were used at lower than usual pressures to minimize damage to the cathedral and its contents. Aerial firefighting was not used because water falling from heights could cause structural damage and heated stone could crack when suddenly cooled. Helicopters were not used due to dangerous rising currents, but drones were used for visual and thermal imaging and robots for visual imaging and directing watercourses (Fig. 2). Molten lead falling from the roof posed a particular danger to firefighters.

Fig 2. Robot for visual display and guidance of watercourses

Fig 3. Fire extinguishing from platform

The fire, which lasted 15 hours, destroyed the tower of the building, the roof of the entire ship, the upper parts of the walls, medieval stained-glass windows, and part of the interior. However, the cause of its occurrence has not yet been precisely determined. It is assumed that the fire originated from a cigarette or electrical short circuit during reconstruction work. But there is no indication that this was intent or arson.

At 23:00, the head of the Paris fire brigade announced that the building, including the two front towers, had been ,,saved and preserved as a whole", but that two-thirds of the roof had been destroyed. The 69-meter-long tower, with a wooden frame covered with lead, was destroyed (Fig. 4). Although the 800-ton tower was certainly one of the most distinctive features of Notre-Dame, it was not actually part of the original building. The first tower built between 1220 and 1230 began to deteriorate after several centuries and was removed at the end of the 17th century. The cathedral was without a tower until 1859, when the builders completed work on a new design by architect Eugène Viollet-le-Duc - which, according to popular mechanics, was not an exact replica of the original.

Fig 4. Collapse of the Sanctuary tower

Weeping Parisians and stunned tourists watched in disbelief, while hell raged on the cathedral, which marks the very center of Paris. Some sang liturgical music in harmony long into the night as they stood alert, others prayed.

The French Ministry of Culture has announced that the government has set up an online portal for all those who want to contribute to the reconstruction work - more than 900 million euros have been promised to repair the cathedral from several people, companies, and institutions (Vasilko, 2019; Wikipedia, 2021; Topky, 2021; Henley, 2019.).

3.3 Status after destructive fire

The Gothic cathedral is like a house of carats: - if one side weakens, the whole side will collapse. Due to its bold height and the fact that the outer walls are weakened by several layers of windows, its structure is fragile. For months, no one could enter the cathedral due to the danger of lead dust and debris falling from the broken vault. A lone robot, controlled by a remote control, was able to clean up the burnt remains.

The first phase of restoration - conservation and protection - lasted 15 months. President Macron has appointed General Jean Louis Georgelin, the former head of President Sarkozy´s office, to oversee the work. Under the 28 pillars, wooden supporting vaults are placed, which, however, are not fixed in the stone (Fig. 6). Each of the beams had different dimensions, and therefore its mounting required maximum accuracy.

Fig 5. Notre-Dame Cathedral after fire

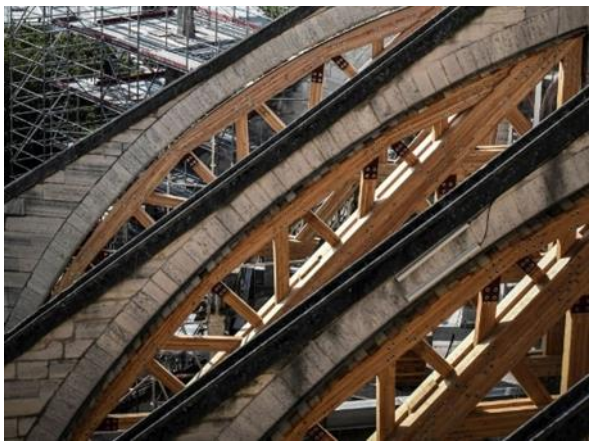

Fig 6. Wooden support vaults

Then began the most difficult and dangerous operation: the dismantling of the scaffolding, which was built in May 2018 to repair the crumbling tower (Fig. 7). This scaffold melted to form an ugly and ill-looking black mass of 40,000 metal pieces glued together. Workers with a rope approach (Fig. 8) (called cordists in French) had to collect the pieces by hand one by one, hanging on ropes high in the air. Sensors were placed under this unstable mass.

At one point, an alarm sounded. They all ran away. Disassembling this mass was like playing a huge game with a mikado, which consists of removing the sticks without disturbing the rest of the pile. Restoration work on the cathedral was interrupted twice: first when the fear of lead contamination forced all activities to stop. Workers had to wear white protective suits with masks connected to a filtered air supply. Before entering the construction site, every single worker must take a shower and change in a special cabin and keep a two-meter distance from his colleagues, which is almost impossible due to the space (TV Noviny, 2020; Regióny, 2020; Logan, 2021; Moneycontrol, 2021).

Fig 7. Wrenched scaffolding

Fig 8. Rappelling workers in protective suits

3.4 Rescued works

Some works of the cathedral were saved due to reconstructions (from fire). For example, 16 copper statues representing the twelve apostles and four evangelists to cleanse and restore them. The rooster that was on top of the tower is now on display in the Archaeological Museum and will remain there as well. He will be replaced by a replica. Fortunately, the organ and the three pink windows have been preserved, but they will require a lengthy renovation. It is particularly gratifying to know that the rose window at the southern end of the transept is intact (Fig. 9) (Logan, 2021).

Fig 9. Pink Window at South End Transept

3.5 New (old) roof design on cathedral

Just days after the fire that destroyed Notre-Dame in Paris on April 15, 2019, then-French Prime Minister Édouard Philippe announced plans for an international competition to design a new, more modern tower „suitable for the techniques and challenges of our time“.

It attracted more than 200 designers from 56 countries and motivated more than 30,000 people to sign up and vote for their favorite designs. Visualizations of the designs are shown in fig. 10 and 11. Some architects have proposed to replace a wooden glass roof with a metal structure like the original, either a solar roof (Fig. 10) or a greenhouse full of plants (Fig. 11).

Fig 10. Paris Cathedral could be equipped with a new solar roof

Fig 11. Greenhouse full of plants

A team of two Chinese architects won a design competition. The design by Chinese architects, entitled ,,Paris Heartbeat" (Fig. 12), boasts three creative elements.

Fig 12. Proposal „Paris Heartbeat"

When designing, the new tower is interpreted into poly mirrors that subtly reflect the context along with the mirrored roof. In addition, a time capsule floats to the top of the tower every half century. The installation of magnetic levitation is made to preserve the memory of the past and reserve space for the

future story. The new tower represents the memory, presence and hope of humanity. The time capsule can move rhythmically up and down, breathe, and beat along with the city.

However, these architects will have to bring their inventive designs to life elsewhere. According to the artnet News report, the French Senate has passed legislation ordering the cathedral to be ,,put into its last known visual state". President Emmanuel Macron issued a statement in support of the decision, explaining that city officials should instead add a ,,current gesture" to the ,,restoration of the cathedral area".

All renovations will be carried out in compliance with the guarantees set by ICOMOS (International Council on Monuments and Sites) (Fiolova, 2019; Zestec, 2019; Baldwin, 2019; Gutoskey, 2020).

3.6 Status after two years from fire

At present - two years after the fire (April 15, 2021), the process of restoring the Notre Dame Cathedral is being strengthened by strengthening the vault of the cathedral and preparing a future wooden structure that will support the roof. It should be ready by next summer. Most of the interior of the cathedral is now filled with metal scaffolding. To protect against the rain, an umbrella sail was installed above the through hole, where the tower once stood. The stone, metal, glass in the interior have already been cleaned. Wooden scaffolding is still being installed to stabilize the fragile areas of the cathedral vault, as well as the vaults. Stonemasons fill in the gaps and missing stones in the perimeter walls. They reinforce the most damaged areas with glass fibers.

Fig 13. Wooden beams supporting vault

The next step will be the insertion of ,,half hangers" (also called ,,centering frames") under the six rib vaults in the choir, the northern part of the transept and the nave. Other major works are underway above the vault and under the roof. Reconstruction of a wooden frame from the 12th - 14th century, called a forest, is currently being prepared. To support the roof, there are custom-made ,,half-blocks" wedged under the roof and large triangular frames. One thousand of the best oaks have already been selected in several French forests. It was found that the beams from the 13th century were made of trees younger than 60 years, they were 12 m long and 30 cm in diameter. In addition, the trees were not allowed to dry for 18 months but were still used fresh after felling.

President Emanuel Macron reiterated his vision of reopening the cathedral by 2024 - both for religious purposes and for visitors to the Olympic Games, acknowledging that full restoration is likely to take several years longer (Dnes24, 2019; Plus Jeden Deň, 2021; Timeslive, 2021; Logan, 2021; Moneycontrol, 2021).

Fig 14. Current reconstruction work

Fig 15. Reconstruction work indoors

3.7 Square in front of Cathedral

Square before the Notre-Dame Cathedral in Paris was closed after the tests again revealed the high concentrations of the toxic particles of lead as just after the fire informed the Paris Police Department. Although the square has since been opened, concentrations of toxic lead particles have been regularly tested at selected locations, and local concentrations of lead dust are still higher than normal for Paris. Therefore, it was re-enclosed and to a new cleaning operation (Rfi, 2021).

3.8 What is the system of measures to protect historical and cultural monuments from fire?

The system of measures for the protection of historical and cultural monuments against fire is based on the following aspects (Jirásek et al. 2015, Decree of the Ministry of Interior of the Slovak Republic No. 202/2015 Coll. amending and supplementing Decree of the Ministry of Interior of the Slovak Republic no. 121/2002 Coll. about fire prevention):

- Fire risk analysis - this analysis is key to the fire prevention system at the monument and cultural facility and will help identify their weaknesses.
- Fire prevention - consists in setting internal regulations so that the occurrence of fire is minimized. These include regular inspections of the building, revisions of electrical installations and appliances, technical equipment, and equipment for the removal of combustion products from the building and other measures resulting from applicable regulations.
- Early fire detection - ensuring automatic fire detection by EPS system, resp. arrange regular inspections of the building at the end of working hours.
- Preparation for fire extinguishing - includes the deployment of portable fire extinguishers, hydrant systems, knowledge of fire water sources, as well as ensuring free entry and stands for units of the Fire and Rescue Corps and other components of the Integrated Rescue Corps. It is necessary to provide retraining and training of personnel in case of fire extinguishing, including the processing of fire reporting documentation.
- Measures against the spread of fire - in a minimalist sense, it consists in ensuring the principle for closing the door, especially at the end of working hours. When working on the renovation and maintenance of the building, pay special attention to ensure fire protection of the workplace. Also divide the building into fire sections.
- Preparation for the evacuation of persons and objects of a cultural nature - includes evacuation plans, but also the preparation of packaging materials and crates and regular exercises of rescue teams. This also includes the effective marking of escape routes and the installation of emergency lighting.

In practice, the method of a checklist is used to verify the condition of the fire protection system in cultural heritage sites. The form was adapted and used by British expert Stewart Kidd in 1990 (Kidd

1995). Since then, the method has been used to assess monuments in Scotland, Wales, or other Central European countries. From 2010 to 2014, up to 91 monuments under the administration of the National Monuments Institute of the Czech Republic were assessed using this method (Jirásek et al. 2015). The form consists of:

Basic information about the building - type of monument, owner / administrator and the person filling in the questionnaire and his professional focus. The following are information about the object, such as approximate age, number of floors, number of visitors per year and number of rooms.

Part A - Fire hazard assessment - aimed at an analysis of the fire hazard resulting from the materials used, internal equipment and operational activities that are carried out on the castle (Table 2).

Part B - Fire-fighting measures - aimed at identifying fire-fighting measures that reduce the risk of fire (Table 2) (Jirásek et al. 2015, Gašpercová et al. 2018).

Tab 2. Criteria for verifying fire protection system.

Part A - Fire hazard assessment	Part B Fire-fighting measures
1) Predominant building materials	1) Fire detection
2) Roof covering	2) Alarm and evacuation system
3) Roof construction	3) Automatic fixed fire extinguishing system,
4) Design of corridor walls - escape routes,	4) Regulation of combustion exhaust ventilation
5) Construction structure and division into fire sections	5) Fire equipment
6) Interior treatment of floors, walls, and ceilings of room interiors	6) Technical means for emergency units
7) Fire load of rooms	7) Doors
8) Fragmentation of the interior	8) Escape routes
9) Height of the ceilings	9) Protection against lightning
10) Possible sources of ignition	10) Building care
11) The threat of the spread of fire from the vicinity of the building	11) Building management
12) Materials of cultural objects, roofing building materials	

The result of the analysis is an overall assessment of the risk of fire in cultural heritage sites, which is the difference between the number of points in Part A and Part B. The overall assessment results from the following scale: up to 19 points = low fire risk, 20-39 points = normal fire risk, 40- 79 points = increased risk of fire, 80 and more points = high risk of fire.

By processing such an analysis, we get a picture of the fire danger of the object. This analysis can also be the basis for determining the protection of objects. The analysis is also important in planning the restoration of monuments in connection with the expansion of accessible spaces and associated collections. On April 7, 2021, it was published (Teraz.sk 2021) that by the end of 2022 the Ministry of Culture of the Slovak Republic should prepare the conditions for the establishment of a separate Fund for Monuments, a new public institution whose mission will support the protection and restoration of immovable and movable national cultural monuments. This follows from the proposal of tasks and measures within the Strategy for the Protection of the Monument Fund for the years 2017-2022 and the action plan for the years 2021-2022.

4 Conclusions

By processing this work, we have prepared a general view of the destroyed historical and cultural monuments because of the fire. We did not delve deep into history, rather we tried to describe the devastating effect of fire. At the same time, we described the course of the fire, the ongoing repairs and the interesting design process as Notre-Dame Cathedral in Paris will look like in the future. According to a statement by the French president, this cathedral should be opened to the public in 2024, when the Olympic Games will be held in Paris. However, despite this statement, all experts agree that this extensive repair of the cathedral will take much longer in terms of accuracy, safety, and quality of repair.

This situation was the impetus for obtaining information about the system of fire protection of historical and cultural monuments in our country. We introduced the method of a checklist, which they successfully use abroad and are gradually establishing in the conditions of the Slovak Republic. Preventive organizational measures have a major impact on the possibility of fire and cooperate with preventive systems based on electrical signalling devices. Unlike them, however, it costs almost nothing.

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