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HISTORICAL CONSTRUCTION WOOD – EXTENDED RESEARCH METHODS ON THE EXAMPLE OF OLD ROOF TRUSSES

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ABSTRACT: Old wooden structures are integral parts of monuments. These constructions are often insufficiently recognized and documented. Scientific information contained in them is often obliterated or destroyed during renovations or as a result of disasters. The progress of wood research methods and their interdisciplinary scope allows today to collect a lot of important data not only on the construction itself, but also on the history of the object and the changes that have occurred in the environment from which the building material was sourced.

KEY WORDS: Old wooden structures, contemporary research methods, National Heritage Board of Poland, research of historic wooden structures, interdisciplinary studies

On April 15, 2019 a great fire took place in Paris. As a result, the extremely valuable historical roof structures of Notre Dame Cathedral were annihilated, and the cathedral itself was also on the verge of total obliteration. Those roof trusses, dating back to the 12th and 13th centuries, were among the most valuable examples of medieval carpentry works in the world, and the structures above the transept and the spire towering over the cathedral were the work of Viollet le Duca[1]. As a result of the fire, the spire collapsed, and some of its structures and elements of

[1] https://www.notredamedeparis.fr/decouvrir/architecture/la-charpente/, access 01.06.2020.

rafter framing smashed the vaults, falling inside the cathedral, burning and threatening its brick structure and valuable equipment. This extremely violent fire was extinguished after thirteen hours.

This tragedy reminded us of the important role played by historical wooden constructions in the monuments, of which are an integral part. They co-create their universal values and are an important document of history. The old roof structure, attic space and roofing contain a lot of scientific information, insufficiently researched and documented[2]. These data are often destroyed during renovation works or as a result of fires or other disasters. These and other wooden parts of the monument should obligatorily be subject to extensive interdisciplinary research, the conclusions of which must be taken into account in renovation projects and ongoing maintenance of the object. They may serve to broaden the knowledge about the history of the studied object and be extremely useful in other fields of science.

The difficult accessibility and the risks occurring in attics were often an obstacle to the thorough recognition and analysis of historic wooden roof trusses. For these reasons, many roof trusses have been omitted or only superficially recognized and studied in the conservation documentation. In Poland the situation changed in the late 1990s, when the National Center for Research and Documentation of Monuments in Warsaw began its own extensive research on these historical structures and spread knowledge about them. At that time, attention was drawn to the need for more precise identification and documentation of preserved historic roof structures, a new look at their typology, and comparative research on a national and European scale - they began to be examined, researched and described in greater detail[3]. The experience and knowledge gained was passed on to the conservation community. This extended recognition and research consisted, among other things, in conducting detailed visual inspections of the rafter framing, but also of the attic, roof and its covering. The type of roof structure was determined, dimensional analysis of the structure elements was carried out, more detailed inventories were made, attention was paid to carpentry connections and dendrochronological tests were commissioned. These observations allowed for the preliminary determination of the historical value of the structure, its authenticity and completeness, but also allowed for the discovery of deformations, damage to the structure and traces of its repairs. The inspection of monuments conducted from the attic side, so far less appreciated, began to enrich and supplement the knowledge about the objects, because some elements of their construction are well visible there and often more easily accessible than from the other storeys. The wood of the structure was described, and the samples taken helped to identify its species. Analyses of the surface of the elements made it possible to determine the method of processing wood. Traceology (a field of knowledge dealing

[2] Mączyński D., *Drewniana, historyczna konstrukcja dachowa - ważnym źródłem informacji naukowej,* [in:] Lubuskie Materiały Konserwatorskie 2017 vol.14, pp. 177-192.

[3] Mączyński D., Warchoł M., *Opis i analiza konstrukcji dachowej nad nawą główną kościoła ss. Wizytek przy ulicy Krakowskie Przedmieście w Warszawie*, [in:] Monument, Studia i Materiały Krajowego Ośrodka Badań i Dokumentacji Zabytków, issue 2, 2005. https://www.academia.edu/38274849/Opis_i_analiza_więźby_dachowej_nad_nawą_główną_kościoła_ss._Wizytek_przy_ulicy_Krakowskie_Przedmieście_w_Warszawie(DOA 01.06.2020).

with the traces of tools on the surfaces of materials) has developed a lot in recent years and also provides a lot of important information related to techniques and technologies of erecting wooden structures. Traces of axes, various types of saws and chisels remain on the surface of processed wood and on this basis it is possible to deduce not only about the shape of the tools, size and method of their use, but also about the adopted methods of processing, its quality and even the number of carpenters employed. We can distinguish between tools used by left and right-handed people, and each, even slightly damaged blade has left characteristic micro marks on the wood, which tell us about the use of this tool on the construction site and about the uniformity of all the work done. Carpentry marks are currently being thoroughly inventoried and their completeness, method of manufacture and the construction elements numbering systems used are being analyzed. Trademarks - sets of letters and numbers cut out at the edges of the processed elements are characteristic of the 19th century constructions, but have not yet been fully studied and their detailed meaning has not been explained[4]. Epigraphics fixed on the surfaces of wooden elements of the structure are often dates and inscriptions related to the history of the object, which constitute an important trace documenting its history[5]. It should also be mentioned, by the way, that in wooden carpentry structures there are sometimes metal elements from the times of erection of the monument or introduced during repairs of the structure. It is also a valuable material for metallurgical research and structural analysis. The upper parts of the walls may have preserved plasters and decorations coming from earlier stages of construction - these surfaces are generally available in the attic and give the possibility to obtain complementary information on the evolution of the object under study. The remnants of wooden roof coverings, such as shingles and shakes (*dranice*) , found in the attics allow to formulate conclusions about the earlier coverings, the material from which they were made and the ways of their arrangement. It is sometimes possible to date them using dendrochronology. The elements of ceramic and tin roofing preserved in the attic space or on the roof are also examined. The gable walls in the attic very often show traces of previous roof constructions, which may have had a different layout and slope than those existing today. Quasi-destructive tests include the use of endoscopes that allow to complete the visual inspection in places that are difficult to access - in the space of walls, ceilings or when assessing the condition of the endings of truss beams or rafters. The diameter of the endoscope tip is about 5 mm, so an existing gap or a small hole can be used to make such a diagnosis.

Historical roof constructions are often catalogued with modern methods, using data recording obtained using laser scanning[6], electronic tachometry, digital photogrammetry and 360 degree

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[4] Mączyński D., Jedlikowska M., *Znaki handlowe na powierzchniach zabytkowego drewna konstrukcyjnego* https://docplayer.pl/40061739-Znaki-handlowe-na-powierzchniach-zabytkowego-drewna-konstrukcyjnego-commercial-signs-on-the-surfaces-of-historical-wood-constructions.html (DOA 01.06.2020).

[5] Mączyński D., *Znaki, inskrypcje i ślady w zabytkowych konstrukcjach dachowych*, http://www.dachy.info.pl/technika/znaki-inskrypcje-i-slady-w-zabytkowych-konstrukcjach-dachowych-cz-2 (DOA 01.06.2020).

6 Zapłata R., *Pomiar, inwentaryzacja i diagnostyka drewnianej architektury wernakularnej – wybrane zagadnienia zastosowania technologii skanowania naziemnego,* [in:] Budownictwo i Architektura 14 940 2015, 165-181, https://yadda.icm.edu.pl/baztech/element/bwmeta1.element.baztech-e4250636-6be1-4d79-b5ec-291107d03af9/c/zaplata.pdf (DOA 01.06.2020).

photography. However, it should be remembered that instruments automatically recording sometimes large amounts of data may omit information relevant to the construction or places where the construction is not clearly visible or accessible. Therefore, a detailed inspection of the structure by competent specialists who know and understand the old construction techniques and pay attention to and analyze all, even small details of the applied solutions (e.g. joints and carpentry marks, damage, surface finish, etc.) can complete and significantly enrich the measurement and basic inventory. Each rafter, each element of the structure, viewed from many sides and examined helps to establish and understand the nature and material of the structure, its history, layout and work in the context of the entire structural structure of the monument[7].

In recent decades there has been a rapid development of methods and techniques for testing wood as a material. Dendrochronological research is becoming easier and easier, covering more and more areas and objects. In general, it is easy to identify the species of wood, and once the place where the wood was collected for the construction site, the date of felling can be determined with an accuracy of one year. On this basis, by examining more samples from one site, it is possible to date and determine the phases of construction. The sixth generation of resistographs, already in use, provides measurements of wood density with an accuracy of 1/100 mm. At the same time, when wood is drilled with the help of this device with a 3 mm drill, a wirelessly connected printer prints out a graph corresponding to the annual grain pattern in the examined element. In the case of wood samples taken with the classical drilling method, new systems of scanning and recognizing the pattern of the analyzed wood rings have been developed, which allows to significantly speed up and improve the research work. The methods using mass spectrometry have also been developed. Tests of the content of carbon ions C12, C13, C14 in the collected samples of wood or charcoal allow to determine the radiocarbon age. The margin of error of such tests has decreased and is: for the period of 500 years - 40-50 years, for 20000 years - 200 to 300 years. Currently, the weight of samples prepared for testing is measured not in grams but in milligrams. Unique in the world scale is a spectrometer designed especially for examining monuments, which is in the possession of the Louvre Museum in Paris - the results of material analysis are obtained by placing the object under the head of the device, without the need to prepare samples[8].

There has been a rapid development of such research areas as dendroarcheology, which, using dendrochronological methods, dates and studies ancient cultures, ancient wooden constructions and utility objects made of wood[9] and dendroclimatology, which studies patterns

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[7] For the possible reconstruction of the burnt rafter framing of Notre Dame de Paris Cathedral, a manual rafter frame measurement performed in 2015 may turn out to be the most useful. https://www.atelier32.fr/projet/ndp/ (accessed 01.06.2020).

[8] AGLAE - spectrometer in the Louvre Museum - https://fr.wikipedia.org/wiki/Acc%C3%A9l%C3%A9rateur_Grand_Louvre_d%27analyse_%C3%A9l%C3%A9mentaire (accessed 01.06.2020).

[9] Bleicher N., *Dendroarcheology of late-neolithic timber in the Federseebasin,* https://www.researchgate.net/publication/267381113_Source_Dendroarchaeology_of_late-neolithic_timber_in_the_Federseebasin (DOA 01.06.2020).

and variability of climate elements[10]. Climate changes are permanently recorded in wood, such as rapid temperature reduction visible in the wood grain system in the form of frost cracks or drought and high temperatures disturbing regular growth. It is therefore possible to track various climate changes. Dendrohydrology examines and reconstructs hydrological phenomena (ground water flow, river floods, floods and their frequency), because the soil moisture level is clearly recorded in the tree tissue[11]. Dendroecology examines the past and present of forests and their species composition (and the occurrence of fires and insect activity)[12]. Dendromorphology studies geomorphological processes including volcanic eruptions, earthquakes, avalanches, glacial movements and tectonic plates[13]. Dendroisotope chemistry, in turn, is the study of stable isotopes of carbon, oxygen and hydrogen in wood and the application of results in the field of climatological and hydrological research[14]. Dendroenvironmental studies enable the analysis of inorganic elements contained in annual growth jars and interpretation of chemical changes occurring in the environment both now and over the centuries. A number of methods improving and developing dendrochronology with the use of advanced techniques and technologies (such as X-ray densitometry, new image analysis techniques, infrared and ultraviolet studies) are also evolving, extending the possibilities of analysis of wood rings and the cells forming them. Research conducted at many universities and institutes also helps to establish new methods of wood conservation.

In Poland, the research described above is performed by specialized research units. Unfortunately, in many cases the renovation and maintenance of historic roof structures is hardly ever performed. Therefore, I think that it is worth considering the establishment of a national institute, specializing in the recognition and documentation of historical monuments, which could conduct and coordinate such modern research and collect and share their results and documentation.

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[10] Sheppard P. R., *Dendroclimatology: extracting climate from trees*, https://www.researchgate.net/publication/229883385_Dendroclimatology_Extracting_climate_from_trees (DOA 01.06.2020).

[11] Loaiciga H. A., *Dendrohydrology and long-term hydrologic phenomena,* [in:] Reviews of Geophysics, 31, T. 2, May 1993, pp. 151-171.

[12] Fritts H. C., Swetnam T. W., *Dendroecology: A Tool for Evaluating Variation in Past and Present Forest Environments,* [in:] Advances in Ecological Research, vol.19 ISBN 0-12-01.3919-7. https://www.ltrr.arizona.edu/~tswetnam/tws-pdf/Fritts&Swetnam.pdf (DOA 01.06.2020).

[13] Decaulne A., Saemundsson T., *Dendrogeomorphology as a tool to unravel snow-avalanche activity: Preliminary results from the Fnjóskadalur test site*, Northern Iceland https://www.researchgate.net/publication/228964695_Dendrogeomorphology_as_a_tool_to_unravel_snow-avalanche_activity_Preliminary_results_from_the_Fnjoskadalur_test_site_Northern_Iceland (DOA 01.06.2020).

[14] Mccarroll D., Pawellek F., *Stable carbon isotope ratios of Pinus sylvestris from northern Finland and the potential for extracting a climate signal from long Fennoscandian chronologies,* http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1008.9183&rep=rep1&type=pdf (DOA 01.06.2020).

Fig. 1 Archival view of a fragment of wood truss structure in the transept of the Notre Dame cathedral in Paris, photo D. Mączyński 2009

Fig. 2 A fragment of the Gothic structure of the roof truss of the Notre Dame cathedral in Paris, photo D. Mączyński 2009

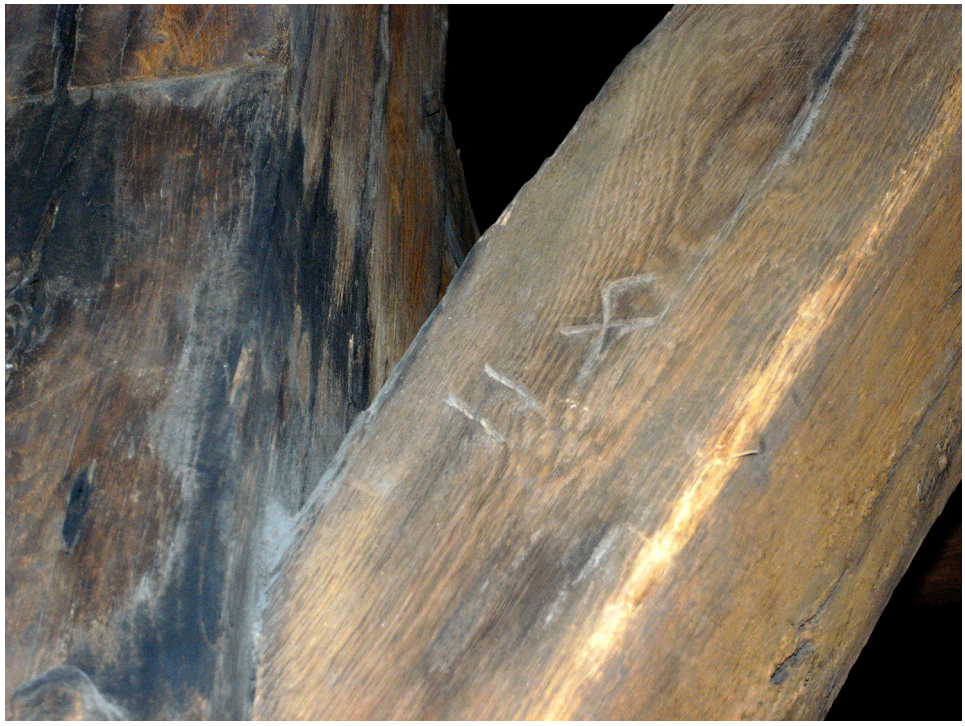

Fig. 3 Carpentry marking on an element of the roof truss of the Notre Dame cathedral, photo D. Mączyński 2009

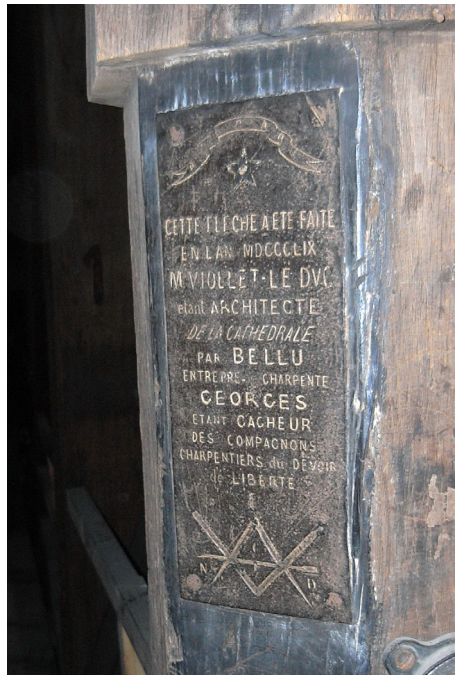

Fig. 4 A plaque commemorating Viollet le Duc and the builders of the spire, mounted in the attic on the central wooden pillar of the spire structure, photo D. Mączyński 2009

Bibliography

Blacha J., Novotny J., *Report assessing innovative restauration techniques, technologies and materials used in conservation*, [in:] Inrerreg Central Europe Ruins 04/2018 v.1.3, https://www.interreg-central.eu/Content.Node/D.T1.3.1-Report-innovative-techniques-technologies-materials.pdf, DOA 01.06.2020.

Bleicher N., *Dendroarcheology of late-neolithic timber in the Federseebasin*, https://www.researchgate.net/publication/267381113_Source_Dendroarchaeology_of_late-neolithic_timber_in_the_Federseebasin, DOA 01.06.2020.

Decaulne A., Saemundsson T., *Dendrogeomorphology as a tool to unravel snow-avalanche activity: Preliminary results from the Fnjóskadalur test site*, Northern Iceland, https://www.researchgate.net/publication/228964695_Dendrogeomorphology_as_a_tool_to_unravel_snow-avalanche_activity_Preliminary_results_from_the_Fnjoskadalur_test_site_Northern_Iceland, DOA 01.06.2020.

Fritts H. C., Swetnam T. W., *Dendroecology: A Tool for Evaluating Variation in Past and Present Forest Environments*, [in:] Advances in Ecological Research, vol.19 ISBN 0-12-01.3919-7, https://www.ltrr.arizona.edu/~tswetnam/tws-pdf/Fritts&Swetnam.pdf, DOA 01.06.2020.

Loaiciga H., *Dendrohydrology and long-term hydrolic phenomena*, [in:] Reviews of Geophysics, 31,issue 2, May 1993, pp. 151-171; file:///C:/Users/dom/AppData/Local/Packages/Microsoft.MicrosoftEdge_8wekyb3d8bbwe/TempState/Downloads/Loaiciga_et_al-1993-Reviews_of_Geophysics%20(1).pdf, DOA 01.06.2020.

Mączyński D., *Drewniana, historyczna konstrukcja dachowa - ważnym źródłem informacji naukowej*, Lubuskie Materiały Konserwatorskie 2017 v.14, pp.177-192.

Mączyński D., *Znaki, inskrypcje i ślady w zabytkowych konstrukcjach dachowych*, http://www.dachy.info.pl/technika/znaki-inskrypcje-i-slady-w-zabytkowych-konstrukcjach-dachowych-cz-2, DOA 01.06.2020.

Mączyński D., Jedlikowska M., *Znaki handlowe na powierzchniach zabytkowego drewna konstrukcyjnego*, https://docplayer.pl/40061739-Znaki-handlowe-na-powierzchniach-zabytkowego-drewna-konstrukcyjnego-commercial-signs-on-the-surfaces-of-historical-wood-constructions.html, DOA 01.06.2020.

Mączyński D., Warchoł M., *Opis i analiza konstrukcji dachowej nad nawą główną kościoła ss. Wizytek przy ulicy Krakowskie Przedmieście w Warszawie*, [in:] Monument, Studia i Materiały Krajowego Ośrodka Badań i Dokumentacji Zabytków, no 2, 2005, https://www.academia.edu/38274849/Opis_i_analiza_więźby_dachowej_nad_nawą_główną_kościoła_ss._Wizytek_przy_ulicy_Krakowskie_Przedmieście_w_Warszawie, DOA 01.06.2020.

Mccarroll D. , Pawellek F., *Stable carbon isotope ratios of Pinus sylvestris from northern Finland and the potential for extracting a climate signal from long Fennoscandian chronologies*, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1008.9183&rep=rep1&type=pdf, DOA 01.06.2020.

Sheppard P. R., *Dendroclimatology: extracting climate from trees*, https://www.researchgate.net/publication/229883385_Dendroclimatology_Extracting_climate_from_trees, DOA 01.06.2020.

Zapłata R., *Pomiar, inwentaryzacja i diagnostyka drewnianej architektury wernakularnej – wybrane zagadnienia zastosowania technologii skanowania naziemnego*, [in:] Budownictwo i Architektura 14 940 2015, pp.165-181, https://yadda.icm.edu.pl/baztech/element/bwmeta1.element.baztech-e4250636-6be1-4d79-b5ec-291107d03af9/c/zaplata.pdf, DOA 01.06.2020.