PAPER • OPEN ACCESS

Historical and Modern Bridges over the Elbe-Vltava Waterway

To cite this article: Petra Nešvarová Chvojková et al 2021 IOP Conf. Ser.: Mater. Sci. Eng. 1203 022014

View the article online for updates and enhancements.

You may also like

- Historical River Training Works on the Lower Elbe
 Pavel Fošumpaur, Martin Horský and Tomáš Kašpar
- <u>Technical Cultural Heritage on the Elbe-</u> <u>Vitava Waterway</u>
 P Fošumpaur, T Kašpar and M Zukal

- <u>Neutron irradiation test of Hamamatsu,</u> <u>SensL and AdvanSiD UV-extended SiPMs</u> M. Cordelli, E. Diociaiuti, R. Donghia et al.

241st ECS Meeting

May 29 – June 2, 2022 Vancouver • BC • Canada Extended abstract submission deadline: **Dec 17, 2021**

Connect. Engage. Champion. Empower. Acclerate. Move science forward



This content was downloaded from IP address 109.81.208.232 on 04/12/2021 at 06:47

Historical and Modern Bridges over the Elbe-Vltava Waterway

Petra Nešvarová Chvojková¹, Pavel Fošumpaur¹, Martin Hladík¹, Martin Horský¹, Tomáš Kašpar¹, Martin Králík¹, Milan Zukal¹

1203 (2021) 022014

¹ Czech Technical University in Prague, Faculty of Civil Engineering, Thákurova 7, 166 29 Prague 6, Czech Republic

fosumpaur@fsv.cvut.cz

Abstract. The Elbe-Vltava Waterway (EVW) consists of continuously navigable sections of the Vltava and Elbe rivers in the Czech Republic comprising a total length of over 300 km. Most of the length of this waterway was obtained by building a system of interconnected weir basins using the canalization method. Detailed plans for making this waterway navigable started in the early 19th century, and the construction of the structures was enabled by the Austro-Hungarian Water Act of 1869. So, most locks along this waterway constitute a part of industrial heritage. Among its main structures are weirs, hydroelectric power stations and locks designed by pre-eminent Czech architects of the 19th and early-20th centuries. Many of them are excellent examples of modernist industrial architecture. Since the beginning of construction of the weir system along the EVW, bridge construction also came into focus in order to provide transportation access to both banks of the Elbe and Vltava rivers in this historically heavily urbanised area of Bohemia. This article deals with the historical development of bridge constructions over the EVW, systematically categorising them as road, railway and pedestrian bridges. Focus is on the basic technical aspects of the bridge design and technical solution, but also on their historical value and the need for a sensitive approach to their modernisation. The goal of the research is to complete the current web application www.lvvc.cz devoted to the EVW structures with the architectonically and technically most interesting bridges, including their histories. The system has been designed as an expert system, making the archived historical documents, maps, plans and photographs available for use by government institutions as well as by the general public for education and for the protection of this technical cultural heritage. The research was conducted as part of project no. DG18P02OVV004 entitled "Documentation and presentation of technical cultural heritage along the Elbe-Vltava Waterway" within a support programme for applied research and experimental development of national and cultural identity, funded by the Ministry of Culture of the Czech Republic.

1. Introduction

The beginnings of settlement in the Czech lands of Bohemia are located in fertile areas around the rivers Elbe and Vltava. Here, a densely populated cultural landscape was gradually created, and therefore it was necessary to implement numerous water management modifications. Watercourses have been modified to fulfil many different purposes, including the use of water power and the navigability of watercourses for the transport of persons and goods on ships [1]. Among the first stone bridges over the Elbe-Vltava waterway (EVW) is the Judith's Bridge over the Vltava in Prague, probably built between 1158–1172. The first significant modifications of watercourses were carried



Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI. Published under licence by IOP Publishing Ltd

out during the reign of Charles IV. in the 14th Century, when the Charles Bridge was also built, arguably the most famous bridge in all of Bohemia.

The Commission for Channelling the Vltava and the Elbe Rivers in Bohemia was established in 1896, and since then, the EVW has been approached systematically, with great emphasis on their multi-purpose character. Modifications of navigable watercourses and the structures built over them still fulfil many important purposes, related to not only the protection of navigation depths and of the surrounding area from floods, but also to the production of electricity in hydroelectric power plants and the supplying of water demand. Parallel with the construction of EVW, road and rail transport are developing significantly, and therefore many bridges are being built on the Vltava and Elbe Rivers. The construction of EVW and its connection with road and rail transport was another important step in the developing industry and growing trade in the Czech Republic since the 19th Century as well as in other European countries.

In Central Europe, the first mention of road transport dates back to around 805. The routes effectively crossed the territory of Central Europe so that the roads bearing goods were as direct as possible and also safe. The logistics and interconnection of transport trade routes have been constantly evolving since the Middle Ages and continued on from the previous prehistoric period [2]. The network of European trade routes connected the most important cities of trade. The most important structures on these roads were foremostly bridges. In Europe, there had been a great development in the construction of wooden and stone bridges since the time of the Roman Empire, despite large European watercourses such as the Danube and Rhine Rivers. Road and railway bridges were built in such a way as to be purposeful and only later also decorative. The greatest development of road, water and rail transport is associated with technical progress and industrial development, so the largest-scale construction of these bridges took place at the turn of the 19th and 20th Centuries.

Some original bridge structures from the 19th Century (Rudolf's Footbridge in Prague near Rudolfinum, the Chain Bridge of Emperor Francis Joseph I. at the National Theatre in Prague) and earlier periods, which did not meet the demands of the dynamically developing road and rail transport, were replaced by new bridges. Important architects (J. E. Schnirch, A. Engel, F. Roith, J. Hlávka, etc.), designers (F. Křižík, F. Prášil, S. Bechyně, F. Mencl, etc.), builders (V. Lana, F. Müller, V. Kapsa, the Klein brothers, etc.), sculptors and other artists all participated in the designing of bridge structures, as well as in construction projects of various weirs, locks and hydroelectric power plants. Therefore, these buildings acquired a highly valuable architectural dimension and are valued as our industrial cultural heritage.

In our research, we focused mainly on the documentation of the unique industrial cultural heritage at EVW through a specialised database [3]. Attention was focused on the most historically significant road and railway bridges and pedestrian footbridges. The primary purpose of the documentation is the effective protection of industrial heritage structures and their presentation to the general public.

2. Study area

The Vltava and the Elbe Rivers are the most important watercourses in the Czech Republic and drain waters from most of its territory. Along the river Elbe, life since the 13th Century had focused mainly on the development of important royal cities around its banks. And thus, cities such as Dvůr Králové, Jaroměř, Hradec Králové, Kolín, Nymburk, Poděbrady, Mělník, Litoměřice, and Ústí nad Labem were established [4]. In addition to the beneficial effects of the river's proximity, local inhabitants also had to deal with the devastating effects of floods, which flooded and destroyed their homes and washed away crops from their fields. During dry periods, on the other hand, people had to deal with water shortages. The Elbe and Vltava Rivers have been used since the beginning of the settlement of Bohemia as advantageous transport routes, which encouraged the establishment of settlements, trade

WMCAUS 2021		IOP Publishing
IOP Conf. Series: Materials Science and Engineering	1203 (2021) 022014	doi:10.1088/1757-899X/1203/2/022014

and later industry. Another significance of the Elbe and Vltava Rivers was the use of hydro power through mills, also saw mills and hammer mills, which were established as early as the 13th and 14th Centuries [3]. The significant development of EVW was made possible by Water Act No. 66 of 11 June 1901, which enabled continuous navigability of the Vltava River from Prague to the city of Mělník and the Elbe River from the city of Pardubice to Ústí nad Labem. Together with the creation of the railway network from the 1820s and the road network, a multi-modal logistics infrastructure began to emerge, which could not have been created without the parallel construction of bridges to ensure transport services on both banks of the Vltava and the Elbe.

In the Middle Ages, ford crossings (shallow places with good footing) were most often used to overcome watercourses. The ford was not merely a reinforced and maintained crossing of the river, but any place where the watercourse could be crossed [5]. The fords were used by merchants of goods, therefore the season, the level of the water and the difficulty of crossing of each individual fords had a decisive influence on the development of trade routes. With the advancement of fluvial transport, ferries were set up in places where it was not possible to cross the river.

Bridges were initially built of wood, but they had to be regularly maintained and rebuilt after major floods. Pontoon bridges (also floating bridges) are of note, often being used to transport troops. Bridges were also important for military tactics and were often demolished by advancing armies. For this reason, they had been fortified since the Middle Ages and were often unsafe [5]. Until the 16th Century, there were 4 bridges on the EVW in Bohemia (Figure 1), on the Vltava River, it was the stone Charles Bridge in Prague and the bridge to the Šítkov Water Tower, on the Elbe in the city of Roudnice nad Labem, the remains of a stone bridge of Bishop John IV. of Dražice destroyed by the Swedes, and in Litoměřice, a wooden bridge, later in 1786 replaced by stone. By the end of the 18th Century, a wooden bridge was built in the city of Lysá nad Labem. During the 19th Century, with the development of industry and growth of road and railway transport, 22 new bridges were built, e.g. a two-storey combined road and railway bridge in the city of Ústí nad Labem, a railway bridge of Friedrich Harkort's design in Prague at Vyšehrad, etc. During the course of the 20th Century, 125 bridges are built on the EVW (Figure 1).



Figure 1. Time evolution of bridge construction at EVW.

IOP Conf. Series: Materials Science and Engineering 1203 (2021) 022014 doi:10.1088/1757-899X/1203/2/022014

The map in Figure 2 shows the current bridges on the Elbe and Vltava Rivers according to the purpose of their use and labelled as per their cultural protection.



Figure 2. Overview of bridges on EVW, labelled per their type and cultural protection.

3. Materials and methods

3.1. Data Sources

Due to its rich cultural history, the Czech Republic has a long tradition of archiving historical documents in connection with bridge construction, which are deposited in numerous archives, museums and with administrators of these buildings. Many of these resources have already become digitalised and can be viewed remotely. This is evidenced, for example, by the digital archive of the National Library of the Czech Republic. The Geoinformatics Laboratory of the University of J. E. Purkyně provides a look at historical maps from the 1st, 2nd and 3rd Military Survey (Figure 3 left and middle), which took place in the years 1764–1880. The Czech Office for Surveying, Mapping and Cadastre is used for digital access to geo-referenced maps of the stable land register (1824–1843) and to historical orthophoto images from 1937–1997 (Figure 3 on right).

The National Heritage Institute web app is used to access information about monuments in the Czech Republic. Here, data is available not only on cultural monuments, but also on monument reserves, zones, etc. The technical aspects of bridges in terms of navigation on EVW are collected by the River Information Services of the Czech Republic.

The aim of our research is the documentation of historic bridges over EVW and its implementation into the database system of cultural heritage sites in the form of a web app www.lvvc.cz. This documentation serves the administrators of individual structures and waterways from the point of view of protection and preservation of their cultural and historical value. The web app clearly interconnects information and maps from the above sources, which are supplemented by their own technical descriptions, interactive maps and photographs.

1203 (2021) 022014

doi:10.1088/1757-899X/1203/2/022014



Figure 3. Development of bridging in Prague from publicly available maps and orthophotomaps. On the left 1st Military Survey (1764–1783), in the middle 2nd Military Survey (1836–1852), on the right orthophotomap (1953).

3.2. Structural and material aspects

Bridges are traffic structures that are used to transfer roads, canals, pipelines and other facilities over a natural or artificial obstacle. The main parts of the bridge are the substructure (supports of the loadbearing structure), the load-bearing structure (composed of the bridge deck and the main girders), the superstructure and the bridge add-ons [6]. The first bridges were made of wood, later replaced by stone due to its better durability and resistance to external effects. The oldest historically recorded wooden bridges date from around 600 BC. The first builders of arch bridges were probably the Sumerians. Bridge construction in the Roman Empire achieved great development, at a time when bridges were built for administrative, religious and military reasons. Stone bridges were being built until the beginning of the 20th Century. From the end of the 18th Century, the requirements for bridge structures and their construction began to change significantly. Iron, as a new building material, saw new progress in the construction of bridges. In the second half of the 19th Century, concrete and subsequently reinforced concrete began to be used for bridge construction. For the sake of cultural heritage preservation, each industrial monument is assessed not only for its cultural value, but also for the possibility of repairs and renovation by modern means of preservation to preserve its historical value and operability. Within the research in the field of operability and safety of bridge structures, static and dynamic analysis is performed. Dynamic analysis is necessary for the operational condition of the bridge under loads caused by traffic, weather, earthquakes and pedestrians. Scientific approaches can be divided into a numerical part and an experimental part, their suitable combination can be used to very accurately assess the technical condition of the bridge. Based on regular measurements, the service life of individual parts of the bridge structure can be predicted [7].

From a water management point of view, the requirement for sufficient capacity of bridges during floods is important [8]. This aspect takes into account not only the need to ensure the stability of the bridge structure, but also the protection of the adjacent area from floods. Insufficient capacity of the bridge profile may reduce the flow capacity and undesirable flood spill into the surrounding built-up areas. The basic conditions for the capacity of bridge structures are imposed by the Czech Technical Standard [9], which determines the minimum permissible vertical distance between the design or control design level and the lowest point of the bridge structure. The formulation of the design flow and the control design flow depends on the hydrological characteristics of the flood regime of the watercourse and the design category of the bridge structure according to its significance.

3.3. Bridge Architecture

The aesthetic aspect of bridge design at the beginning of bridge construction was not emphasised, as the primarily focus lay in the structure's functionality. The most important bridge builders of antiquity,

the Romans, built bridges that were very costly, but above all strong and solid. From a static point of view, they mainly used arch for their bridges [10]. The relationships between the basic elements of the design used to be defined by the "golden ratio" rule, which added harmony to the structures [11, 12]. The Middle Ages did not bring bridge design any new aesthetic shifts. Most medieval bridges did not reach the technical and artistic level of those of the Romans. It was not until the Renaissance, which sought to revive ancient Roman art and knowledge, that better architecture was implemented to bridge construction. At this time, important historic bridges were supplemented by sculptural embellishments.

The development of bridges was always directly influenced by the construction materials available during that given period. The period of the Industrial Revolution, when new materials (such as steel) began to be used more, could be considered a breakthrough in terms of the integration of bridge structures into their surrounding environment. Designers and builders were able to use new properties and material options for their designs. From the beginning of the 19th Century, more people began to write and talk about the structural elegance and aesthetics of buildings. From a professional point of view, three perspectives on the assessment of aesthetics can be defined. The first perspective, when the structure of the bridge is exclusively the domain of the architect and beauty can be achieved only by adding architecture. The second perspective points to "pure engineering", where aesthetics are achieved by simply using the materials used as effectively as possible. The third perspective states that architecture is not necessary, but that designers must consider the ways in which to beautify a structure [13]. For example, as early as 1924, Teige states that: "The need for ornamentation is not a primary need: it is poetry applied to a purpose-built structure" [14]. From today's point of view, the construction of bridges is viewed not only from a technical and aesthetic perspective, but also as facilitating important elements of spatial planning with several associated functions [15].

The register of the National Heritage Institute lists 18 architecturally significant bridges located on the EVW. From a wide array of historically significant bridges, Charles Bridge deserves first mention (Figure 4), being the second oldest preserved bridge in the Czech Republic. The foundation stone of this bridge was laid down in 1357. It was built on the medieval foundations of the original Judith Bridge in the Gothic style. The statues on its ledges date from 1683–1938. Another bridge of high importance is the Legion Bridge (Figure 4) whose architecture is evidence of eclecticism at the turn of the 19th and 20th Centuries. The bridge features a distinctive relief decoration by the leading artists of its time. Also, in terms of urbanism, in the context of the overall layout of the adjacent development site, it is a structure of great value.



Figure 4. Charles Bridge (left), Legion Bridge (right).

Further development in the field of the properties of construction materials offers new possibilities in modern bridge construction. The completion of the overall aesthetic result is achieved, for instance, by appropriate use of new lighting technologies. With regard to this, two very interesting projects by

architect Koucký deserve mention. In 1998, the construction of the bridge named Mariánský Bridge in the city of Ústí nad Labem was completed (Figure 5). A year later, the European Convention for Constructional Steelwork awarded this bridge the European Steel Design Award and ranked it among the ten most beautiful structures (which used steel) of world architecture of the 1990s. In Prague, the Troja Bridge was completed in 2014 [16] (Figure 5). It is a suspension arch bridge, the arch of which is extremely flat. The ratio of span to rise is 10, which makes the bridge unique in the world (the usual ratio is around 20). The bridge also differs from other Prague bridges in that it spans the Vltava without pillars set in the river.



Figure 5. The Mariánský Bridge in Ústí nad Labem (left), Troja Bridge in Prague (right).

Ultimately, bridges belong to the public, who is the final arbiter of their aesthetics. In general, bridges can be partitioned into two groups: standard bridges and bridges with a unique design. "A bridge cannot be a mere design. A bridge cannot be just mere statics. A bridge cannot be just mere something. It is always a synthesis of the ways of thinking of the given period" (R. Koucký).

4. Results and discussions

4.1. Database

For the introduction and presentation of bridges, a broadcast database was created, which is processed on the MS Access platform. The proposed database structure for bridges is shown in Figure 6 and consists of 8 tables. The basic table contains the default data set containing the name of the bridge, the construction period, links to the designer, builder, operator or owner, as well as type of use, technical specifications and data on its history and architecture. The table also includes links to external databases of waterway administrators and to the catalogue of monuments of the National Monuments Institute. The Tables, Pictures, Technical Drawings, and Documents are used to store information about associated documents, such as photos, technical drawings, diagrams, and documents in the form of books, articles, reports, or projects. This information includes the period of origin, the author, the place of storage, references to specific structures (bridges), etc. The Owners Table is used to store information about entities such as owners, operators, designers and builders. The Personalities Table contains complete information about prominent persons who are linked to individual bridges from a technical, architectural or historical point of view. A separate chapter is the Lexicon Table, which serves as an explanatory dictionary of terms used.

1203 (2021) 022014

doi:10.1088/1757-899X/1203/2/022014



Figure 6. Structure of the part of the database dedicated to the Elbe-Vltava waterway related to bridges.

4.2. Geographic information systems

The basic Bridges Table also contains items for Geographical Information Systems in the form of geographic coordinates of bridge locations, from where they are taken over by the GIS module running as a part of the app *www.lvvc.cz* on the API maps portal platform *www.mapy.cz*.

4.3. Preservation and conservation of cultural heritage

The aim of this information system is to document bridge structures in order to protect them and preserve their cultural value, as well as to present these buildings to both the academic and general public. An example of sensitive renovation and modernisation is the bridge over a lock chamber in Hořín on the Vraňansko-hořínský navigable canal (Figure 7). In order to meet the criteria of the *Va* waterway classification, the existing bridge with an underpass height of 4 metres was modified to a drawbridge. This unique solution lay in the dismantling of the original bridge, which consisted of a reinforced concrete load-bearing structure with stone cladding, and fitting it with a new steel load-bearing structure. The walls bearing the original stone cladding were concreted to it. Hydraulic presses are able to lift the entire 400 t structure 5 metres upwards. All works were carried out in cooperation with the National Monuments Institute, which guaranteed the maximum possible degree of preservation of the original appearance of the building [17].

The 1,120 metres long Negrelli viaduct (Figure 7), built between 1846–1849 had been carefully renovated in 2017–2020. This bridge is the second oldest in Prague and at the time of its commissioning, was the longest railway bridge in Europe. Its load-bearing structure underwent complete renovation and the stones from its dismantled arches were reinstalled as meticulously as possible. Due to the historical value of this work, its renovation was also carried out in cooperation with the National Monuments Institute [18].

Charles Bridge must not be overlooked. UNESCO World Heritage - the second oldest bridge in the Czech Republic, was built in the years 1342–1402. It has survived many floods over the centuries, some of which left their destructive mark. It was torn in 1432 and its repair took 71 long years.

Extensive damage during the flood of 1890 was, in contrast to proposals for enlarging arches and the use of other materials, repaired so that its historical character did not suffer damage. The worldfamous Czech architect and builder, Josef Hlávka, among others, takes credit for these repair works. The first complete renovation from 1965-1978 prevented leakage into the load-bearing structure, increased its rigidity and the asphalt of its roadway was replaced by stone. Extensive repair works of the bridge's arches are currently being prepared, estimated to take 20 years [19, 20].



Figure 7. Elevated field of the bridge in Hořín (left) (source: Vltava River Board, state ent.). Negrelli Viaduct in Prague (right).

5. Conclusions

Within the research, attention was focused on the systematic documentation of bridge structures on EVW. The research reached the following main conclusions: (1) Elements of multi-modal transport infrastructure, which include road, rail and water transport, were built simultaneously at EVW. The individual modes of transport have been developed on the basis of carefully preplanned concepts. (2) The current state of the transport infrastructure is based primarily on a proposal from the 19th Century and the system is supplemented as needed in accordance with the strategic plans in the field of transport policies of the Czech Republic. (3) The research made it possible to map, in particular, historically valuable bridge structures, which represent important industrial heritage. The documented structures were entered into the cultural heritage database on EVW on the server www.lvvc.cz. (4) Documentation of historically valuable bridge structures is a basic prerequisite for their protection as well as their presentation as industrial monuments to both the academic and general public.

Acknowledgment(s)

The article was written with support from the project "Documentation and Presentation of Technical Cultural Heritage on the Elbe-Vltava Waterway" No. DG18P02OVV004 solved within the National and Cultural Identity program for 2016 to 2022 (NAKI II) administered by the Ministry of Culture of the Czech Republic.

References

- P. Fošumpaur, T. Kašpar, and M. Zukal, "Technical Cultural Heritage on the Elbe-Vltava [1] Waterway," IOP Conf. Series: Earth and Environmental Science, vol. 290, 2019.
- J. Martínek, Moderní metody identifikace a popisu historických cest: metodická příručka (in [2] Czech). Brno: Centrum dopravního výzkumu, 2013.
- P. Fošumpaur, M. Horský, T. Kašpar, M. Králík, J. Kučerová, P. Nešvarová Chvojková, and M. [3] Zukal, "Historical structures and technical heritage on the Elbe-Vltava waterway," IOP Conf. Series: Materials Science and Engineering, vol. 960, 2020.
- K. Trejtnar, Střední Labe (in Czech). Prague: State agricultural publishing, 1978. [4]
- [5] T. Klimek, Krajiny českého středověku (in Czech). Prague: Dokořán, 2014.

- [6] J. Vítek, Světové mosty: od antiky po současnost (in Czech). Prague: Grada Publishing, 2019.
- [7] V. Šána, M. Polák, and T. Plachý, "A Dynamic Analysis of the Cable-Stayed Footbridge in Čelákovice Town," *Procedia Engineering*, vol. 199, no. 1877–7058, pp. 2877–2882, 2017.
- [8] T. Picek, A. Havlik, D. Mattas, and K. Mares, "Hydraulic calculation of bridges at high water stages "*Journal of Hydraulic Research*, vol. 46, no. 4, pp. 560–562, 2008.
- [9] ČSN 73 6201 Projektování mostních objektů (in Czech). Prague: Český normalizační institut, 2008.
- [10] M.-C. Tang, "The art of arches," *Structure and Infrastructure Engineering*, vol. 11, no. 4, pp. 443–449, 2014.
- [11] N. Kazhar, "Evolution of styles in architecture of bridges," Zeszyty Naukowe Politechniki Częstochowskiej. Budownictwo, vol. 17, iss. 167, pp. 67–79, 2011.
- [12] C. Kulasuriya, W.P.S. Dias, and M.T.P. Hettiarachchi, "The aesthetics of proportion in structural form," *Structural Engineer*, vol. 80, iss. 14, pp. 22–27, 2002.
- [13] H. Shirley-Smith, D. P. Billington, and P.N. Billington. "Bridge," *Encyclopedia Britannica*, 2020. [Online]. Available: https://www.britannica.com/technology/bridge-engineering. [Accessed: 5-Mar-2021].
- [14] K. Teige, *Mechanická krása* (in Czech). Prague, 1924. [Online]. Available: https://www.archiweb.cz/news/karel-teige-mechanicka-krasa. [Accessed: 5-Mar-2021].
- [15] M. Salamak and K. Fross, "Bridges in Urban Planning and Architectural Culture," *Procedia Engineering*, vol. 161, pp. 207–212, 2016.
- [16] J. L.Vítek and R. Coufal, "High performance concrete for the Troja Bridge in Prague," Life-Cycle and Sustainability of Civil Infrastructure Systems - Proceedings of the 3rd International Symposium on Life-Cycle Civil Engineering, IALCCE 2012, pp. 1376–1381, 2012.
- [17] J. Špaček, "Modification of the Gates Chamber at the Hořín Lock (in Czech)," *Stavebnictví*, vol. 20, pp. 22–29, 2020.
- [18] J. Soukup, *Pražské mosty: studie se zřetelem na současné podniky* (in Czech). Prague: E. Weinfurter, 1904.
- [19] Z. Drobná and V. Hlavsa, *Karlův most* (in Czech), Prague: *Sportovní a turistické nakladatelství*, 1958.
- [20] J. Benešovský-Veselý, Velká povodeň v Čechách ve dnech 2. až 5. září 1890 (in Czech). Prague: Alois Hynek, 1890.