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НА
НАУКИТЕ И ИЗКУСТВАТА

BULGARIAN ACADEMY
OF
SCIENCES AND ARTS







# ДОКЛАДИ
## МЕЖДУНАРОДНА НАУЧНА КОНФЕРЕНЦИЯ ПО ОПАЗВАНЕ НА НЕДВИЖИМОТО КУЛТУРНО НАСЛЕДСТВО БАНИ' 2024

**21-23 ноември 2024**

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**21-23 november 2024**



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**Антоанета Димитрова Димитрова**

# BULGARIAN STUDENTS AT SLOVAK TECHNICAL UNIVERSITY IN BRATISLAVA IN THE YEARS 1938-1948

**Baláž Ivan[1], Balážová Pavla[2]**

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***Abstract:*** *Information about Bulgarian students, who studied during the World War II at Slovak Technical University during period 1938-1948.*

***Key words****: Bulgarian students, Slovak Technical University, World War II*

## 1. Introduction

Among the students of the Slovak Technical University (STU, in Slovak: SVŠT = Slovenská Vysoká Škola Technická) during the war years there were many Bulgarian students, our brothers. They came from the Czech lands, preferring Slovak universities instead of German schools, where they would have had to study after the closure of Czech technical universities by Nazi Germany. At a meeting of university professors of STU on December 15, 1939, the rector Prof. Dr. Jur Hronec reported: "A large number of Bulgarian students came to our university from Brno and, according to the report the other will come soon from Prague. We will do our best for them." He also announced that he will ask the Ministry to forgive all fees for the students from Balkan Slavic states. It was decided which regular students will help Bulgarian students with repeating lectures. At a meeting of university professors of STU it was prolonged on May 10, 1940 the rule stating that students from Balkan Slavic states need not to pay for their study. The rule lasted also in the next years till to the school year 1943/44. Even during the Nazi terror, Bulgarian students could illegally participate in excursions and in practice. Due to Nazi terror there was in 1944/45 at STU only one Bulgarian student (see Fig. 1). In the next year Bulgarian students returned home. Only students who were finishing their studies remained in Bratislava (Fig.1).

Several Slovak and Bulgarian students participated in the Slovak National Uprising in August 1944. 10 Slovak and 10 Bulgarian students died in the fight against the German occupiers and the STU awarded them the title engineer in memoriam.

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Table 1 Bulgarian engineers in Department of Structural, Transportation and Hydraulic Engineering and Land and Water Resources Management

| No. | First and family name | Place of birth in Bulgaria | Year of birth | Day of examination |
|---|---|---|---|---|
| 1 | Zachari Angelov Petkov | Dobriča | 1905 | 10.VI.1941 |
| 2 | Georgi Kjučukov | Kolju Gančevo | 1905 | 18.XII.1941 |
| 3 | Georgi Rajčev Šišmanov | Plovdiv | 1915 | 18.XII.1941 |
| 4 | Ilia Milev Todorov | Kameno-pole | 1917 | 10.VI.1943 |
| 5 | Bočo Nikov Petrov | Dermanec | 1913 | 22.VI.1943 |
| 6 | Christo Stojkov Ivanov | Kameno-pole | 1914 | 22.VI.1943 |
| 7 | Makňo Nenov Nenov | Toros | 1914 | 26.II.1943 |
| 8 | Asen Jordanov Stojanov | Bratanica | 1917 | 26.IV.1944 |
| 9 | Stoil Jančev Petkov | Dobrava | 1916 | 10.XII.1943 |
| 10 | Penčo Christov Ivanov | Kazanlik | 1914 | 10.XII.1943 |
| 11 | Ivan Christov Ivanov | Osikovec | 1906 | 23.III.1943 |
| 12 | Nikolaj Tod. Chvarčilkov | Belej | 1918 | 10.XII.1943 |
| 13 | Štefan Penčev Stojkov | Sojač-Popov | 1919 | 1.IX.1944 |
| 14 | Lilo Manoljov Najdenov | Borovce | 1914 | 1.IX.1944 |
| 15 | Minčo Christov Mandžurov | Dubovo | 1915 | 1.IX.1944 |
| 16 | Vilchaim Ferdinadov Vaklev | Velkovce | 1918 | 1.IX.1944 |
| 17 | Radi Dimov Radev | Carski Izvor | 1919 | 21.VI.1944 |
| 18 | Vladimir Charitomov Novkov | Sofia | 1918 | 21.VI.1944 |
| 19 | Stamo Vlčev Dimitrov | Čameren | 1915 | 1.IX.1944 |
| 20 | Steafn Stefanov Runcev | Dubovo | 1919 | 26.IV.1944 |
| 21 | Marin Bonev Todorov | Elena | 1915 | 10.II.1944 |
| 22 | Rangel Kostadinov Minčev | Kalotinec | 1907 | 10.II.1944 |
| 23 | Gerasim Cekov Ivanov | Novy Sel | 1908 | 26.IV.1944 |
| 24 | Todor Kocev Curinsky | Čuprene | 1918 | 29.XI.1944 |
| 25 | Peter Petrov Barakov | Dabovo | 1919 | 29.XI.1944 |
| 26 | Mito Ivanov Kocovski | Borovan | 1915 | 23.I.1946 |
| 27 | Lazar Simeonov Ivanov | Sevlievo | 1909 | 5.XII.1945 |
| 28 | Ivan Minčev Vojnikov | Dabovo | 1910 | 25.VI.1946 |
| 29 | Angel Vichrovský | Kneža | 1918 | 6.IV.1946 |
| 30 | Vasil Pop Vasilev | Vasil | 1920 | 6.IV.1946 |
| 31 | Atanas Tankopišev | Jambol | 1910 | 6.IV.1946 |
| 32 | Dimiter Georgiev Christov | Pisarovo | 1914 | 6.IV.1946 |
| 33 | Charizan Nikolov Charizanov | Akandžalji | 1915 | 6.IV.1946 |
| 34 | Emil Georgiev Bersinký | Küstendil | 1922 | 6.IV.1946 |
| 35 | Petko Dragiev Marinov | Kalugerica | 1919 | 30.X.1946 |
| 36 | Veselin Tončev Goljamtončev | Gorsko Slivovo | 1915 | 27.II.1947 |
| 37 | Peter Georgiev Petrov | Krivo Pole | 1915 | 27.II.1947 |
| 38 | Christo Nikolajev Puškarov | Kramolín | 1913 | 27.II.1947 |
| 39 | Tomčo Tomčev Stančev | Zaraevo | 1919 | 27.II.1947 |
| 40 | Stojan Petrov Dimitrov | Radevo | 1919 | 27.V.1947 |
| 41 | Ljuben Zlatkov Kačov | Luta | 1919 | 26.VI.1947 |
| 42 | Milko Videnov Krstov | Drenovec | 1919 | 26.VI.1947 |

Note: engineer in memoriam

Table 2 Bulgarian engineers in Department of Surveying.

| No. | First and family name | Place of birth in Bulgaria | Year of birth | Day of examination |
|---|---|---|---|---|
| 1 | Ljuckanov Stojan Stanev | Dedovo | 1913 | 27.VI.1941 |
| 2 | Lukanov Simeon Simeonov | Kojnare | 1912 | 29.XI.1941 |
| 3 | Vlado Kano Ivanov | Barkač | 1912 | 29.XI.1941 |
| 4 | Bobčev, Krum Asen Ivanov | Ruse | 1904 | 29.XI.1941 |
| 5 | Stajanov Asen Penev | Belovo | 1903 | 29.XI.1941 |
| 6 | Dončev Stojčo Ivanov | Srenevec | 1912 | 29.XI.1941 |
| 7 | Christo Mitev Christov | Dolna Bešovica | 1907 | 27.VI.1942 |
| 8 | Žekov Alexander St. | Leskovec | 1919 | 17.XII.1943 |
| 9 | Stankov Tomčo Tomov | Drinovo | 1919 | 17.XII.1943 |
| 10 | Sandev Stojčo Velev | Ostra Mogila | 1906 | 17.XII.1943 |
| 11 | Raškov Gavail Makaveev | Brenica | 1911 | 17.XII.1943 |
| 12 | Stoičev Ognian Teofilov | Rakilovec | 1911 | 25.VI.1946 |
| 13 | Gusakov Metodi Dim. | Sofia | 1914 | 25.VI.1946 |
| 14 | Christov Genčo Alex. | Varna | 1909 | 25.VI.1946 |
| 15 | Pakalev Zdravko Georg. | Gelendžik | 1911 | 25.VI.1946 |
| 16 | Radev Kolju genov | Vinarovo | 1921 | 13.XII.1946 |
| 17 | Ionev Iovi Petrov | Lom-Čerkovno | 1900 | 16.IV.1947 |
| 18 | Ninov Pelo Dim. | Džurov | 1913 | 16.IV.1947 |
| 19 | Ivanov Napoleon Simeonov | Sofia | 1912 | 16.IV.1947 |
| 20 | Železkov Georgi Petrov | Osojnica | 1911 | 16.IV.1947 |

Table 3 Bulgarian engineers in Department of Technochemical Engineering

| No. | First and family name | Place of birth in Bulgaria | Year of birth | Day of examination |
|---|---|---|---|---|
| 1 | Christo Nikolov Taškov | Akrebatno | 1921 | 28.V.1946 |

Table 4 Bulgarian engineers in Department of Mechanical Engeneering

| No. | First and family name | Place of birth in Bulgaria | Year of birth | Day of examination |
|---|---|---|---|---|
| 1 | E. E. Ignatov | Stoil Vojvoda | 1915 | 22.III.1946 |
| 2 | S. R. Valkov | Kazanka | 1912 | 22.III.1946 |

Note: engineer in memoriam

Table 5 Bulgarian engineers in Department of Electrial Engineering

| | | | | |
|---|---|---|---|---|
| 1 | Marko Tomov | Sofia | 1914 | 27.VI.1947 |
| 2 | Vičko Telbizov Petkov | Šumenu | 1920 | 6.IV.1946 |
| 3 | Ivanov Stoilov Alexander | Pleven | 1920 | 6.IV.1946 |

Note: engineer in memoriam

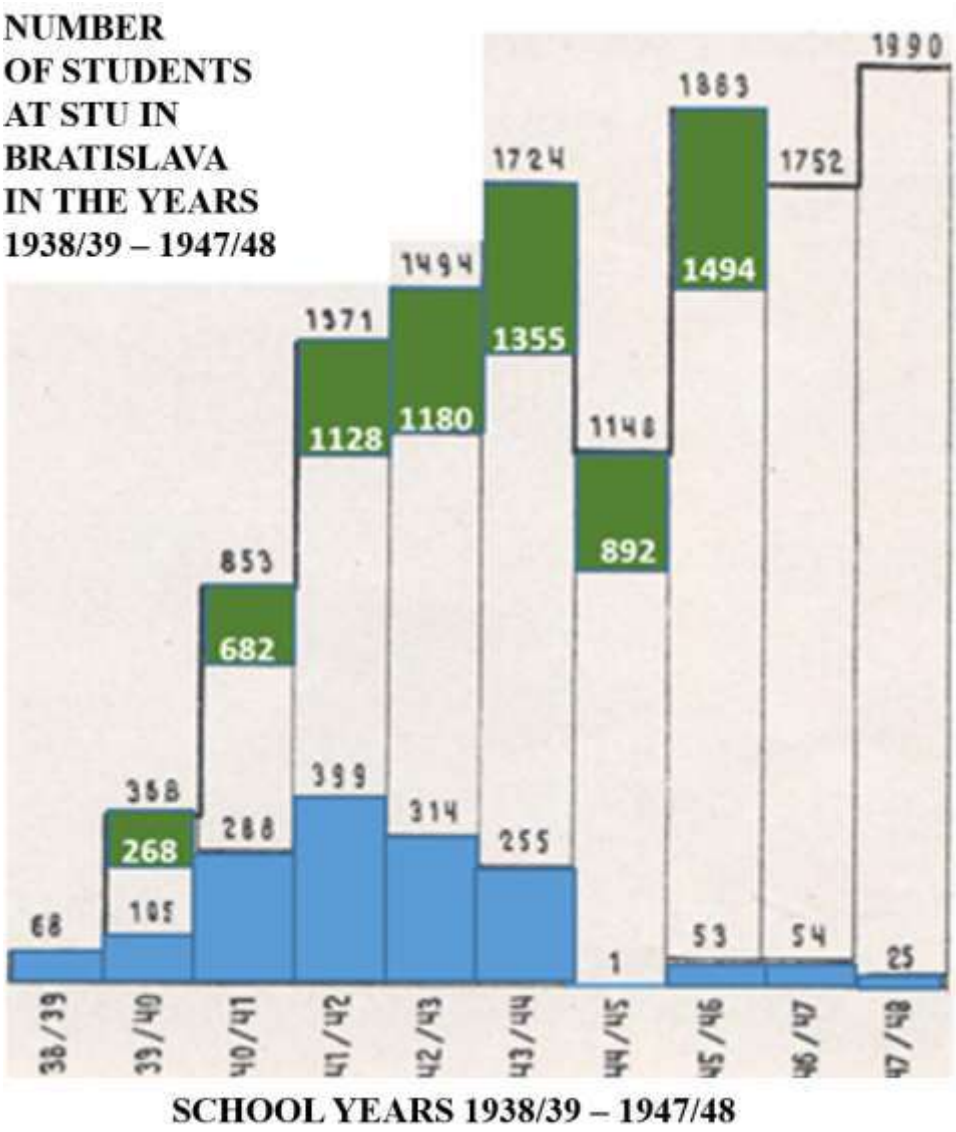



**Fig. 1. Number of students at Slovak Technical University in Bratislava in the years 1938/39 – 1947/48: a) total number of students, b) blue colour indicates number of Bulgarian students, c) green colour indicates students at Department of Forest and Agricultural Engineering.**

**Conclusion**

The contribution is dedicated to Bulgarian students, who studied during the World War II at Slovak Technical University in Bratislava, Czechoslovakia, during period 1938-1948. Ten of them lost their lives in the fight against the Nazi occupiers during the Slovak National Uprising in August 1944. The Slovak people will never forget the sacrifice of these 10 brave Bulgarian students and other Bulgarian partisans (see Fig. 2). On the pedestal there is the inscription "To the heroic Bulgarian partisans who laid down their lives for our freedom". At the feet of the partisans there is engraved the inscription in the Slovak and Bulgarian languages: "Whoever falls in the fight for freedom will not die".



a) b)

**Fig. 2 Monument to Bulgarian Partisans: a) on Vajanský`s embankment in Bratislava. The statues are made of bronze, the base is covered with granite. The author of the work is academic sculptor F. David. The statue was cast in the Anýž foundry and it was unveiled on September 3, 1949. It is National Cultural Monument - Number in the ÚZ PF: 226 / 0; b) in Hronský Beňadik. Christo Botev (06.0.1848, Kalofer, Bulharsko – 01.06.1876, Vola): "Който падне в бой за свобода, той не умира" !**

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# A MAGNIFICENT NO.7: IVAN MIROSLAV VIEST

**Baláž Ivan[1], Koleková Yvona[2]**

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***Abstract:*** *A brief overview of the live and work of a prominent Slovak designer of steel and composite steel and concrete structures: Ivan Viest, who studied at SVŠT (STU) in Bratislava from 1941-1946 and emigrated in USA in 1948. He collected date about the civil engineers (CE), architects (AR) and surveyors (SU) – the graduates of SVŠT in Bratislava who emigrated from 1948 -1989 in more than 12 countries. They are all an integral part of the cultural heritage of The Slovak Republic.*

***Key words****: Slovak structural engineers, emigrants, cultural heritage*

## 1. Introduction

Dr. Ivan M.Viest published a complete list of the names, including the electrical and mechanical engineers, in his autobiography, An Immigrant's story, Xlibris Corporation [3]. He gathered the data together during the period from 1990-1999. His efforts and the support of his friends, acquaintances and a wide circle of emigrants (B. Albrecht, A. K. Skovranek, N. E. Samek, F. Bakeš, J. Závesky, P. Kaiser, B. Sevruk, J. Vlček, P. Lizoň, V. Mocák, etc.) resulted in obtaining very valuable information.

## 2. Dr. Ivan Miroslav Viest, Ph.D

Dr. Viest has been active in the building industry in the USA for 41 years in the field of the design of steel, concrete and composite steel-concrete structural members. He has achieved results which have had a decisive influence on the development of this type of construction both in the USA and other developed countries.

He studied at SVŠT from 1941-1946. In the last year of his study he served as an assistant to a professor of steel structures. He was a member of VRO (the Panslavic Revisionist Organization). Its basic goal was the restoration of the democratic Czechoslovak Republic. He was also a member of the Resistance Movement of the Young

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Generation (Odbojové hnutie mladej generácie) until the liberation of Slovakia in 1945. In addition, he took part in the Slovak National Uprising (SNP). He passed his final examination with honors at the Branch of Construction Engineering (OIS) of the Slovak Technical University in Bratislava. He graduated and obtained the degree of Ing. in1946. In the same year he accepted a job as an engineer with the Slovak construction enterprise Lanna. In March 1947, he was awarded a scholarship by the Rotary Clubs of Georgia for studies in the United States. Due to the events in February 1948, he decided to accept the position of a research assistant at the University of Illinois in Urbana in the Department of Theoretical and Applied Mechanics.

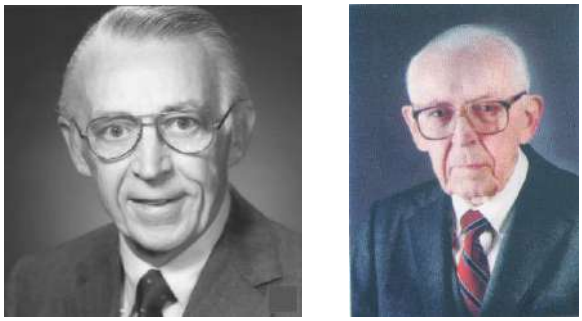


**Fig. 1 Dr. Ivan Viest (10.10.1922, Bratislava – 11.02.2012, Bethlehem, USA)**

His advaned studies were completed with his achievement of the degree of Doctor of Philosophy (PhD.) in 1951. He celebrated the Golden Jubilee of his marriage to Barbara K. Stevenson. He met his wife 1952 as she was completing her studies in Chemistry at the University of Illinois. They were married in May 1953. In the following year he became a member of the Council of Free Czechoslovakia (Rada slobodného Československa).

In May 1953, Dr. Viest was placed in charge of the shear strength of reinforced concrete and the strength of long reinforced concrete columns research. The significant results he achieved have been exclusively used up to the present. In March 1954, he started experimental research into stud shear connectors of composite steel- concrete structural members. The requirements for the design of stud shear connectors, developed by Dr. Viest were adopted by AASHO (the American Association of State Highway Officials) in 1956. The studs were first used in a bridge in the same year.

In 1955, Dr. Viest became a citizen of the United States.

In 1956, he proposed the formation of a committee on composite structures that was established jointly by ASCE (the American Society of Civil Engineers) and ICI (the American Concrete Institute). The Committee's design recommendations were published in 1960. Guidelines for the design of composite structures were published by AISC in 1961. Around 1970, composite design became an accepted practice throughout the United States. The results in the field of repeated loading of bridge members and the achievement of an ultimate limit state were utilized in practice after AASHO issued the Load Factor Design for steel highway bridges in 1971.

After leaving the Bethlehem Steel Corporation in 1982, he opened an independent practice as a consulting structural engineer. He named it IMV Consulting. Dr. Viest organized and chaired the first Engineering Foundation Conference on Composite Construction held in 1987 in New Hampshire. The conference was repeated in 1992 in Missouri, in 1996 in Germany, in 2000 in Canada, in 2004 in South Africa, and in 2008 in Denver. In March 1990, Dr. Viest made his first visit to Slovakia. During this and subsequent visits he re-established personal contacts and contacts with the professional public and universities in Slovakia. Over the years, Dr. Viest has participated in the activities of many national and international professional societies including among others, the NAE, ASCE, AASHO, AISI (the American Iron and Steel Institute), BSSC (the

Building Seismic Safety Council), TRB (the Transportation Research Board), IABSE (the International Association for Bridge and Structural Engineering), RCRC (the Reinforced Concrete Research Council), etc. He has held important positions in many of these associations and has been awarded honours. In 2002, he was honoured with the title Doctor Honoris Causa by the Technical University of Košice. After 1989 visited several times Department of Metal and Timber Structures, Faculty of Civil Engineering, STU in Bratislava. He gave lectures there and donated a collection of professional American journals to the department. He corresponded with the first author for several years.

Dr. Viest has authored and co-authored five books and about 150 articles published in refereed professional journals devoted to: a) Composite Structures [2], b) History of Engineering Foundation [1], Fig.2, c ) his autobiography: "An Immigrant's Story" [3], Fig. 2. There has also been a family tree of the Viests since 1700. He is the son of Ivan G. Viest and Mária Zacharová. His father was a mechanical engineer with the Slovak Railroad and became president of its operations in 1936. His older sister, Zora, died in 2002 and Ivan was survived by his younger sister, Tatiana Maria Šimková, several nieces and nephews in Slovakia. General Rudolf Viest is his uncle and Ivan Šimko, a politician, is his nephew. General Viest, a member of the Czechoslovakia government in exile in London during WWII, became a commander of the Army in Slovakia in 1944. He was captured by the Germans in 1944 and killed in Berlin in 1945.

Some of his publications may be seen in Figs. 2 and 3.

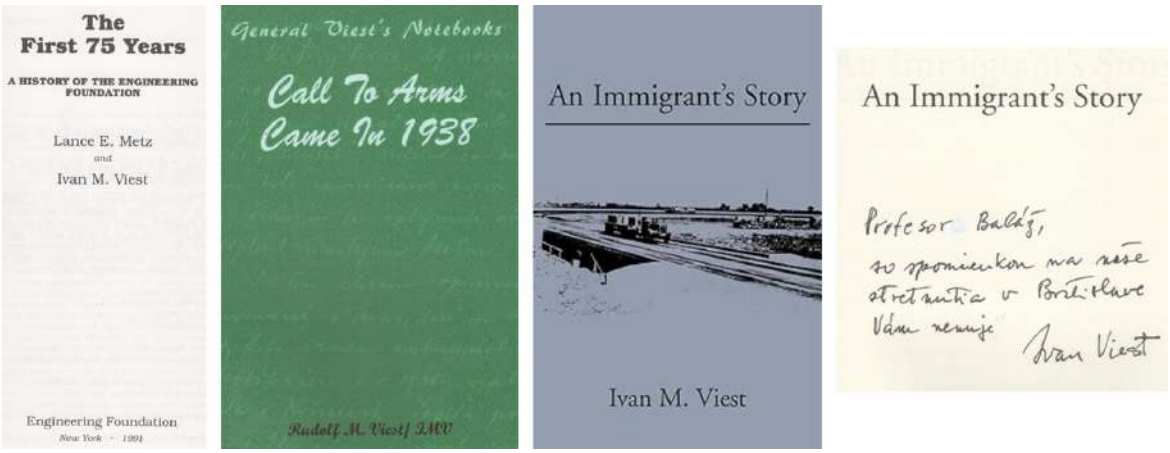
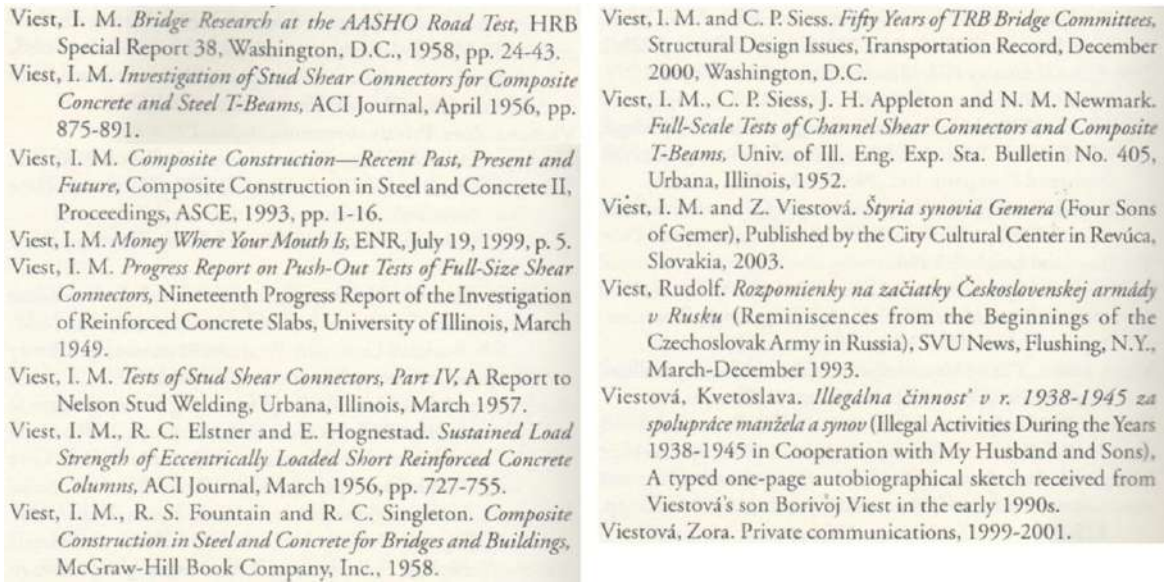



**Fig. 2 Books written by Dr. Viest. From the left: 1991 [1], 2009 [4], 2006 [3]**



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**Fig. 3 Publications written by Dr. Viest**

### 3. The civil engineers (CE), architects (AR) and surveyors (SU) – the graduates of SVŠT (STU) in Bratislava who emigrated from 1948 -1989

**Table 1 The list of civil engineers (CE), architects (AR) and surveyors (SU) – the graduates of STU (SVŠT) in Bratislava who emigrated from 1948 -1989, where the data about the year of graduation and study fields are known**

| No | Name Surname | Graduation at STU | Field of study | Occupation (institution/position) | Workplace (country) | Year of emigration |
|---|---|---|---|---|---|---|
| 1 | Bohumil Albrecht | 1944 | CE | Univ. of NM/Professor of Mechanical Engineering | USA | 1947 |
| 2 | Juraj Bajgar | 1964 | CE | | USA | |
| 3 | Frank Bakeš | 1958 | CE | Burns & Roe/Hydraulics | USA | |
| 4 | Mária Bakeš | 1960 | CE | N. Massand/Project | USA | |
| 5 | Peter Bart | 1966 | AR | U. S. State Department | USA | |
| 6 | Bruno Beisetzer | 1967 | AR | Private Practice/Project | USA | 1969 |
| 7 | Vladimír Bláha | 1959 | CE | Deutsche Welle/ Television Editor & Author | Germany | 1963 |
| 8 | Boris Boor | 1951 | CE | | Peru | |
| 9 | Dušan Botka | 1966 | AR | | Greece | |
| 10 | Ľubomír Brezina | 1963 | AR | | Canada | |
| 11 | Oldrich Brychta | 1964 | CE | Road & Traffic Authority NSW Australia/Designer | Australia | 1968 |
| 12 | Miroslav Bubak | 1966 | CE | | Canada | |
| 13 | František Bubenko | 1966 | AR | | USA | 1968 |
| 14 | Ján Buzák | 1967 | CE | Architect M. Bolczek | USA | |
| 15 | Ladislav Černý | 1952 | CE | Univ. of MN/Professor of Civil Engineering | USA | |
| 16 | Karol Chlebana | 1979 | CE | U. S. Army Corps of Engineers, / Project Leader | Germany | |
| 17 | Dušan Chovanec | 1958 | CE | Cantonal Gov./Bridges | Switzerland | 1968 |
| 18 | Emery (Imrich) Csintalan | 1953 | CE | | USA | |
| 19 | Peter Danišovič | 1959 | CE | | Canada alebo USA | |
| 20 | Thomas Day-Madunicky (Tomáš Madunický) | 1961 | CE | Greater Vancouver Region. District/Proj. Manager, Consultant & Lecturer | Canada | 1968 |
| 21 | Jozef Dolezel | 1966 | AR | | Canada | |
| 22 | Ladislav Domen | 1967 | AR | Vlastimil Koubek Architects | USA | 1968 |
| 23 | Tomáš Dratva | 1960 | CE | | Switzerland | |
| 24 | Miloslav Drobný | 1973 | CE | H. A. Simons/Structural Engineer | Canada | 1974 |
| 25 | Oldřich Držmíšek | 1962 | CE | | Switzerland | 1968 |
| 26 | Jean Eteny (Ján Hetényi) | 1967 | AR | Digital Equipment Corp. International | Switzerland | 1968 |
| 27 | Lubomír A. Farkaš | 1978 | AR | | USA | |
| 28 | Martin Gregor | 1976 | AR | | USA | |
| 29 | Robert Havrančík | 1978 | AR | | | |
| 30 | Ivan Hliva | 1968 | CE | | Canada | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 31 | Irena Hliva rod. Kuliačková | 1969 | CE | | Canada | |
| 32 | Aladár Horský | 1963 | CE | | Germany | 1968 |
| 33 | Peter Horvay | 1961 | AR | | Germany | 1968 |
| 34 | Peter Hron | 1967 | AR | | Germany | 1968 |
| 35 | Ján Hudoba | 1968 | CE | Regional Municipality Hamilton/Struct. Eng. | Canada | 1968 |
| 36 | Otília Hudoba | 1968 | CE | Regional Municipality Hamilton/Struct. Eng. | Canada | 1968 |
| 37 | Štefan Izakovič | 1959 | AR | | Switzerland | 1968 |
| 38 | Valéria Janek | 1966 | AR | | Germany | 1968 |
| 39 | Igor Jeník | 1966 | AR | | Germany | 1968 |
| 40 | Ján Alexander Janovjak | 1961 | CE | Shell Canada Products Ltd./Engineering Coordinator | Canada | 1969 |
| 41 | Ludwig (Ľudovít) Jochmann | 1967 | CE | Hess | Switzerland | 1969 |
| 42 | Alica Juldašová | 1967 | CE | Stahlton | Switzerland | 1969 |
| 43 | Martin Kianička | 1965 | CE | | Switzerland | |
| 44 | Ján Kočí | 1949 | AR | | Austria | |
| 45 | Ivan Kocián | 1964 | AR | Technical University Braunschweig/Architect | Germany | |
| 46 | Mária Korónyiová | 1974 | CE | | USA | |
| 47 | Jozef Košinár | 1961 | CE | | Australia | |
| 48 | Ivan Kot | 1967 | AR | | Germany | 1968 |
| 49 | Ivan Kralovič | 1963 | CE | | Canada | 1968 |
| 50 | Michal Kravec | 1968 | AR | Private Practice | Germany | 1968 |
| 51 | Anton Krivosudský | 1976 | AR | | | |
| 52 | Vlasta Krupková rod. Flamiková | 1966 | AR | Columbia Broadcasting | USA | 1968 |
| 53 | Igor Labuda | 1978 | AR | | USA | |
| 54 | Jana Lebeda rod. Čižmáriková | 1963 | CE | | Switzerland | |
| 55 | Peter Lizoň | 1961 | CE | Univ. of Tennessee/Prof. of Architecture | USA | 1968 |
| 56 | Milan Lojdl | 1965 | AR | Private Practice, Milan Architects Inc. | USA | 1970 |
| 57 | Eva Lojdl rod. Virsíková | 1965 | AR | Private Practice, Milan Architects Inc. | USA | 1970 |
| 58 | Leo Longauer | 1962 | CE | | Switzerland | 1968 |
| 59 | František Lošonský | 1964 | CE | | Germany | 1968 |
| 60 | Helena Macková rod. Lednárová | 1966 | AR | | | 1968 |
| 61 | Mária Maderová rod. Veselá | 1977 | CE | | Switzerland | |
| 62 | Magdaléna Majeská rod. Furdová | 1963 | CE | Ontario Department Transportation | Canada | 1968 |
| 63 | Fedor Maňka | 1961 | CE | | USA | |
| 64 | Anton Mathia | 1976 | AR | | Germany | |
| 65 | Fedor Medek | 1966 | AR | | Australia | 1968 |
| 66 | Tibor Mernický | 1966 | AR | | Canada | 1968 |

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|---|---|---|---|---|---|---|
| 67 | Pavol Miklian | 1967 | AR | | Sweden | 1968 |
| 68 | Rudolf Mitura | 1963 | CE | | Switzerland | 1968 |
| 69 | Valér Mocák | 1955 | AR | Private Practice/Expert Consultant | USA | 1969 |
| 70 | Vladimír Fedor Obrcian | 1944 | CE | Ammann & Whitney/Head, Geotechnical Laboratory | USA | 1947 |
| 71 | Ivan Ondruš | 1963 | CE | | Sweden | 1968 |
| 72 | Júlia Ondruš rod. Denčíková | 1964 | CE | | Sweden | 1968 |
| 73 | Oldřich Pajkrt | 1961 | CE | | Netherlands | 1968 |
| 74 | Branislav Pavúk | 1970 | CE | | | |
| 75 | Stanislav Pisončík | 1964 | CE | Holmes & Narver, Inc./Design Leader | USA | 1968 |
| 76 | Ivar Plašil | 1955 | CE | Krup Stahl AG/Head, Design of Engineered Structures | Germany | 1969 |
| 77 | Rastislav Porubský | 1965 | CE | | Switzerland | 1968 |
| 78 | Alena Pospíšilová | 1967 | AR | | Great Britain | 1968 |
| 79 | Milan Ružek | 1963 | CE | | Switzerland | 1968 |
| 80 | Zoltán Šáro | 1974 | AR | | USA | |
| 81 | Angela Schmidt | 1967 | CE | Architektbüro | Switzerland | 1968 |
| 82 | Marián Sečanský | 1964 | CE | | Switzerland | |
| 83 | Boris Sevruk | 1961 | CE | Federal Institute of Technology/Senior Scientist | Switzerland | 1968 |
| 84 | Stefan Simek | 1964 | CE | Ferguson Simek Clark/President & Principal | Canada | 1968 |
| 85 | Františka Sitnaiová (Szitnyaiová) | 1957 | CE | Beatti & Pronse | Australia | |
| 86 | Tomáš Skalský | 1967 | CE | | Switzerland | 1969 |
| 87 | Pavol Slávik | 1966 | AR | | Germany | 1968 |
| 88 | Peter Soldát | 1971 | CE | | USA | |
| 89 | Pavel Stankay | 1967 | CE | | USA | 1968 |
| 90 | Norbert Štibráni | 1958 | CE | Project Planning, Ltd. | Canada | 1969 |
| 91 | Peter Straka | 1964 | CE | Sze Straka Engineers Ltd./President | Canada | 1968 |
| 92 | Charles S. Strelka | 1966 | CE | Kuchar & Strelka | Canada | 1968 |
| 93 | Ladislav Stucka | 1967 | AR | | USA | 1968 |
| 94 | Ján Švihra | 1965 | CE | Keewatin-Aski Ltd./Vice-President | Canada | 1969 |
| 95 | Juraj Sýkora | 1963 | CE | | Canada | 1968 |
| 96 | Darina Sýkora rod. Uhrínová | 1963 | CE | | Canada | 1968 |
| 97 | Dennis S. Tarnay | 1957 | CE | U. S. Department of Energy-Federal Energy Regulatory Commission | USA | 1967 |
| 98 | Ján Teichner | 1962 | CE | | Germany | 1968 |
| 99 | Pavol Timkanič | 1967 | CE | Hackensack Water Co. | USA | 1968 |
| 100 | Peter Toth | 1958 | CE | | Canada | |
| 101 | Martin Trnovský | 1966 | CE | Ground Water Technology Inc./Manager, Caribean Operations | USA | 1967 |

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|---|---|---|---|---|---|---|
| 102 | Danica Truchlík | 1965 | AR | Lawrence Berkeley Labs Univ. of California/Facilities Architect | USA | |
| 103 | Boris Uskert | 1966 | CE | Morrison Knudsen Co.-International Engineering Co./Head Architect | USA | 1968 |
| 104 | František Veleba | 1967 | CE | | Germany | 1968 |
| 105 | Peter Venetianer | 1964 | CE | | Switzerland | 1968 |
| 106 | Ivan Miroslav Viest | 1946 | CE | Private Practice/Consulting Engineer | USA | 1947 |
| 107 | Juraj Višný | 1962 | AR | | Switzerland | |
| 108 | Josef Karl Vlček | 1956 | CE | C & V Engineering/Principal | Canada | 1969 |
| 109 | Josef Anton Vlček | 1950 | CE | Private Expert/Construction Logistics | Switzerland | 1969 |
| 110 | Marián Weber | 1968 | AR | | Switzerland | 1968 |
| 111 | Joseph Yeast (Kvasnica) | 1966 | AR | | Great Britain | 1968 |
| 112 | Ján Zavesky | 1959 | CE | Road & Traffic Authority NSW/Head, Bridge Design | Australia | 1968 |
| 113 | Aristíd Zelenay | 1953 | CE | | Switzerland | |

**Table 2 The list of civil engineers (CE), architects (AR) and surveyors (SU) – the graduates of STU (SVŠT) in Bratislava who emigrated from 1948-1989, where all the data are not known**

| No | **Name Surname** | **Graduation at STU** | **Field of study** | **Occupation (institution/ position)** | **Workplace (country)** | **Year of emigration** |
|---|---|---|---|---|---|---|
| 1 | Jozef Andraško | 1967 | CE | Private Practice | Hamburg, Germany | 1968 |
| 2 | Ivan Bolcek | | AR | | USA | |
| 3 | Igor Čelko | | AR | | Switzerland | |
| 4 | Viera Držmíšková | | CE | | Switzerland | 1968 |
| 5 | Jakub Hluchý | | AR | | Switzerland | |
| 6 | Bern Pavol Karamann | | AR | | Switzerland | 1968 |
| 7 | Jaroslav Kevický | | AR | | Canada | 1968 |
| 8 | Mária Kianičková | | CE | | Switzerland | |
| 9 | Ivan Klinovský | | CE | | Canada | 1968 |
| 10 | Anna Kohler | | CE | Private Practice | Australia | 1969 |
| 11 | Lucia Korbelová | | AR | | | |
| 12 | Peter Korda | | SU | Government | Switzerland | 1965 |
| 13 | Dušan Lamoš | | CE | Fondexcan | Canada | |
| 14 | Amer Massarani | 1977 | CE | | Canada | |
| 15 | Pavol Minárik | | AR | | | |
| 16 | Milan Miske | | AR | | USA | 1968 |
| 17 | Jevoslav Opial | 1966 | CE | | Switzerland | |
| 18 | Marcela Pauer | | CE | | Germany | 1969 |
| 19 | Paul Putora | | AR | Lanny Investment, Inc. | USA & Switzerland | 1968 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 20 | Boris Rajek | | CE | | USA | 1968 |
| 21 | Pavol Rázgha | | CE | | USA | |
| 22 | Rastislav Schrenk | | AR | | Germany | |
| 23 | Vojtech Šebesta | | CE | Private Practice | USA | 1968 |
| 24 | Šebestová | | CE | Private Practice | USA | |
| 25 | Fero Šimko | | AR | Schultze Simko/Partner | Germany | |
| 26 | Stanislav Stančík | | AR | | Switzerland | 1968 |
| 27 | Paul Štefka | | CE | | Great Britain | 1968 |
| 28 | Otto Švec | | CE | National Research Council/Building Research | Canada | |
| 29 | Náco Vacval | | CE | | Canada | |
| 30 | Ada Weberová | | AR | | Switzerland | 1969 |

## 4. Statistical evaluation

The list of data about 249 persons is divided into two parts in the book. In the first part there are 172 names whose year of graduation from the STU and field of study are known. In the second part the data are not complete. The structure of the graduates of STU (SVŠT) who are listed as emigrants in the first part can be seen in Table 1. The percentage that depended on the period of emigration is illustrated in Table 2. The graduates of STU (SVŠT) emigrants on Dr. Viest's list of names settled in more than 12 countries. The table shows the percentage ratio depending on the country they emigrated to. Their application in practice is shown in the next table.

**Table 3 The percentage ratio of graduates of STU – the emigrants in the first part of the list**

| Civil engineers | Architects | Electrical engineers | Electrical engineers | Chemical Engineers |
|---|---|---|---|---|
| 43 % | 23 % | 14 % | 14 % | 5 % |

**Table 4 The percentage ratio of graduates depending on the period of emigration in the first part of the list**

| Before 1968 | in 1968 | in 1969 | After 1969 |
|---|---|---|---|
| 6 % | 70 % | 16 % | 8 % |

**Table 5 The percentage ratio in depending on the country the persons from the first part of the list emigrated to**

| USA | Canada | Switzerland | Germany | Australia | Other countries (Austria, Great Britain, Greece, the Netherlands, Peru, South Africa, Sweden) |
|---|---|---|---|---|---|
| 1/3 | 1/4 | 1/5 | 1/10 | 1/20 | 1/15 |

**Table 6 Application in practice of the graduates of the STU emigrants from the first part of the list (most of them are employed in the private sector)**

| Design and consultations | Industry | State organizations, universities, etc. |
|---|---|---|
| 1/2 | 1/4 | 1/4 |

Dr. Viest quotes from an article by J. Vlček in his book Czechoslovak Engineers and Architects (1990): "The knowledge of graduates of Czechoslovak technical universities

enabled them to be highly respected and to become successful. The quality of Czechoslovak universities meets the requirements of universities abroad. Dr. Viest gives examples of the unique structures, the emigrant graduates of STU (SVŠT) participated in.

They are, e.g., high-rise office buildings, banks, and hospitals in cities such as New York, Boston, Montreal, Paris, Singapore, the Opera House in Sydney, prestressed bridges in Australia, the Verrazano Narrows suspension bridge in New York, the Kohlbrandbrücke cable-stayed bridge in Hamburg, etc.

The shortened version of the first and second part of the list of graduates of STU (SVŠT) which was developed by Dr. Viest can be found in the above tables. Some parts of both lists concerning only the graduates related to the Faculty of Civil Engineering: civil engineers, architects and surveyors have been used with his permission [11].

The first author has several letters from Dr. Viest, including his own biography with very interesting details not given in this paper. The biography was submitted by the first author to authors of encyclopedia Beliana.

Interesting is the following taken from one of his letter: „I have a computer, I am writing this letter on it. I was first introduced to computers during the 1947/48 school year at the Georgia Institute of Technology. I started programming myself in the late 1950s. I bought my first personal computer in the early 1980s. I am not connected to the Internet, as I have decided to prevent anyone else from accessing my computer". The letter was written in perfect Slovak on January 11, 2009.



**Fig. 4 Dr. Ivan Viest's residence in Bethlehem, Pennsylvania, USA.**

**Conclusion**

The five Slovak prominent designers: Kozák, J., Bustin, J., Behul, V., Martinček, M. and Bezák, A. and their structures are described in [13]. As Magnificent No.6 can be considered Poštulka, J. [14]. Dr. Ivan Viest is therefore considered as Magnificent No.7. All these great men were exceptionally modest.

The guiding principles of Dr. Viest:

1. Learn to like your everyday work and embrace it fully;
2. Steer your work toward the future but also endeavour to learn from history;
3. Maintain good relationships with your co-workers, as well as with a wide circle of

friends and acquaintances; and
4. Do not forget the need for relaxation in a variety of forms such as sports (he has climbed several peaks, he enjoyed skiing and playing tennis and he is fond of playing golf), reading books and magazines, travel, participation in cultural events, etc.

Memorial Tribute to Dr. Viest was written: a) by GT Georgia Tech, School of Civil and Environmental Engineering, College of Engineering [5] and b) by famous John W. Fisher (1931), who visited Bratislava in 1994 with group of several American professors [6] on web side National Academy of Engineering [7]. Dr. Viest wrote Memorial Tributes to three famous Americans: a) Anton Tedesko (1903-1994) [8], b) Eivind Hognestad (1921-2000) [9] and c) Jackson Leland Durkee (1922–2007) [10], who thanks to Dr. Viest sent to the first author his collection of bridges with world record spans. Durkee obtained collection from LaBelle, both worked at Bethlehem Steel Corporation.

Information about three Slovak emigrants may be found in [12].

**Acknowledgement**

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# THE MAGNIFICENT FIVE

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***Abstract:*** *A brief overview of the lives and work of five prominent Slovak designers of steel structures: Juraj Kozák, Ján Bustin, Vojtech Behul, Mikuláš Martinček and Anton Bezák. There is no doubt that, due to their remarkable achievements in steel, composite steel and concrete and aluminium building and civil engineering structures in the former Czechoslovakia, the Slovak Republic, and abroad, they are an integral part of the cultural heritage of the Slovak Republic.*

***Key words****: Slovak structural engineers, steel structures, cultural heritage*

## 1. Introduction

This contribution is dedicated to five exceptional Slovak designers, primarily in the field of steel structures, who were recognized by both the entire Czechoslovak technical community and internationally. Four of them spent an extended period at the former design and construction office of the national enterprise Vítkovice, the branch located in Bratislava. Ing. Behul served as the Head of the design bureau at the national enterprise Hutný projekt in Bratislava. Kozák, Bustin and Behul were born in the 1920s, Martinček in the 1940s and Bezák, the youngest, the founder of the successful family-based company Ingsteel spol. s.r.o., was born in the 1950s.

Kozák began his university studies during World War II at TU Darmstadt under the guidance of Prof. Kurt Klöppel, alongside Josef Poštulka. He later completed his studies externally at the Slovak Technical University in Bratislava (SVŠT = Slovenská Vysoká

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Škola Technická, it was renamed much later in Slovak University of Technology = STU), graduating in 1949.

In 1950, a highly accomplished class graduated from SVŠT, including Bustin, Behul and Poštulka. About Poštulka see [4]. Their classmates included, among others, František Kruml, Head of Department; Gustáv Martinček, Head of Department, and Rudolf Skrúcaný, Director of the Institute of Construction and Architecture (Ústav Stavebníctva a Architektúry = ÚSTARCH) at the Slovak Academy of Sciences (SAV) in Bratislava. All three worked at ÚSTARCH as Ing. DrSc. from 1953. Ján Szolgay (Ing. CSc. at Water Research Institute, VÚVH = Výskumný Ústav Vodného Hospodárstva) was another their classmate.

Martinček graduated from SVŠT in 1964. His classmates included, among others, Zoltán Sadovský (Ing. DrSc. at ÚSTARCH SAV), and Ján Siegel (Ing. CSc. at the Slovak Forest Products Research Institute in Bratislava, Slovenský Výskumný Ústav Drevársky v rámci VÚPC = Výskumný Ústav Papiera a Celulózy). Ing. Gustáv Martinček, DrSc., famous scientist mentioned above was uncle of Mikuláš Martinček.

Bezák graduated from STU in 1979. His classmates, included among others, Stanislav Bojmír (Ing. CSc. designer of steel masts), Ján Brodniansky (Prof. Ing. CSc. Head of Department at STU), Vincent Kvočák (Prof. Ing. CSc. Dean at FCE, TU Košice). Ján Palkovič, Ing., designer of steel structures at Vítkovice, Bratislava branch, was also his classmate.

The main sections dedicated to these structural engineers, written by the authors of this contribution, are complemented by memories from their former colleagues and followers. Included are recollections from Dr.h.c. Prof. Eng. Doncho Partov, PhD., who studied and consequently worked in the former Czechoslovakia for several years. He personally knew many Czech and Slovak professors and designers, and the idea to write about Slovak designers of steel structures for the BASA 2025 proceedings originated from him.

## 2. Ing. Dr. Jiří (Juraj) Kozák, CSc. (By Magura, M., the grandson)

Ing. Dr. Jiří (Juraj) Kozák CSc. completed his primary and secondary education in his hometown of Benešov near Prague (today Czech Republic) with honours. He received his first education in civil engineering during World War II at the Technical University of Darmstadt in Germany, where he completed six semesters at the Faculty of Civil Engineering.

After the war, he returned to the Czech Republic, where he briefly worked as a structural designer at ČKD Prague. In 1946, he permanently moved to Slovakia. While working, he successfully completed his university studies in 1949 at the Faculty of Civil Engineering at SVŠT in Bratislava, specializing in structural and transportation engineering. He graduated with honours after passing the Second State Examination.

He also obtained his academic degrees at SVŠT:

- Dr. techn. in 1953 for his dissertation Buckling Based on Random Imperfections of Bars.
- CSc. in 1969 for his research on Steel Masts.

In 1949, he joined the newly established Stavoprojekt Bratislava as a structural engineer, where he worked until 1957. That year became a turning point in his professional career, he joined the design and engineering office of the Vítkovice national enterprise, Bratislava branch. He remained there for more than thirty years as the head of the steel structures department and chief designer.

Initially, he was involved in the design and production of steel structures for major industrial facilities, particularly metallurgical complexes. In the 1960s, with the allocation of financial resources and the expansion of production and assembly capacities, favourable conditions were created for the use of steel structures in civil construction as well.

Under the leadership of Dr. Kozák, the steel structures division of Vítkovice, n. p., Bratislava branch became one of the most sought-after teams in Czechoslovakia due to their expertise in complex structural design and collaboration with architects. With a strong manufacturing background and a long tradition, they were entrusted with significant projects across the country. They did not exploit this opportunity but rather used it to become equal partners to architects. This partnership led to the creation of numerous unique buildings.





**Fig. 2.1 Jiří (Juraj) Kozák (27.03.1922, Benešov u Prahy – 24.07.2003, Bratislava)**

Among the most notable projects Dr. Kozák contributed to are:

- 300-meter guyed television masts at Suchá hora (1960) and Dubník (1961), Fig. 5.14, Fig. 6.2.
- Hotel Kyjev – Bratislava (1968–1973) (architect: Ivan Matušík), Fig. 2.3.
- Kamzík Television Tower – Bratislava (1967–1975) (architects: Tomašák, Májek).
- Superstructure and extensions of the former Federal Assembly Building – Prague (1968–1973) (architects: Karel Prager, Jiří Kadeřábek), Fig. 2.5, Fig. 5.5.
- SHD Most High-Rise Building (now SaS Group Tower) (1970–1984) (architects: Krejčí, Fojt).
- Tranzgas Tower Buildings – Prague (1972–1978) (architects: Václav Aulický, Jindřich Eisenreich).
- Completion of the National Theatre Complex – Prague (1977–1983) (architects: Kupka, Loos, Prager).
- Czech Savings Bank Building (Česká spořitelna) – Prague 4 (architect: Alena Machoninová-Kordovská).
- Press Center High-Rise Building – Bratislava (1984) (now Tower 115 after reconstruction in 2004–2006, architects: Prof. Lacko, A. Dóra), Fig. 2.7.
- Žižkov Television Tower – Prague (1985–1992) (architect: Václav Aulický), Fig. 2.6, Fig. 6.3, Fig. 6.4.

- VÚB Bank Headquarters High-Rise Building – Bratislava (1996–1997) (architects: Bahna, Palčo, Závodný, Juráni).



**Fig. 2.2 Kozák at Faculty of Civil Engineering. He frequently co-operated with its employees. The moment when Kozák congratulates Prof. Lapos on his 50th birthday. From the left: Prof. Jozef Lapos (he is now 85 years old), Assoc. Prof. Vladimír Vořišek (he is now 100.5 years old), Ing. Kozák, Prof. Eugen Chladný (1928 – 2020) , Head of Department of Metal and Timber Structures.**

At his department, among other things, the design and production documentation for the SNP Bridge and the Prístavný most (Harbor Bridge) in Bratislava were developed. He represented the quality of Czechoslovak steel construction at major international conferences as an active member of the International Association for Shell and Spatial Structures (IASS).

Throughout his professional career, he sought to promote the use of steel structures and their combinations with other building materials, particularly composite steel-concrete structures.

His publishing activity was also remarkable—he authored seven monographs, with the most notable being Steel-Concrete Structures for Multistorey Buildings, published by the prestigious scientific publishing house Elsevier in 1990.

After retiring in 1990, Dr. Kozák continued to work actively as a consultant in the field of construction. He collaborated not only with Czechoslovak designers but also with international experts, particularly from Germany. His last significant project was the new-generation high-rise headquarters of VÚB in Bratislava.

At the same time, he continued his teaching career at the Academy of Fine Arts and Design (VŠVU) and the Faculty of Architecture at STU. His approach to projects elevated the role of the engineer to that of a co-creator of architectural and engineering works. The relationship between engineers and architects was a subject that deeply fascinated him throughout his career.

After the dissolution of Czechoslovakia, he became significantly involved in issues concerning national minorities in Slovakia, particularly the Czech minority. He was one of

the founders of the Czech Association in Slovakia and also served as vice-chairman of the civic association Mosty.

Towards the end of his life, he combined his professional work with his long-standing interest in history. He focused on the Bratislava Danube bridges, not only from a technical but also from a historical perspective. He collected a vast amount of material, both from witnesses and state archives, particularly about the Old Bridge and the SNP Bridge (formerly New Bridge). His findings were compiled into a three-volume publication titled "Bridging the Danube in Bratislava in a Broader Context" (11/2002), which he unfortunately did not manage to publish.

Dr. Kozák passed away on July 24, 2003, in Bratislava.

His technical legacy became an integral part of the panorama of both the Czech and Slovak capitals—in the form of iconic television towers, visible from afar.

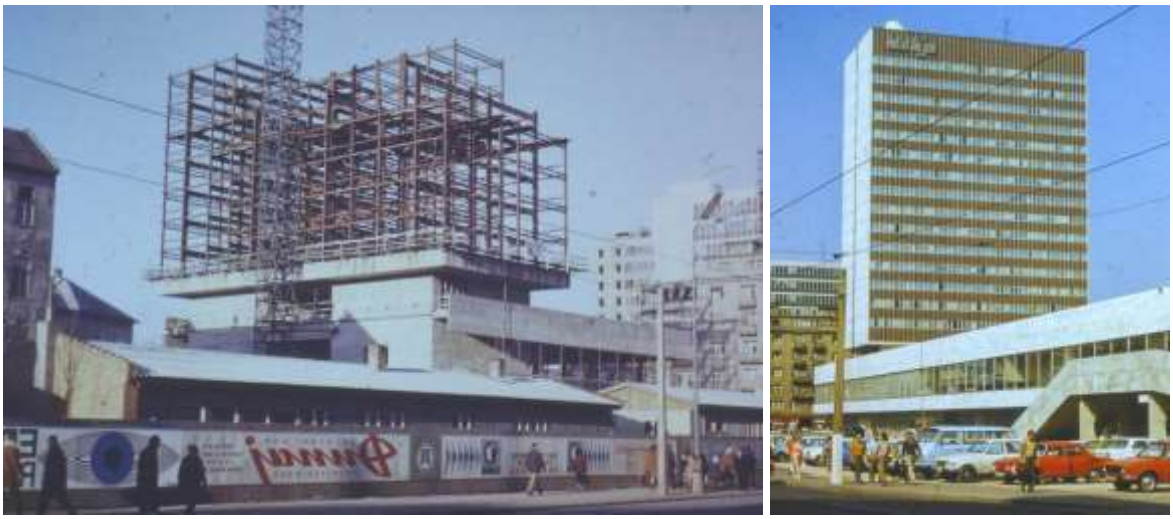


**Fig. 2.3 Hotel Kyjev – Bratislava (1968-1973)**



**Fig. 2.4 Kamzík Television Tower – Bratislava (1967-1975)**



**Fig. 2.5 Building of Federal Assembly of the Czech and Slovak Federative Republic – under construction (1968 -1973)**



**Fig. 2.6 Žizkov TV Tower under construction (1985–1992)**



**Fig. 2.7 Press Center High-Rise Building in Bratislava (1984). Tower 115 after reconstruction in 2004–2006. Photo is from 2010.**
**(Courtesy of Doko Ing. Mgr. Jozef Kotulič)**

Ing. Dr. Jiří (Juraj) Kozák, CSc., left a significant mark in Czechoslovakia through his outstanding architectural and structural contributions. He played a crucial role in expanding awareness of steel load-bearing structures and composite steel-concrete structural systems.

His philosophy was to closely collaborate with architects from the very beginning of a construction project and to integrate the structural framework into the architectural concept in a way that not only ensured efficiency but also contributed to an aesthetically refined outcome. He sought to instil this philosophy in university students during his academic career.

Dr. Kozák left behind not only a professional and pedagogical legacy but also, after the dissolution of Czechoslovakia, actively worked to maintain close relations between Czechs and Slovaks, significantly contributing to the continuation of mutual understanding between these nations.

### 3. Ing. Ján Bustin, CSc. (By Šuppa, F., Štujberová, M.)

Ing. Ján Bustin was one of the key figures in the design and construction of civil engineering structures in Czechoslovakia and later in the independent Slovak state. He completed his university studies in Civil Engineering at the Slovak University of Technology in Bratislava in 1950. He developed his expertise in the statics and dynamics of building structures at the Vítkovice State Enterprise design office, Bratislava branch. The close connection between this office and the production organization VŽKG Ostrava further showcased his design abilities, allowing him to contribute to numerous significant projects across Czechoslovakia. The scope of his design activity was vast, a level of output that would be difficult to math by today's standards. It would be impossible to list all the buildings he contributed to in this article. His extensive collaboration on projects also stemmed from a practice in the design department during the 1980s, where junior designers were required to report on the projects they were working on during "production meetings".



**Fig. 3.1 Ján Bustin (17. 02. 1926, Bratislava - 11.02.2017, Bratislava)**

The "monuments" of Ing. Bustin's design and construction activities from this period can still be admired across the territory of the former Czechoslovakia (now the Czech Republic and the Slovak Republic), and the scope of his contributions is truly extensive. Some of the buildings completed before 1989, in which Ing. Bustin was involved, are listed here. A large portion of his work includes technological structures, such as steel structures for the Chvaletice and Mělník power plants, the lifting auditorium at the cultural center in

Trnava, the Gabčíkovo navigation control room (suspended on a reinforced concrete core), and the "flaps" and gates on the Vltava, Elbe, and Danube rivers.

a) 

b) 

b) 

**Fig. 3.2 a) Large-scale machine K2000, b) Waterworks Gabčíkovo**

As both an author and co-author, Ing. Bustin contributed to the design of numerous bridges. The most significant of these is the Slovak National Uprising (SNP) Bridge (known as the New Bridge from 1993 to 2012) in Bratislava. This cable-stayed bridge spans the Danube River, with a main span of 303 meters and a back span of 75 meters. It was officially opened in August 1972.

The Harbor Bridge (formerly known as the Bridge of Heroes of Dukla until 1993) in Bratislava is a two-storey highway-railway steel bridge over the Danube River. It is part of Slovakia's highway network, with the highway running on the upper level, and a double-track railway on the lower level. Pedestrian and cyclist paths are located on cantilevers near the lower level. Additionally, the bridge accommodates water supply lines, gas pipelines, high-voltage cables, and telecommunications connections. The spans of the bridge are 102.4 + 204.8 + 64.0 + 89.6 meters. It was partially opened on December 17, 1983 and fully completed in 1985 [7].



**Fig. 3.3 Harbor Bridge**

The Red Army Bridge, featuring (forespans - steel truss structure, single-span from the Bratislava side and double-span from the Petržalka side), was dismantled in 2014 and replaced with a new structure.



**Fig. 3.4 Red Army Bridge**

Other notable bridges include the composite bridge in Tlmače, the arch bridge without upper bracing in Bytča, the cofferdam for the Lanfranconi Bridge pillar in Bratislava, the composite bridge on Sihoť in Trenčín, the pedestrian bridge at Dlhé diely in Bratislava, the reconstruction of the railway bridge over the Hron River near Štúrovo, inspection walkways, and the trolleys for the Red Army Bridge in Bratislava.

Another equally noteworthy group of works consists of buildings. The Slovak Radio building in Bratislava holds the title of Building of the Century in Slovakia in the category of Social Buildings, awarded by the ASI. In 2017, it was declared a national cultural monument. Construction of the complex began in 1970 and was completed in 1983. It features spacious interiors, an exceptional concert hall, and well-equipped recording studios. Additionally, one of the largest organs in Slovakia is housed there. The building's total height, including the antenna, is 80 meters [8].

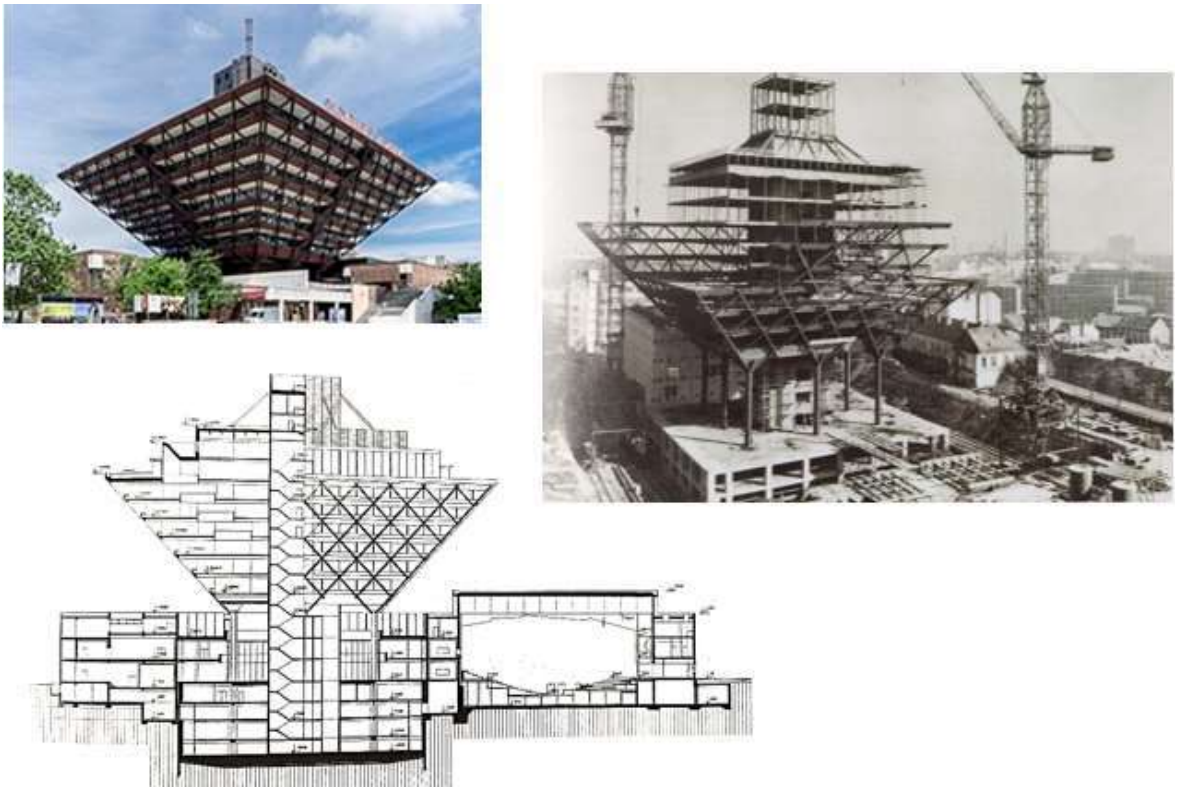


**Fig. 3.5 The Slovak Radio building in Bratislava [10]**

The Federal Assembly building in Prague (Fig. 2.5, 5.5) was the result of an architectural competition in 1964. Construction began in 1966 and was completed in 1973. The building's design and structural concept, which incorporated unique steel beams, fulfilled the requirement to preserve the former "crop exchange" building.

The administrative building in Považská Bystrica, constructed between 1968 and 1978, features a structure consisting of a reinforced concrete monolithic core that extends to the top floor and rises above the roof level. A steel support system of the seesaw type is mounted on this core, with steel ties suspended from it. These ties support the floor structures and the perimeter aluminum cladding [9].

Other notable buildings include the Družba convalescent home in Yalta, the Poprad – Tatry station, the TEŽ Poprad – Tatry hall, and the multifunctional hall in Ostrava (Palace of Culture and Sports, later ČEZ Arena, now Ostravar Arena). The hall in Ostrava was opened in 1986 and underwent reconstruction in 2003 and 2004.



**Fig. 3.6 Multifunctional hall in Ostrava**

Ing. Bustin's portfolio also includes telecommunications structures, such as the TV transmitter Prague (Fig. 2.6, 6.4), the TV tower at Kamzík in Bratislava, and various anchored masts, including those at Dubník (height 300 m) (Fig. 6.2), Suchá hora (300 m), Kráľova hoľa, and Krížava (116 m). Additionally he contributed to the design of the Drahňov water reservoir tower, among others.

Ing. Bustin, together with his colleague Ing. Šubr, co-authored the book "Composite Steel and Concrete Structures" in 1964.



**Fig. 3.7 Ing. Bustin (left) and Ing. Šubr inspecting the construction of the SNP Bridge in Bratislava**

After 1989, Ing. Bustin "retired", but continued to work as a consultant, primarily guiding young designers and passing on his knowledge and experience. He offered his expertise mainly to companies specializing in the design and implementation of buildings, such as Dopravoprojekt PLC, Geoconsult Ltd, Cemos Ltd, Distler-Šuppa Ltd, and others. He was able to apply his extensive professional knowledge, experience, and ability to understand complex issues in their broader context, also collaborating with construction companies like Doprastav PLC, Hydrostav PLC, SES MONT Ltd (Tlmače), MONTIRP Ltd (Žilina), and Vihorlat Snina PLC.

Below are the most important projects on which Ing. Bustin collaborated.

Proposal for the implementation of crossings of the 5th line of the gas pipeline across the Laborec and Hornád rivers, involving the installation of a shaped steel pipe with a diameter of 1420 mm ("shaped bend") for Hydrostav PLC.

a) 

b) 

**Fig. 3.8 a) Implementation of the crossings of the 5th line of the gas pipeline across the Laborec and Hornád rivers, b) Concreted bend over the Váh River**

Ing. Bustin also provided technical assistance for the steel structures of the silo roof at Považská cementáreň PLC in Ladce. This was done for MONTIRP Ltd, Žilina, which manufactured and assembled the steel structures for the project. The steel structures of the silo roof were assembled "on the ground" (Fig. 3.9 a)) and launched into position during the concreting of the walls, as specified in the project. In Fig. 3.9 b), the completed silo is shown, featuring the so-called "lantern" on top.

a) 

b) 

**Fig. 3.9 Roof of the silo, Ladce**

Ing. Bustin provided technical assistance in the installation of a tank weighing approximately 320 tons at the Slovnaft PLC refinery. His role involved designing the assembly tools necessary to move and position the tank as specified in the project, without the use of a crane. The installation was carried out by SES MONT Ltd Tlmače.



**Fig. 3.10 Tank installation at the Slovnaft refinery**

Ing. Bustin provided technical assistance in the transport and assembly of tanks weighing approximately 150t and 200t at the MOL refinery in Hungary. His role included designing the assembly tools necessary for unloading the tanks from the ship, moving them, and installing (lifting and positioning) them into place as specified in the project, all without the use of cranes. The work was carried out by SES MONT Ltd Tlmače.
He also contributed to the design of antenna carriers for the construction of mobile operator networks in Slovakia.



**Fig. 3.11 Mobile operator antenna carriers**

In the field of civil engineering, he contributed to various projects, including the documentation for the zoning and land use decision for the Košická Bridge. He also visited the construction site during its execution and worked as a consultant for the investor's supervision. Additionally, he was involved in the dismantling of a concrete bridge over the Váh River in Nové Mesto nad Váhom (proposal for the dismantling procedure) and the assembly of a concrete bridge structure in Lipovec. He also proposed a procedure for extending a reinforced concrete bridge structure to the position prescribed by the project using an auxiliary steel structure. His expertise extended to the diagnostics and reconstruction of steel bridges over the Hron in Podbrezová, the Danube in Medveďov, and the Váh River canal, as well as the bridge structure over the Čuňovo power plant.

a)  b) 

**Fig. 3.12 a) Lifting bridge over Morava river in Moravský Svätý Ján b) Reinforced concrete bridge over the highway**

A 700-meter-long bridge on the D1 Jablonov - Studenec highway is designed as an arch bridge, with architectural features reminiscent of the Gothic monuments of the region. The bridge structure combines steel elements with a composite reinforced concrete bridge deck

.

**Fig. 3.13 The D1 motorway Jablonov – Studenec**

The Skalité Bridges, located on the border between the Slovak Republic and the Polish Republic, consist of four bridge structures with a total length of 1,352 meters on the D18 motorway. All the bridges are designed with two composite steel beams and a reinforced concrete deck. The longest of these is Bridge D201, with a total length of 492 meters. Bridge D202 is 150 meters long, D203 is 270 meters long, and D204 is 440 meters long.


**Fig. 3.14 Skalité bridges**

The Church of Divine Mercy in Jacovce features a roof that combines steel trusses with timber beams and boards. The vertical load-bearing structures consist of prefabricated and monolithic reinforced concrete elements, while the tower is a prefabricated reinforced concrete structure "secured" with prestressed cables.



**Fig. 3.15 Church of Divine Mercy, Jacovce**

In 2009, Ing. Bustin won second place in the competition for the "Design of the Concept for the New Lower Gates of the Lock Chambers for SVD G-N, Gabčíkovo Level".
Finally, an interesting example is the Ellipsion family house near Slnečné jazerá in Senec, built between 2000 and 2002. The architect was Ivan Matušík, with collaborators Jozef Pavelčák, Ján Bustin, and František Šuppa. The contractors were Montzvar from Stará Ľubovňa. In 2002, Ellipsion won the Dušan Jurkovič Award, and the following year, it received the CE.ZA.AR Award and a nomination for the European architectural Mies van Der Rohe Award.



**Fig. 3.16 Family house Ellipsion [11]**

Ing. Bustin's lifelong passion was, even in his later years, a continuous pursuit of self-education. He systematically and purposefully kept up with changes in standards, new technologies, and the latest advancements in science and technology, commenting on them in his unique way. Those he deemed significant contributions to his field, he later sought to incorporate into new projects and implementations.

The buildings in which Ing. Bustin played a role, both in design and construction, bear the mark of his exceptional engineering and design skills. Many of these buildings continue to serve as landmarks in their respective locations, such as the Harbor Bridge and the Slovak Radio building in Bratislava. He left a lasting impact on the Slovak design community, where many of his former trainees continue to carry forward his legacy, designing buildings not only in Slovakia but also across other European countries.

***"Let us now sing the praises of famous men, our ancestors in their generations...." (Sirach 44.1)***

**4. Ing. Vojtech Behul, CSc. (By Bukov, D.)**



**Fig. 4.1 Ing.Vojtech Behul, CSc. (22.09.1926, Nitra – 22.05.2019, Bratislava)**

Ing. Vojtech Behul, CSc. completed his studies at the grammar school with the graduation exam in 1945. He took the exam twice: the first time in the school's basement during the front line, and the second time after the liberation. He grew up in modest conditions; his father was a tailor, and there were two other children in the family, a brother and a sister. During his time at the grammar school, he helped wealthy and less capable classmates with their level of knowledge during the holidays.

After graduating in 1945, he enrolled in medical studies with the goal of studying psychiatry. On his way back from the enrollment, he met his class professor on the train, with whom he discussed this enrollment. However, the professor convinced him that, given his mathematical talent, it would be more appropriate to use his abilities in the field of engineering. Therefore, the next day he went to enroll at the Faculty of Civil Engineering at the Slovak University of Technology, where he completed his studies in 1950. Both of his siblings also pursued similar fields of study—his brother as a civil engineer and his sister as an architect.

After graduating from the Faculty of Civil Engineering, he started working on August 16, 1950, at a branch of Vítkovice Ironworks in Bratislava, in the department of Prof. Tesár, who had transferred to the branch from the railways. A design and commercial branch was established with its office at Palisády 61 in Bratislava. In addition to designing and drafting production documentation for Vítkovice Ironworks, the branch also engaged in commercial activities, such as selling boilers.

On July 1, 1951, the Metallurgical Design Institute (Hutný projekt) was established, and the first department was Prof. Arpád Tesár, DrSc.'s department, which fully transferred with 21 staff members to the Metallurgical Design Institute. The office of this department was located in the well-known Olympia café, as the new regime was closing cafés as bourgeois relics, and these spaces began to serve as workspaces during the emerging industrialization. Later, after the expansion of the Metallurgical Design Institute's activities and the establishment of other departments, the company moved to another café, the famous Luxor café. Prof. Tesár became the director of the Metallurgical Design Institute. A story is associated with this café: Prof. Tesár, as the director of the Metallurgical Design Institute, took the keys to the Luxor café's premises, but he feared the anger of the regular patrons in Bratislava, who would soon see their café taken over. Therefore, when he visited the premises for the first time, he brought along a group of colleagues for support. On October 14, 1951, he got married. His chosen one was a colleague who worked as an economist at the Metallurgical Design Institute.

In July 1955, Prof. Tesár left his position as the director of the Metallurgical Design Institute to join the Welding Research Institute.

In 1956, the Metallurgical Design Institute completed the construction of a new building on Gajova Street in Bratislava.



**Fig. 4.2 Metallurgical Design Institute in Bratislava**

He dedicated more than 40 years of his active working life to the Metallurgical Design Institute. Since 1965, he had a long-term collaboration with the Department of Metal and Timber Structures at the Faculty of Civil Engineering, Slovak University of Technology (former SVŠT), as an external collaborator. He participated in the teaching process for students and served as an opponent during diploma theses and final defenses.

In 1969, Ing. Behul completed his external scientific doctoral studies on the topic "Fatigue Cracks in the Webs of Crane Runway Girders." The results of his work were also published in the renowned Italian journal *Metallic Construction* at the time. During his time at the Metallurgical Design Institute, he served as the chairman of the Scientific and Technical Society (VTS) and as the chairman of the Regional Committee of VTS for Steel Structures.

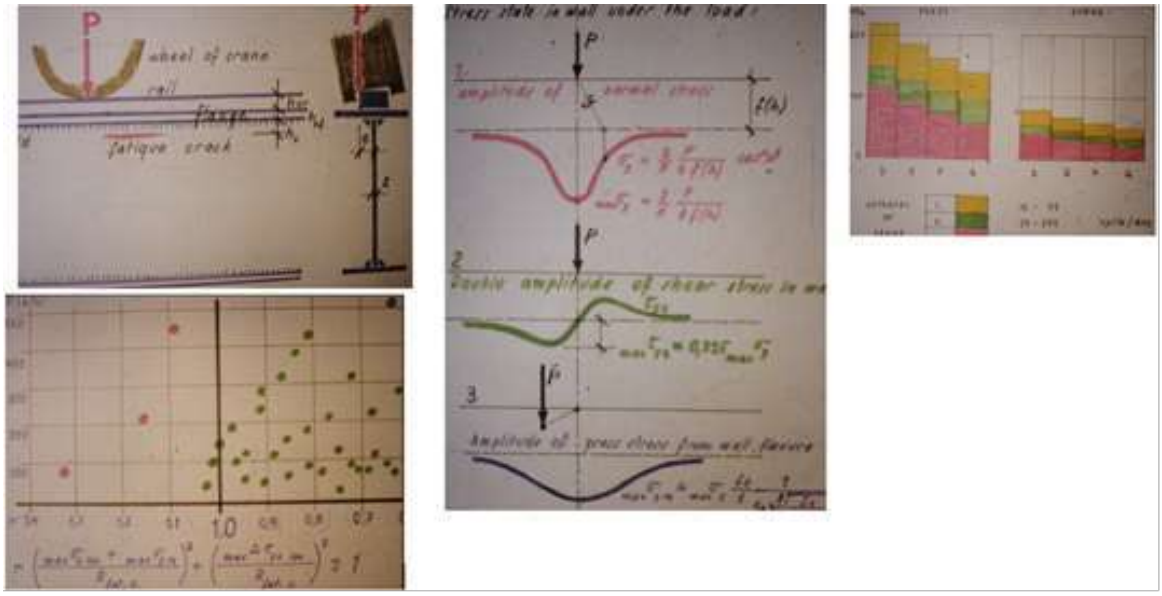



**Fig. 4.3 From the presentation of the dissertation results**

A significant contribution of Ing. Behul to the development of the field of steel structural engineering was the organization of meetings/conferences for the experts in the steel structures. These events were of a high professional standard and also served as social gatherings for colleagues. During social dinners, accompanied by violin music from one of our colleagues, with bread, lard, and onions, an atmosphere of understanding and creativity was fostered. A characteristic feature of the entire life of the engineer was the search for understanding of good, discovering people's abilities, and encouraging creative work. To us younger colleagues, he opened up opportunities to present our own work, as well as our employer's, at professional events. We could feel his genuine joy in the professional growth of his subordinates. As the department head, he treated every subordinate as a partner. His department was always full of young people and women, and with the kindness he was known for, he would willingly explain the principles of design and calculations to everyone.

A significant characteristic of Ing. Behul's work was his constant support for creative thinking. Under his leadership, no concept for solving structural designs was condemned to failure. He creatively assessed concepts for load-bearing structures, connection details for complex constructions, all with admirable knowledge of simplified assessment methods. He constantly encouraged, especially younger colleagues, to present their work results to the technical community at conferences. For us, younger collaborators at the time, this approach gave us a sense of confidence and pride in our own work. The entire department under his leadership functioned as a cohesive unit with a deep understanding of both technical and personal issues. Ing. Behul never used harsh words; his strictest expression was "I kindly ask you." When female colleagues left a few minutes before the end of the working day to care for their children, Ing. Behul would simply remark, "It's approaching 4 p.m., the girls are leaving." His kindness, immense goodness, and joy in the success of others helped shape our characters as adults.



**Fig. 4.4 A smile, a good mood, followed by a serious conversation with the director (circa 1985)**

In the years 1981–1983, the steel structures department, under the leadership of Ing. Behul, developed the project for the "Stripping Hall" for the Oxygen Converter Steelworks (KKO) of the Třinec Ironworks, currently TŘINECKÉ ŽELEZÁRNY, a.s. (the largest steel producer in the Czech Republic). This is a double-aisle hall with a span of 2 x 30 m, a transverse truss spacing of 18.0 m, and a length of approximately 118.0 m, used for the removal of molten iron from molds. In each aisle, two stripping cranes, each weighing 200 tons, move along the hall. The weight of the stripping beam (the crab) is 90 tons. The load suspension is rigid. The cranes operate in the highest fatigue class. The crane runway girders, with a span of 18.0 m, have a closed cross-section with a height of 2500 mm and a width of 1100 mm. The rolled rail is placed eccentrically, with a head width of 120 mm and a base width of 220 mm, weighing 167 kg/m. The girder was designed to ensure that the details did not create notches. The stiffeners are connected to the tension flange by cloning.




**Fig. 4.5 Stripping hall at TŽ Třinec (Czech Republic)**

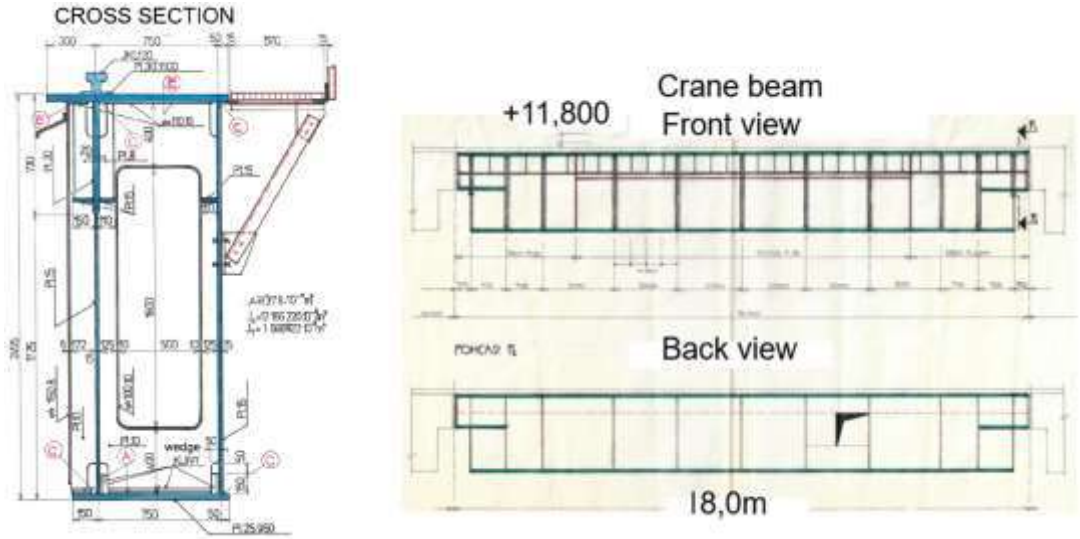



**Fig. 4.6 Crane runway girder**

The transverse trusses of the hall are made of welded frames, with columns at the edges of the aisles using welded I-sections of 600 mm x1800 mm, and columns between the aisles using I-sections of 600 mm x 2400 mm. The beams are made from welded I-sections of 600 mm x1800 mm. The height of the top edge of the rail is 11.5 m, and the height of the hall is 24 m. The transverse aisles have a span of 18.0 m, with the distance between the transverse trusses being 6.0 m, and they are equipped with 20-ton cranes. The total weight of the steel structures is 3,600 tons.

In 1988, he won second place in the national competition "Best Steel Structure Projects" for the design of the Sports Hall in Považská Bystrica. The hall has seating for 1,000 spectators. The span of the frame is 45 m, and the height of the frame beam is 750 mm.

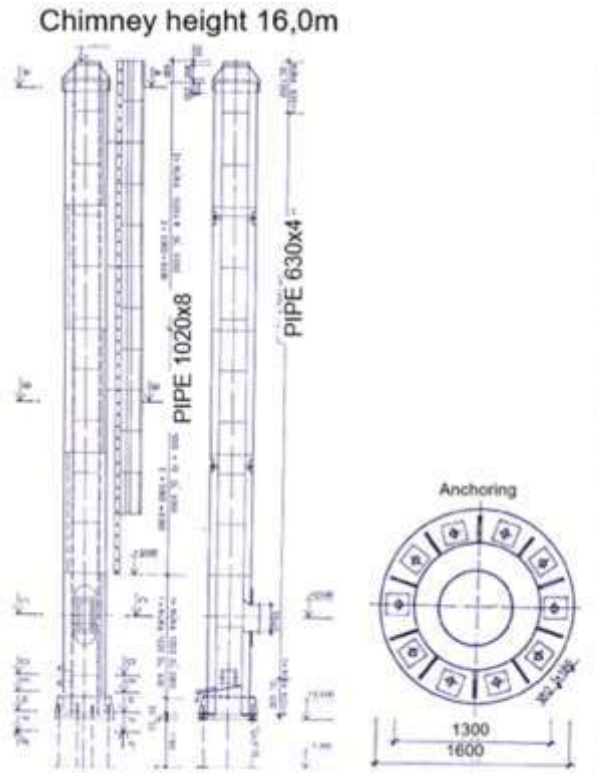


**Fig. 4.7 The Sports Hall in Považská Bystrica during construction**




**Fig. 4.8 The Sports Hall in Považská Bystrica**

Ing. Behul developed standardization guidelines for halls with shed roofs and double-skin chimneys for the Federal Ministry of Metallurgy and Heavy Machinery.




Basic geometry and anchoring data

| | | | | | | |
|---|---|---|---|---|---|---|
| height | 16 | 25 | 32 | 42 | 50 | m |
| Shell diameter | 1,020 | 1,220 | 1,420 | 1,620 | 2,020 | m |
| outside diameter | 1,6 | 1,8 | 2,0 | 2,4 | 2,8 | m |
| inside diameter | 0,8 | 1,0 | 1,2 | 1,4 | 1,8 | m |
| PRIEMER KRUŽNICE UMIESTNENIA SKRUTIEK | 1,2 | 1,5 | 1,7 | 2,0 | 2,4 | m |
| KOTEVNÁ SKRUTKA M | 36×3 | 48×3 | 64×4 | 72×4 | 80×4 | mm |
| HĹBKA KOTVENIA | 1200 | 1500 | 1800 | 2100 | 2400 | mm |
| VÝPOČTOVÝ PRIEREZ JADRA SKRUTKY | 0,865 | 1,604 | 2,856 | 3,658 | 4,586 | $\cdot 10^3$ mm$^2$ |
| VÝPOČTOVÁ PEVNOSŤ (MAT. 37) | 200 | 200 | 190 | 190 | 190 | MPa |
| VÝPOČTOVÁ PEVNOSŤ V ZÁVITE | 160 | 160 | 152 | 152 | 152 | MPa |
| VÝPOČTOVÁ ÚNOSNOSŤ | 138 | 257 | 433 | 566 | 894 | kN |
| ZVISLÁ OSOVÁ SILA | 65,5 | 142,4 | 214,0 | 313,3 | 488,3 | kN |
| OHYB. MOMENT OD VETRA | 161 | 564 | 1140 | 2493 | 4718 | kNm |
| OHYB. MOMENT OD SEIZMICITY | 47 | 87 | 147 | 190 | 303 | kNm |
| ŤAHOVÁ SILA V JEDNEJ SKRUTKE | 33 | 106 | 205 | 390 | 637 | kN |
| NAPÄTIE V BETÓNE | 1,02 | 2,26 | 3,10 | 3,42 | 3,77 | MPa |

**Fig. 4.9 A double-skin chimney with a height of 16.0 m**

The Metallurgical Design Institute underwent various transformations, eventually transitioning from a state-owned enterprise to a limited liability company (s.r.o.), and later to a joint-stock company. Unfortunately, it no longer exists today.

During his time at the Metallurgical Design Institute, Ing. Behul served as the chairman of the Scientific and Technical Society within the institute and as the chairman of the Regional Committee of the Scientific and Technical Society for Steel Structures. During this period, he organized countless study trips to construction sites throughout Czechoslovakia, as well as abroad, thereby contributing to the development of knowledge within the broader professional community. In addition to the study trips, he organized professional conferences and meetings for the steel structures experts for nearly 40 years.
At the end of his time at the Metallurgical Design Institute, Ing. Behul worked as the lead specialist for steel structures. At the end of 1991, he retired.

After retiring, he continued working as a freelance designer until 1994, for Stavomontáže Trnava, a company that supplied double-skin chimneys for boiler houses across Czechoslovakia. The largest chimney they delivered was for a housing company in Nové Zámky, standing at a height of 70 m. Ing. Behul was not only the designer of the chimney but also devised a unique installation method, using a rotating joint on the base plate. This innovative approach allowed the chimney to be erected by two cranes through a tilting process, without the need for lifting the chimney itself.

In 1994, after his wife fell seriously ill, he, at the age of 68, definitively stopped designing. His wife passed away in 2009.
Subsequently, Ing. Behul devoted himself to studies at the University of the Third Age and completed:
A 3-year study at the Faculty of Law
A 3-year study in economics
A 2-year study in environmental science
A 2-year study in psychology

In 2001, Ing. Vojtech Behul, CSc., was awarded the Professor Tesár Prize. In 2009, Ing. Vojtech Behul, CSc., was awarded the Silver Medal of the ZSVTS (Union of Scientific and Technical Societies of Slovakia).
Ing. Behul's life journey came to an end on May 22, 2019, at the age of 93. Ing. Behul was a shining example of an honorable person who lovingly passed on his experiences and knowledge to colleagues and the broader technical community. His support for creativity in every individual broke down stereotypes. The engineer never used the term "this is how we've always done it" — every idea was worthy of consideration. For all that he did for the field of steel structures, he deserves gratitude and recognition.

## 5. Ing. Mikuláš Martinček, CSc., (Miki), visiting prof. (By Ároch, R.)

Mikuláš Martinček completed his university studies with honors in 1964 at the Faculty of Civil Engineering, Slovak Technical University in Bratislava. He received special recognition for the quality of his thesis "Suspension Bridge of 400m Span" (the supervisor was Prof. Arpád Tesár). In 1965, he joined Pozemné stavby Prešov, where he worked as a site manager and development worker. At that time, he was also an active league basketball player.

He then moved to Bratislava, where from 1967 to 1992, he worked at the design and construction branch of VÍTKOVICE – Bratislava as a lead designer, head of development, and chief engineer.





**Fig. 5.1 Mikuláš Martinček (23.09.1942, Sabinov – 10.11.2024, Hamuliakovo)**

In 1969-1970, he completed postgraduate studies in the statics of steel structures at ÚAM Vítkovice (Ústav aplikované mechaniky - Institute of Applied Mechanics), part of VAAZ Brno (Vojenská akademie Antonína Zápotockého = The Military Academy of Antonín Zápotocký). He obtained praise for the final thesis "Calculation of a bridge cross member with consideration of shear".

From 1974 to 1979, he studied as a research assistant at ÚAM Vítkovice at VAAZ Brno in the field of mechanics of rigid and deformable bodies and environments. In 1982, he defended his dissertation on the topic "Automation of calculations of discrete beam systems in an interactive way."

During his employment at Vítkovice, he focused on designing steel structures of all kinds, from design to implementation. Several projects and realizations received awards in various competitions. At the same time, he actively engaged in all theoretical and practical activities related to steel structures. These included the development of system software for steel structures, research, peer reviews, and standardization activities. He was the author of the structural analysis & design program GEPARD (= GEneral and PARametric Design), which was used by the Vítkovice company and by the universities as well (Fig.5.2).




**Fig. 5.2 Logo of the GEPARD program**

In 1968 and 1970 he obtained main prizes in the competitions for a bridge in Znojmo and a bridge in Dubrovnik. Many times, he obtained the award for the best steel structure in Czechoslovakia (in 1981, 1990, 1994).

He frequently published his works in journals and conference proceedings.

Since 1993, he worked as an authorized construction engineer in private practice in the fields of statics and dynamics, engineering structures, and bridges. His activities extended beyond the borders of Slovakia (projects in the Czech Republic, Germany, Austria, France, Russia, Brazil, software development within the European CIMSTEEL 130 project, collaboration with foreign architects and investors in Slovakia). Additionally, he was involved in organizing professional life and creating construction legislation.

Throughout his professional career, he collaborated with universities, especially with the Department of Metal and Timber Structures at the Faculty of Civil Engineering, STU Bratislava. This collaboration included exercises, occasional lectures, lectures in postgraduate courses (on the topic of designing steel structures using plasticity theory), participation in state examination committees for final theses, reviewing diploma and doctoral theses, and serving on committees for dissertation defences.

From 2008 to 2013, he served as a visiting professor at the Department of Metal and Timber Structures. He was very willing to participate, for example, in a series of semester-long lectures organized by the Department for regular students in the 2nd, 3rd, 4th, and 5th years. These were supplementary lectures outside the official study program to expand students' knowledge and engage them in the field of steel structures. Ing. Mikuláš Martinček, PhD. also lectured in a series of lectures for all doctoral students at STU in Bratislava.

In addition to STU Bratislava, he also lectured at the Czech Technical University in Prague, the Technical University of Košice, and the University of Žilina. He frequently collaborated with department staff on standardization activities (as a member of TK 4 at SÚTN) and on professional events.

His long-term professional work and projects of notable buildings were recognized by SSOK (Slovak Society for Steel Structures), STU Bratislava, and the Slovak Academy of Sciences with the award of the Professor Arpád Tesár's Prize for 2003.

In November 2024 we said farewell to this outstanding expert in the field of steel structures, Ing. Mikuláš Martinček, PhD. He lived to be 82 years old.

With the passing of Ing. Mikuláš Martinček, PhD., our professional community lost a great expert with extensive practical experience in both Slovakia and abroad in the field of designing and researching various types of steel structures.

Martinček advised the students to explore and use MATLAB software. He also prepared several MATLAB projects for them, including fire design of structures. Additionally, he encouraged them to always be prepared for collaboration with colleagues.

Martinček's life motto was: "The goal of an engineer is not the calculation, but to achieve a safe structure in good construction!"

In his youth, he was a mischievous boy like most boys. Miki set himself always the highest goals. A promising career in top basketball was interrupted by an injury. Miki loved his wife Marienka, who died 2 years ago. They often went on bicycle tours together along the picturesque Danube River, near which they lived in a family house. One of his last emails: "Hi Ivan, We are going for our last walk with the dog on our street at 11:30 PM. And yesterday there was a beautiful big moon. We are enjoying the last nice sunny days on our bikes. At the pre-lunch beer at 12:00 we are already alone in the restaurant Mini Vyza, they will probably close there too. So I am diligently collecting leaves from our big tree. Destroying nature is starting to be difficult for me. We have already chipped ourselves with all possible doses (flu, corona…) and in a while we will be barricaded again until spring, so let's die healthy now". He worked until his last days. His project, to modify the GEPARD program so that it could be used also on a tablet in 20 languages, was not fully completed.

A selection of various structures that Martinček participated in designing and on which his GEPARD roamed:



**Fig. 5.3 Apollo bridge over the Danube river in Bratislava. Continuous beam has spans: 47.5 m + 231 m + 63 m + 2 x 61 m + 51 m = 514.5 m. (Courtesy of Miroslav Maťaščík, Alfa 04, Inc.)**



**Fig. 5.4 Pipeline bridge over the Váh River in Hlohovec. Flooding of the main span with a weight of 200 tons. Pontoons with a grid of 17 m x 22.5 m for a pressure of 100 tons. (Courtesy of Martinček's archive).**



**Fig. 5.5 Superstructure of the Parliament building in Prague, 60 m x 85 m on 6 pillars. (Courtesy of Martinček's archive).**



**Fig. 5.6 Atrium of the National Bank of Slovakia building in Bratislava, 22.5 m x 67.5 m, module 22.5 m x 7.5 m. (Courtesy of Martinček's archive).**

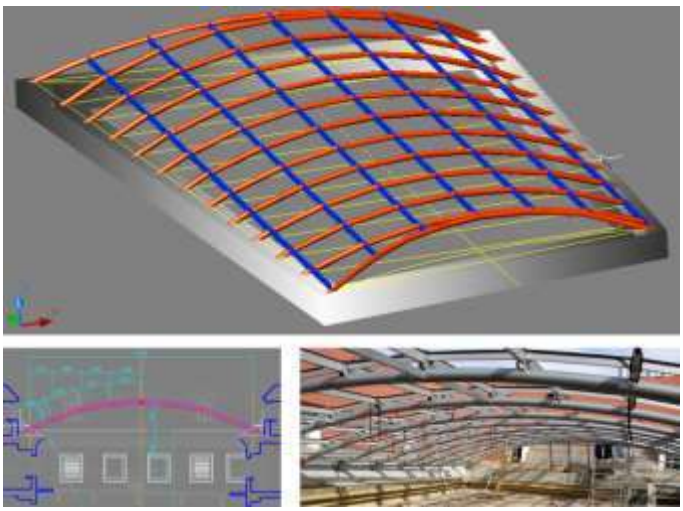


**Fig. 5.7 Atrium of the Comenius University in Bratislava, 25 m x 15 m. (Courtesy of Martinček's archive).**



**Fig. 5.8 Tatra Bank in Bratislava. Roof projection of 4.5 m and 9 m, length 105 m. (Courtesy of Martinček's archive).**



**Fig. 5.9 Football stadium in Detva. Stand for 2,000 spectators, 84 m x 31 m, cantilever 22 m. (Courtesy of Martinček's archive).**

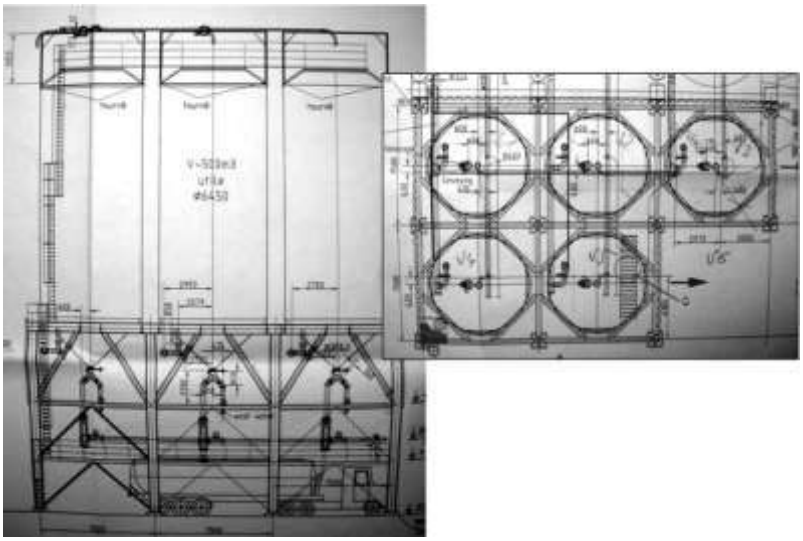


**Fig. 5.10 Structures under silos: Atofina at Carling, France; Figueira, Brazil; Penzlin, Germany. (Courtesy of Martinček's archive).**



**Fig. 5.11 TV guyed mast, Kráľova hoľa. Heigth 43 m + 67 m + 20 m = 130 m. Diameter of the tube 2 m, diameter of the cabin 13 m. (Courtesy of Martinček's archive).**



**Fig. 5.12 TV tower Javorina. Heigth 135 m, bottom part 66.5 m, straddle 11 m, diameter of the middle tube Ø 2 m – to Ø 2.5 m. (Courtesy of Martinček's archive).**



**Fig. 5.13 Advertising totem pole. Height 22.5 m. (Courtesy of Martinček's archive).**

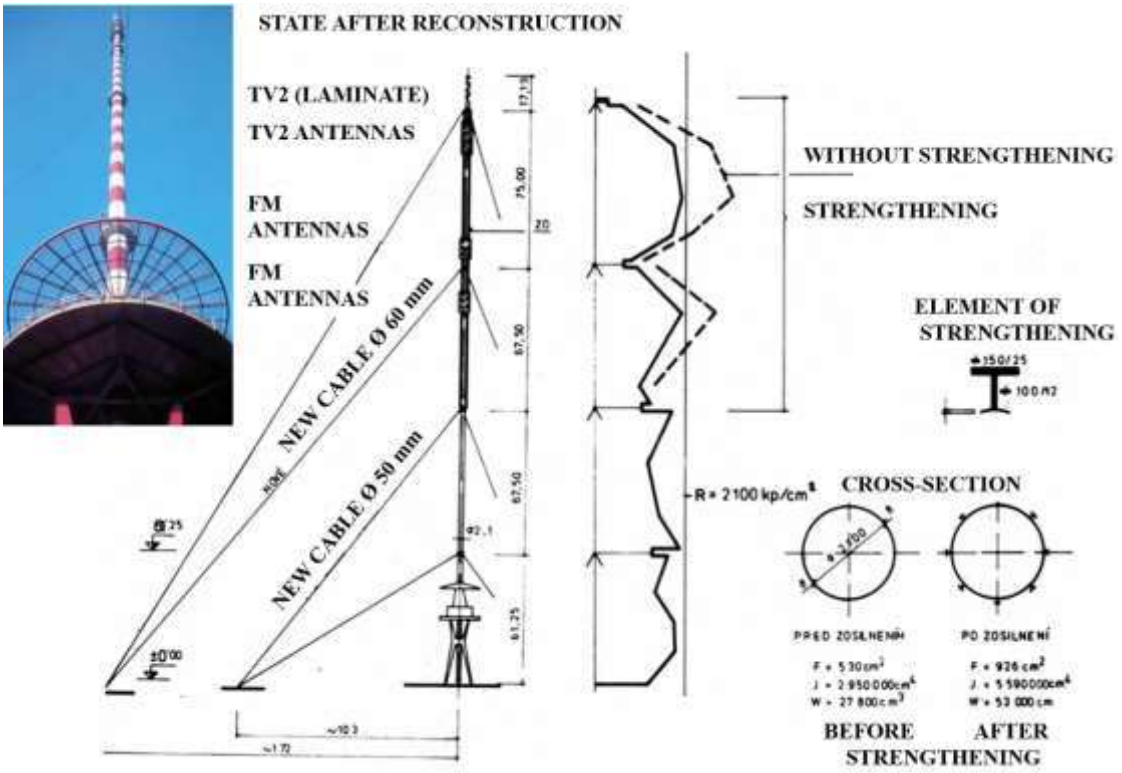



**Fig. 5.14 Reconstructions of TV guyed masts Dubník and Suchá hora. (Courtesy of Martinček's archive).**

## 6. Ing. Anton Bezák, CSc., visiting prof. (By Bezák, I., the son)

Ing. Anton Bezák, PhD. was born in a small village near Topoľčany in 1953. He graduated with honours in 1979 from the Faculty of Civil Engineering, Slovak Technical University in Bratislava. From 1979 to 1990, he worked in the design and construction branch of VÍTKOVICE - Bratislava as a designer of steel structures and later as Head of the Department for Bridges and Masts. In 1990, he co-founded the company Ingsteel s.r.o., which is focused on the design, production, and assembly of steel, stainless steel, and aluminium structures and currently belongs to one of the largest companies in the Slovak Republic in the field with an annual turnover of about 50.0 million €.



**Fig. 6.1 Anton Bezák (28.03. 1953, Nadlice – 19.10. 2015, Bratislava)**

In 1990 he defended his PhD thesis on "Analysis of design of anchored masts" at the Faculty of Civil Engineering in Bratislava. In 36 years of work Ing. Anton Bezák, PhD., has accumulated great experience in the field of design and research of steel structures, especially in the field of design of towers and masts. In summary:

- Lead designer and collaborator on completed projects (67), expert and forensic expert opinions (17), competitions (6),
- Co-author of six research tasks, three project studies
- Publications in the field of realization and theory of design of steel structures in journals and domestic and foreign conference proceedings (6+18).

He co-designed the RS Mělník, the 150.0 m high radio tower, the anchored mast of the RKS Dubník with a height of 306.0 m (Fig. 6.2), and the Television Tower Prague-City with a height of 216.0 m (the towers of the Žiškovský transmitter, (Fig. 6.3 and Fig. 6.4).



**Fig. 6.2 View of RKS Dubník**



**Fig. 6.3 Žižkov Television Tower under construction**



**Fig. 6.4. Žižkov TV Tower completed**

Anton Bezák served two periods as a visiting professor at the Department of Metal and Timber Structures. He gave lectures to regular student and PhD students as well. The Department of Metal and Timber Structures offered voluntary lectures by prominent experts from practice to students of all grades. One of them was Bezák, who also introduced students to the functioning of a large company that he led. Excursions to completed structures, including those structures realised by Ingsteel, were organized for students too. Bezák offered the Department topics for bachelor, diploma and doctoral theses from real life. Many students had the opportunity to visit the Ingsteel company and see with their own eyes how steel and aluminium structures are designed and manufactured. Several of the former students are now successful structural designers at Ingsteel. Bezák did not forget his alma mater and designed and realized: a) the internal structure of the library of the Faculty of Civil Engineering and, b) the new facade of the high-rise faculty building.

He is the recipient of many important awards. The most important awards:

- The Plaque of Academician Havelka, the Award on the occasion of his jubilee for many years of teaching and scientific research cooperation in the field of steel structures, 2003, Faculty of Civil Engineering, STU in Bratislava,
- The Award of Prof. Arpád Tesár for significant contribution in the field of development of steel structures, 2012. Slovak Association of Steel Construction (SASC, SSOK).
- The Award of The Ministry of Economy and the Ministry of Labor, Social Affairs, and Family of the Slovak Republic for the Honorary Recognition for Entrepreneurship in 2011.
- The President of the Slovak Republic awarded him the high state decoration "Order of Ľudovít Štúr II Class" for his significant contribution to the economy and for maintaining employment in the Slovak Republic in difficult economic conditions;
- Ingsteel won the 1st prize in the competition for the best realized building with steel structure in the Czech Republic and Slovakia "Winter Stadium (Fig. 6.5 and Fig. 6.6), in the period 2009 - 2012 under his leadership.




**Fig. 6.5 Ice Hockey stadium in Bratislava under construction**




**Fig. 6.6 Ice Hockey stadium in Bratislava completed**

The most important constructions realized are the multifunctional hall of Poprad Arena (Fig. 6.7 and Fig. 6.8), and the INGSTEEL headquarters were designed as a concrete-steel composite structure (Fig. 6.9), Cycle-bridge Devínska Nová Ves - Schlosshof, with a main span of 120m (Fig. 6.10).




**Fig. 6.7 Poprad Aréna**



**Fig. 6.8 Poprad Aréna – view of roof structures**



**Fig. 6.9 Headquaters INGSTEEL**



**Fig. 6.10 Cycle -bridge Devínska Nová Ves – Schlosshof**

Anton Bezák was a typical example of a Self-Made Man. Everything he created and acquired was achieved by his own work, perseverance, and study, without any help from others. His life path and achievements can be an example for today's young generation. His life motto was "Let´s be polite," which expresses his sense of justice, conscientiousness, and diligence.

## 7. Memories of Prof. Doncho Partov on Ing. Ján Bustin, CSc.

Ján Bustin was the reviewer of the diploma thesis of Doncho Partov, a future engineer and graduate from the Department of Steel Structures and Bridges at the Faculty of Civil Engineering, Brno University of Technology, in August 1969.

I first contacted Ing. Ján Bustin by phone in the summer of 1969. I graduated from the Department of Steel Structures and Bridges at Brno Polytechnic, where I studied from 1964 to 1969. My thesis supervisor, Prof. Dr. Ing. Jiří Bureš, had assigned me a thesis on a railway bridge with a composite steel-concrete structure. He advised me to get in touch with Ing. Ján Bustin in Bratislava to coordinate the review of my thesis. I called Ing. Ján Bustin, and we arranged to meet at his office in Bratislava. This meeting, as I later realized, significantly influenced my future development as a bridge construction specialist in Sofia. In particular, it helped me understand the challenges of addressing the effects of creep and shrinkage of concrete on the stressed and deformed state of composite steel-concrete structures over time.

Ing. Ján Bustin, who had co-authored a book on this topic [12], kindly gave me a copy as a gift.

His review of my diploma thesis, which I presented to him at our next meeting, was very positive. He praised the comparisons I had made between the technical and economic indicators of the bridge of the composite structure and a pure steel structure - an analysis I had not been required to include. I was very pleased to have had the opportunity to meet such a knowledgeable and skilled young specialist in the field of steel bridges. Prof. Bureš, emphasizing Ing. Bustin's professional qualities, did not hide his admiration for his design achievements (some of which are featured in this publication).

In the book on composite steel-concrete structures, the issue of stress transfer from concrete to steel due to concrete creep was addressed using an inhomogeneous system of second-order differential equations, which was quite innovative for that time. My research delved into a more complex area of mathematical theory, specifically Volterra's integral equations of the second kind. Deep down, I realized that, despite the fundamental differences between the two approaches, the physical essence of the problem remained the same, regardless of the mathematical language used to explain it. I understood this essence through Ing. Bustin's reasoning. Since then I have reread his book many times, and I

remain deeply grateful for the opportunity to have met such a remarkable man during my formative years as a civil engineer.

## 8. Ing. Martin Môťovský (By Baláž, I.)

Môťovský graduated from SVŠT in 1956. His classmates included were among others: Bohumil Búci (Prof. Ing. CSc. at FCE STU) (04.10.1931 – 08.08.1998), Svetozár Lichardus (Ing. DrSc. at ÚSTARCH SAV) (19.05.1932 – 27.10.2020), Bartolomej Šechný (Ing. director at DOPRAVOPROJEKT Bratislava), Ivan Zapletal (Prof. Ing. DrSc. at FCE STU), born in 25.03.1932.

Ing. Môťovský is another renowned structural engineer. He worked at ŠÚDOP Bratislava, he later founded together with other colleagues the company PRODEX spol. s r.o. in 1991. He worked there (he was a partner) according to the commercial register until 2009. Today, this company has been taken over by Valbek SK, spol. s r. o.

Ing. Môťovský is author of several steel structures. See for example the unique railway bridge from 1973 on Fig. 8.1. He is together with Ivan Baláž co-author of the study of the influence of openings in the lower flange and in transverse diaphragms on the stresses of a trapezoidal-shaped box-girder of direct loaded steel railway bridge with a span L = 31.2 m on the track Marchegg-Szob for the needs of reconstruction. See [17] from 1988.

Fields 3 to 8 have box girders of trapezoidal shape with a span of L = 31.2 m, fields 9 to 14 have truss girders with L = 30.56 m. Fully welded box girders are statically designed as simple beams. The structures made of steel of strength class 37 were designed by ŠÚDOP (Štátny Ústav Dopravného Projektovania), Bratislava, manufactured by Lískovec bridge factory, welding of parts in Trnovec nad Váhom railway station was carried out by Hutní montáže Ostrava and inserted into the bridge structure by Mostný obvod Bratislava.

The width of compressed upper flange is 2 m, its thickness is t = 28 mm. The upper flange has 4 longitudinal stiffeners 174 / 14 mm. The width of bottom flange in tension is 2,8 m, its thickness is t = 25 mm. The height of box girder is 2,605 m. The upper flange has a roof-like slope of 2% on each side. See Fig. 8.2.



**Fig. 8.1 Reconstruction of the bridge in Trnovec nad Váhom, žkm 117.478. The original steel bridge spans from 1897 were replaced with new ones in 1973/74. Author of the project: Ing. Martin Môťovský. The railway bridge used box girders for the first time in Slovakia. With the length 445,8 m it was the longest railway bridge in Slovakia.**



**Fig. 8.2 Monitoring of the railway bridge on the line TU 2804 Devínska Nová Ves — Štúrovo št. hr., DU 18 Šaľa — Trnovec nad Váhom at žkm 117.748.**



**Fig. 8.3 Replacing of old railway bridge in žkm 122.912 in Trenčín over Váh river in 1984. General designer of the structure: Ing. Martin Môťovský, ŠUDOP Bratislava. Project of steel bridge structure: Ing. Emil Rusko, VSŽ Košice [18].**

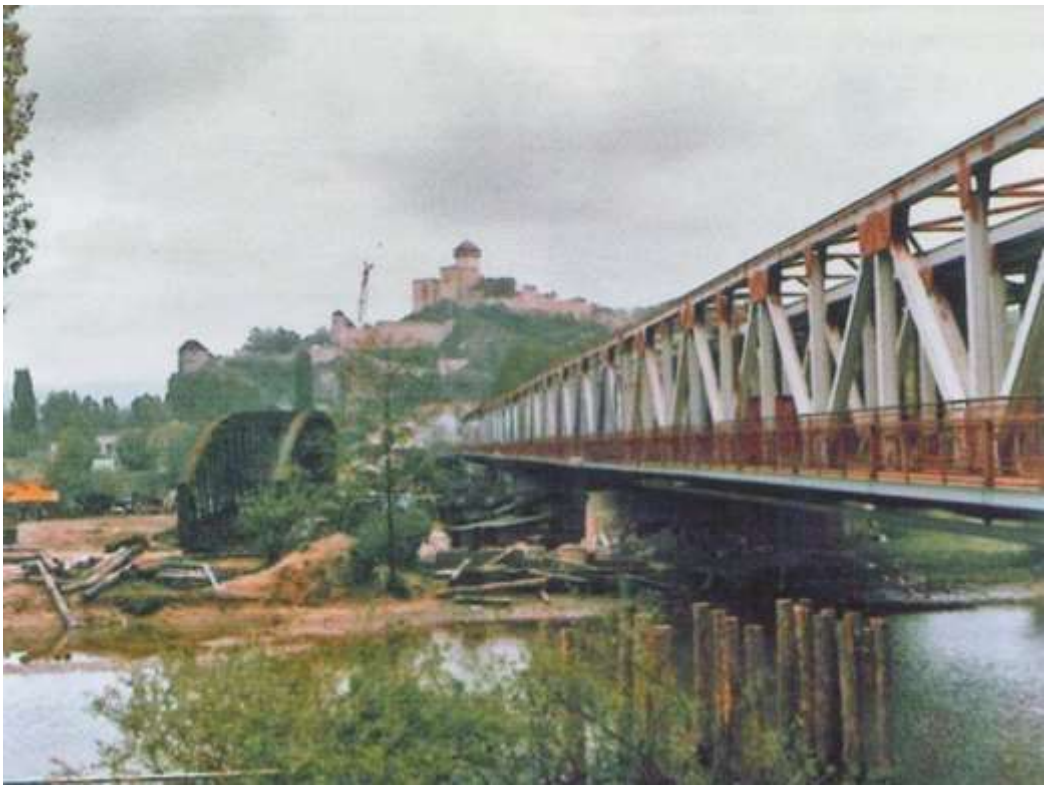
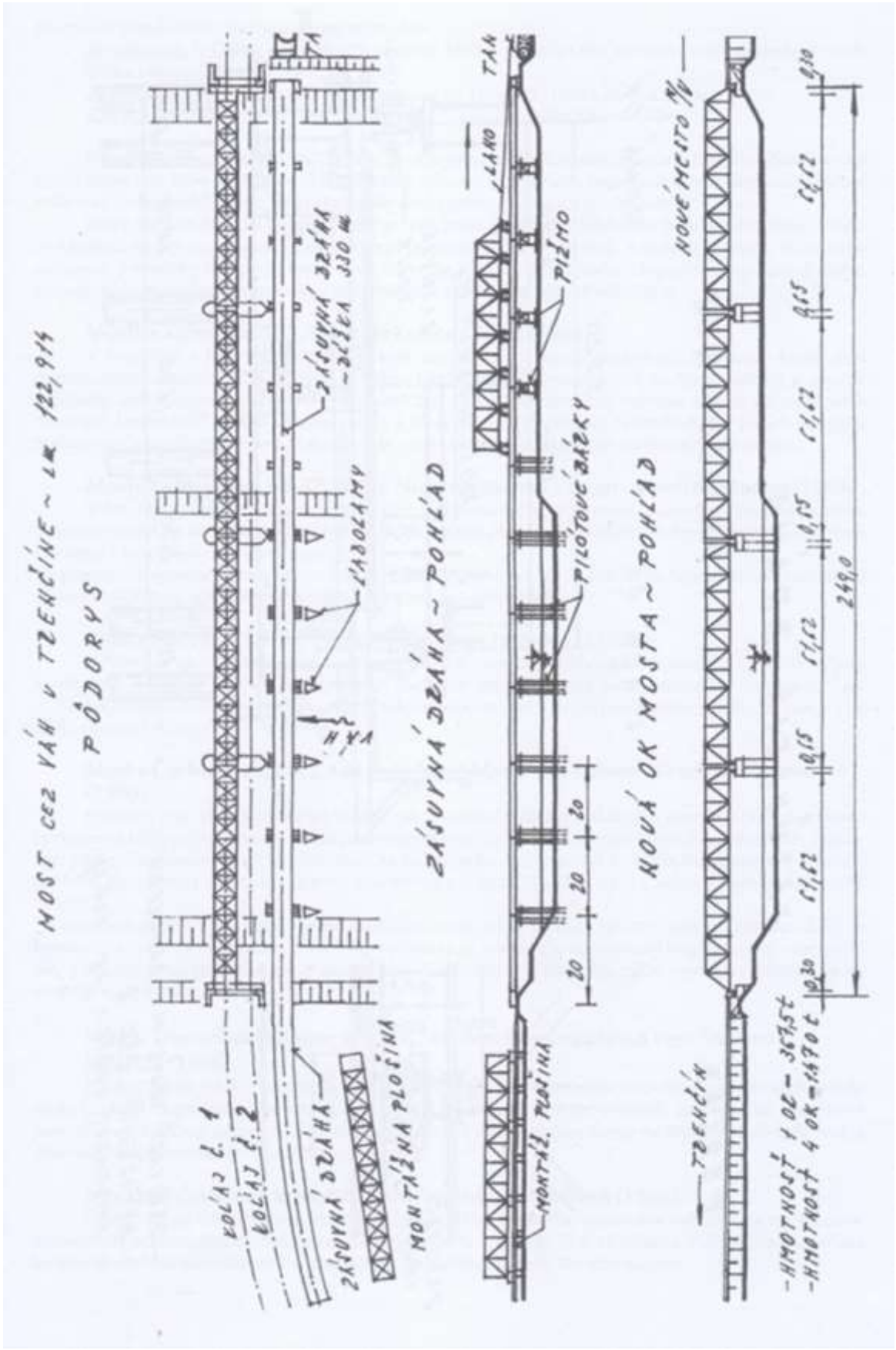


**Fig. 8.4 Finished new steel railway bridge in Trenčín over Váh river in 1984. Four spans of 61,60 m each. The overall bridge length 249 m [18].**



**Fig. 8.5 From the right: Ing. M. Môťovský, Prof. Ing. Eugen Chladný, CSc., Head of department, Ing. Jarmila Mesiariková – Čierna, CSc., specialist for design of timber structures, a member of department at exhibition of the foreign books and codes collected by Department of metal and timber structures, FCE STU in 1991.**




**Fig, 8.6 Erection of the new railway bridge in Trenčín over Váh river in 1984 [18].**

## Conclusion

This contribution is dedicated to five exceptional Slovak designers, primarily of structures, who are recognized by the entire Czechoslovak technical community as well as internationally: Juraj Kozák, Ján Bustin, Vojtech Behul, Mikuláš Martinček and Anton Bezák. Information about another prominent Slovak designer of steel and timber structures, Magnificent No.6: Ing. Josef Poštulka (06.01.1923, Česká Třebová – 05.03.2009, Bratislava), can be found in [4]. Dr. Ivan Viest can be considered as Magnificent No.7 [16]. In addition to their extraordinary professional ability, they are all characterized by unusual modesty.

Several renowned Czech and Slovak professors, also active in the design of steel structures and bridges are discussed in [5] and [6] along with their works.

The Abstract, Introduction, Chapter 8., Conclusion and Acknowledgement were written by Prof. Ing. Ivan Baláž, PhD., emeritus Professor at Faculty of Civil Engineering, STU in Bratislava.

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All those interviewed from the technical community, not only from Slovak one, as well as former collaborators, highly valued their colleagues described in this article and were happy to contribute with their memories and documents. In addition to several unnamed people, they were: Ing. Bočkay, Ing. Daniš, Ing. Jágerský, Ing. Nagy, Ing. Šimun, Ing. Tužinčin. The authors would like to thank them for their time and willingness. The authors would like to express their gratitude also to Dr.h.c. Prof. Ing. Doncho Partov, PhD., from University of Structural Engineering and Architecture Lyuben Karavelov in Sofia, Bulgaria, for his contribution and support.

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# CHURCH NO.2 AT KOKALYANSKI URVICH - ANALYSIS AND INTERPRETATION OF THE ARCHITECTURAL ELEMENTS

***D-r Filip Petrunov***[1]

***Abstract:*** *Church No.2 in the citadel of Kokalyanski Urvich was built in the early 14th c. and functioned until the end of that century, when it was eventually abandoned. At that time, the late medieval monastery around the Church of St. Elijah the Prophet was founded at the foot of the citadel. Church No.2, located in the citadel of Kokalyanski Urvich, is one of the single-aisle churches with a pitched roof typical for southwestern Bulgaria during the 12th–14th centuries. In the early years it functioned as a parish church for the inhabitants of the citadel, and it was presumably converted into a commemorative church for the rulers of Urvich in the mid-14th c. According to its specific architectural design it should be referred to the tomb-churches but featuring not vertical but horizontal arch-shaped markings in the pavement. In the second construction stage of the church, arches were added in the ceramic pavement, and in the third construction stage a narthex was added on the west. The few mural fragments and especially those found on the west give grounds to date the church to the 14th c. and to ascertain that its patron saint was St. Nicholas the Wonderworker, Bishop of Myrlica.*

***Key words****: Bulgarian lands, Kokalyanski Urvich, tomb-church, 14th century.*

Church No. 2 is in the citadel of Kokalyanski Urvich, located on the western hill of Urvich of the Sredobordie. The Sredobordie consists of two hills known as Urvich; they are on the right bank of the Iskar River among the Vitosha, Lozen and Plana Mountains. The road from Sofia to Samokov, laid by construction units in the period 1900-1912, also runs along the river. This was the first automobile road in Bulgaria after the Liberation. Today the site falls within the land of the village of Kokalyane, Pancharevo District, Sofia Municipality (Fig.1). The excavations of the citadel and Church No. 2 at Kokalyanski Urvich began in 2022, under a project of the National Museum of History, funded by the Culture Program of Sofia city.

The data collected on Church No. 2 at Kokalyanski Urvich during the excavations in 2022, 2023 and 2024, shed new light on the life in the medieval fortress and reveal its specific features and function (Fig.2).

During the 2023 excavations hundreds of fragments of mural paintings were found, unfortunately in a rather damaged condition, as the church had been subjected at least twice to damaging digging. There are documented interventions from the 15$^{th}$–16$^{th}$ and 20$^{th}$ centuries.

In 2024, the areas north and south of the church were examined, and boreholes were drilled inside the church, and west and east of it. This paper focuses on the obtained data regarding the function of the facility and its dating.

**Function.** Church No. 2, located in the citadel of Kokalyanski Urvich, is a single-aisle church with a pitched roof from the 12$^{th}$–14$^{th}$ centuries, typical for southwestern Bulgaria. Z. Korkutova summarized and described this type of churches in detail in a

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dedicated study published in 2013 (Коркутова, 2013). The study covers 81 churches, and 47 of these churches were also subject to archaeological investigations and/or surveys relating to their reconstruction and fortification. Based on the data collected, Korkutova identified five types of churches in terms of their function. An interesting detail that came out during the excavations of Church No. 2 is that it was initially built as a family church (parish church) in the citadel and was eventually adapted as a mortuary/commemorative church. The "mausoleums" in question are described by the author as chapels; however, Church No. 2 at Kokalyanski Urvich has the characteristics of a functional church, which makes it belong to the "tomb-church" type, also common during the Second Bulgarian Kingdom. Similar churches have been found most notably in Veliko Tarnovo, Asenovgrad and in other strategic strongholds in the Tarnovo Kingdom.

Yordan Alexiev has undoubtedly contributed to the study and interpretation of burial practices and the representative graves from the period of the Second Bulgarian Kingdom (Алексиев 2009, 271-282). In his work on medieval tomb-churches, he not only presented this type of monuments from Veliko Tarnovo, but also offered a thorough review of the published research. At the very beginning of his study, Alexiev referred to Andrey Grabar (Грабар 1982, 38-52) and provided evidence for two types of burial practices. One of them has its origins in Asian culture and has to do with the special place of the deceased in the church, under the arcosolia. The other has its origins in ancient Greco-Eastern monuments and is better attested at the elite graves of the 13$^{th}$–14$^{th}$ centuries in the present-day Bulgarian territory and especially in Veliko Tarnovo. These are the royal tombs on the hill of Tsarevets and the Church of the Holy Forty Martyrs. Thus, along with these tomb-churches, three variations of elitist burial practices can be noticed. Firstly, in niches, secondly in sarcophagi and masonry graves, and thirdly in tomb-churches.

At this point we need to dwell on the arcosolia (Latin *arcus* - arc and *solium* - grave, sarcophagus, throne). They are arch-shaped niches under which sarcophagi were placed in early Christian and medieval times. They are to be found in churches and catacombs. Traditionally, in such niches stone sarcophagi for people of noble origin or reliquaries for the mortal remains of saints were placed. Arcosolia are not the most common architectural solution for burial practices in medieval Bulgaria, however the data, though limited in scope, point to an example from present-day Turkey. In his new monograph of 2020, Emmanuel Mutafov brings together all that has been published about the Chora Monastery in Constantinople (Istanbul). He also offers a comprehensive survey of the inscriptions in the church and their interpretation, an analysis of the construction periods, and an overview of the historical, artistic, spiritual, and prosopographical context in which the monument functioned, especially during the time of the Palaeologus family. An important point in his work is that descendants of Irina Asenina, i.e., representatives of the Palaeologus and Asen dynasties, and more precisely of Ivan Asen III, might have been buried under the arcosolia in the chapel (Мутафов 2020, 121-140). This makes the example one of the few representative ones, even though it is not from the present-day territory of Bulgaria. Unfortunately, these examples are far too few, so it is also worth considering what has survived in the Boyana Church. The latest publication, which provides a comprehensive account of this monument, is the result of the joint work carried out by Mariela Inkova and Metodi Zlatkov (Златков, Инкова 2019, 120-145). Despite the thorough review of the research so far and some quite interesting and well-founded arguments at the end of the publication, the two authors nonetheless do not find any kind of connection between the unearthed graves and Altimir, the son of Vitomir, depicted in the acrosolium in the Church of Sts. Nicholas and Panteleimon. Another grave shaped in a similar fashion is attested in the excavations of Prof. Mutsopoulos in the Basilica of St. Achilles, where four stone tombs were uncovered, aligned one after another along the inner face of the south wall

(Муцопулос 2007, 137-175). The third tomb, above which there is an acrosolium, is made of whole marble slabs. According to Moutsopoulos, Tsar Samuil was buried in it (Овчаров, 1996, 306-311). Chokoev indirectly confirmed this finding by analyzing textile items from the Middle Ages (Чокоев 2018, 313-327; Чокоев 2021, 34). The above example is earlier, yet it is quite conceivable that this tradition was also followed during the Second Bulgarian Kingdom. Alexiev, in his already mentioned work on medieval tomb-churches, also refers to two-storey tomb-churches, where the upper floor is a chapel and the lower floor is a crypt (Алексиев 2009, 271-282). During the analysis of church architecture, a group of "two-storey" churches was identified. One of them is Church No.10, which is located on the hill of Tsarevets near the western fortification wall, close to the Small Gate. It is one of the most interesting churches of its kind and the only one of the group under consideration on the hill of Tsarevets. The church proper is a cruciform building of the compact cross type. The lower floor replicates the plan of the upper level. There is a semicircular apse on the east, and it is adjoined to the inner face of the fortification wall on the west. The lower level, once referred to as a crypt, is where the author describes three walled graves. A tomb-church, or rather an ossuary, has also been unearthed in the north-west corner of the monastery courtyard at the "Execution Rock", near the North Gate. It has an elongated rectangular plan. Its walls have deep foundations, and the western wall is adjoined to the inner face of the fortification wall. Roughly at 1 m above the floor level of the crypt, traces of wooden beams of solid timber can be noticed. The eastern part of the crypt chapel was destroyed for a later household kiln, but there is no evidence of a representative walled grave there, automatically making it a different type of monument. A similar ossuary was identified at the Church of the Holy Forty Martyrs. It was built as an open narthex to the church, in order to reinforce the western facade of the church, compensating for the denivelation. It was later converted into a mausoleum tomb (Вълов 1974, 37-54). Alexiev also noted three tomb-churches on the hill of Trapezitsa, No.2, No.7 and No.14 (Алексиев 2009, 277). Church No. 2 is in the northeastern part of the fortress, and its eastern part (the apses) overlap the course of the fortification wall. It was built on a very steep slope from west to east and from north to south. It was unearthed during the first excavations of Dr. Vasil Beron. According to his records, the images of the saints were preserved up to the chest. While excavating the nave (the middle compartment, according to Beron) on: "...the right side we saw a large stone, and digging under it we found a fairly large tomb (catacomb) with separate stone walls, and when the whole tomb was uncovered it proved to be two and a half metres deep, two metres wide and six metres long. At a depth of 2 metres, we found up to 6 skulls" (Берон 2004, 19-20). Dr. Beron assumed that "in all likelihood, the just localised church must be dedicated to Sts. Peter and Paul, the Apostles, and that the tomb found in it must be meant not only for the relics of St. Gabriel of Lesnovo, but also for the members of the royal family" (Берон 2004, 84). To this type of monuments Alexiev also refers Church No.14, located in the southeastern part of the fortress, near the fortification wall, on a very steep slope in the north-south direction, i.e., perpendicular to the longitudinal axis of the church (Алексиев 2009, 279). It was unearthed in 1900 by a French treasure hunter whose results remain unpublished to this day. V. Dimov described it and provided its plan. According to him, "...what this church stands out with is its strict regularity, the precise workmanship, and the good building materials. Its walls are made of hewn stone and pure mortar, and the lower end is made of straight rectangular blocks (of bigor)". It has "four compartments: an altar, church proper, and two narthexes" (Димов 1915, 156). It measures internally: length -15 m and width - 4,50 m. N. Mavrodinov also commented on Church No. 14. First of all, he noted that two periods could be made out clearly in the plan of the church - the second narthex (exonarthex) was added later. According to him, Dimov had not shown in his plan the two periods and the plinth of the apse. The original west façade, according to Mavrodinov, was

decorated like any other church on the hill of Trapezitsa, namely with two pseudo niches on either side of the entrance and a third one above it, which must have been in the middle (Мавродинов 1931, 29). Church No. 14 was also cleared, along with all the churches on the hill of Trapezitsa in 1990. L. Quinto published her observations in a separate article (Квинто 1992, 138-145). During the clearing, she found chunks of hydrophobic mortar near the bigor blocks wall. Quinto assumed that the plaster had been brought from the water-tank near the north wall of Church No. 8, which is at a considerable distance from Church No. 14. To carry construction materials over such a long distance seems to run counter to common sense. Quinto admits another alternative: "...it is not unlikely, however, that there might have also been a water tank in the large Church No. 14, with a north-south denivelation of over two metres, bridged perhaps by vaults. The church is near the fortification wall and the southern slope to the Yantra River, the terrain is gently sloping, and the place is suitable to construct a water-tank to be supplied with water from the river" (Квинто 1992, 143). Alexiev, on the other hand, disagrees with the proposed interpretation, pointing to the bigor blocks. According to him, burial chambers were formed in the basement. Another important point that he noted is the low southern half of the church, which was used wisely to make burial chambers. We have already observed a similar situation at the hill of Trapezitsa in Church No.2. Apart from the similar architectural design of the two churches, there are also similar elements in the fresco decoration. In both "royal images" have been uncovered (Алексиев 2009, 281).

Undoubtedly, Church No.2 at Kokalyane Urvich coincides absolutely precisely with Church No. 2 at the hill of Trapezitsa, as we can see in terms of the slope of the site, its location in the fortification, and in the way the graves were shaped - by cutting and shoring. An interesting additional point is also the similar material found, namely a ring with a double-headed eagle, which, however, will be dealt with in a separate publication, since this paper focuses mainly on the architecture of the monument.

An important conclusion can be drawn from what has been said so far. The architecture of Church № 2 in the citadel of Kokalyanski Urvich is the single-aisle church design typical for southwestern Bulgaria in the 12$^{th}$–14$^{th}$ centuries.

**Localization and periodization.** Church No.2 is on the eastern slope, along the course of the citadel wall (Fig.3). It is built in the northern part of the fortified plateau, along the course of the citadel wall. No solid fortification wall has been recorded within its structure, like the one that stands out south and north of the Christian building. Nevertheless, it can be assumed that initially it was part of the overall design of the citadel complex, as a passageway was found to the south of it, adjoining a threshold for a single-wing door that opened to the east. The passageway and the partition to the south used to connect the church with the fortifications to the south. Assuming that the church and the whole complex were completed at the same time, and based on the conducted C14 radiocarbon dating, we have to accept 1173±23 as the earliest date of construction[2]. Considering the materials found in the levelling embankment of the church, largely spherical buttons, we have to assume that the earliest construction date must be in the late 13$^{th}$ or early 14$^{th}$ c. So far, no fortification wall has been found in the north, instead an adjacent workshop was localised, which is isolated with a thick drainage of small stones spread on the northern façade of the church. In this regard, we must assume that the two facilities (the church and the kiln) were used at the same time. Based on the mural decoration and the overall stratigraphic dating of Kokalyanski Urvich, Church No. 2 was no longer in use at the end of the 14$^{th}$ c. These observations were also substantiated by a

[2]The analysis is based on a sample of the fortification wall, studied by SUERC AMS, SUERC-127820 (GU68252), University of Glasgow in 2023.

radiocarbon dating of a second sample from the citadel, where the estimated age of charred wood was 1429± 24[3]. Thus, the dating of the examined monument falls within the 13th–14th c.

**Architectural features.** Initially, in terms of composition, the church had only a nave, and the narthex was added later adjoining the main structure of the church. With its dimensions of 4.90 x 8.55 m, it does not differ substantially from the typical dimensions of this type of building. As it is in a poor condition, the measures of the narthex can hardly be taken accurately, but it must have been 2-2.80 m long to the west and as wide as the main structure of the church. No clear indication of the flooring has survived in the altar area, which was damaged in the 15th–16th centuries, but it was presumably paved with stone slabs, which were found in a considerable number around the altar table. Stone slabs are laid around the entire circumference of the nave, thus framing the brick pavement. The pavement in the narthex of the church was also framed with stone slabs. The apse is semicircular on the outside and inside, and there is no documented plinth between the substructure and the superstructure. The foundation of the building follows the denivelation of the terrain from west to east and from north to south (Fig. 4). The altar table, unlike most published ones (Коркутова 2013, 12), has a stone base made of single-faced stones bonded with mortar and a round ceramic tablet 0.10 m thick. Unfortunately, not enough fragments have been documented to calculate its diameter, but it is unlikely to have been more than 0.60-0.80m given the narrow apsidal space and the depth of the altar niche of 0.96m. The naos is rectangular, its long side aligned to the east-west axis, and this is where the reconstruction carried out during the second construction phase is most clearly visible. The ceramic slabs are placed in a series of arches opening to the east, the largest of which falls in the southwestern part of the pavement and marks grave No. 7 from the necropolis of Church No.2. Grave No.7 occupies the western and central part of the southern sectoin of the nave pavement and was marked by bricks from pavement arranged like an arch, facing east. The bone remains, of a man 45-55 years of age, were placed at a depth of 0.70 m under the pavement, in a casket. To separate the burial pit, a second wall was built on the south, adjoined to the south wall of the church. It is made of three rows of hewn stones measuring up to 0.25x0.30 m and bonded with white mortar, resting on a 0.30 m substructure of coarse gravel. The mortar from the church building contains more impurities (sand and earth) in contrast to the three graves structurally connected to the church (Fig. 5), where the mortar is cleaner, of a better texture and bright white in colour. The rock from the west was also further carved to accommodate the casket. The dimensions of the arch markings formed in the pavement are approximately 0.80 along the north-south axis and 1m east-west. The other two arch-shaped markings, visible in the pavement, are in the southeast, preserved only partially, and one in the northwest measuring 0.20 by 0.40 m. No bone remains were found in them. In the nave, where a brick pavement was formed, the elevation was 724.36 m, while in the stone slab pavement in the narthex it was 724.81 m. The pavement in the naos also contains stone slabs. The pavement in the nave contains also stone slabs, these are documented on its outer frame, as well as on the start of the altar partition, 1.5m west of the altar table. In the narthex of the building, a clearly preserved stone slabs pavement is documented only in its northern part, where an arch-shaped marking measuring 1.20 E-W and 0.80 N-S is also formed. It marks grave No.9, dug into the mainland rock at a depth of 1.10 m under the pavement, with three flat stones below the level of the bone remains placed with the purpose to align the naturally sloping rock. A passageway is documented, formed on the west by slabs and individual ceramic tiles arranged tightly to form an arch. These were found in situ, broken

[3]The analysis is based on a sample from the citadel studied by SUERC AMS, SUERC-127820 (GU68252), University of Glasgow in 2023.

in the passageway (Fig. 6). The structure of the arch is typical of the 12th–14th centuries. The lighting in the church was probably only on the south side, as there was a workshop attached to the north. This observation is still only hypothetical, as the poor condition of the superstructure prevents further analysis. Church No. 2 was built of quarried stones, and individual whole and crushed bricks were found at some places, data recorded for most similar churches in the area during that period (Коркутова 2013, 14). In this regard, there are no particular differences and in general it can be concluded that Church No.2 at Kokalyane Urvich is a typical Eastern Orthodox building from the 12th–14th centuries with special features related to the tomb-churches of the Bulgarian aristocracy during the Second Bulgarian Kingdom. Externally, as well as under the roof space, the church was plastered with clay, and the drainage in the north reaches as high as up to 1.50 m, measured from the pavement level in the naos.

**Mural paintings.** Three fragments, preserved on the walls, measuring up to 0.10x0.30 m, were impregnated and dismantled. To the west of the passageway, a fragmented section of a mural was stabilized and taken to a laboratory. It consists of chequered squares in white and red (Fig. 7). Taking into consideration the place they were found, namely on the western side of the building, they can be attributed to the image of the patron of the church west of the passageway. Comparing the well-known Christian iconographic practices, one might presume that this is St. Nicholas the Wonderworker, Bishop of Myrlica, who is most often depicted wearing a polystavrion, a liturgical vestment consisting of multiple crosses represented by red and white squares. An interesting detail is that the contemporary church, situated on the eastern Urvich hill, which is directly visible from Church No.2, is dedicated to the Nativity of Saint Nicholas the Wonderworker. At this point it is worth noting that the deviation of the church, relative to the E-W axis, apart from the ardent veneration of the saint definitely manifested during the period, provides grounds to believe that the church had St. Nicholas, Bishop of Myrlica as a patron-saint. Based on the collected fresco fragments, to the west, on the pavement of the narthex, as well as the considerable deviation of the church to the south in relation to the E-W axis, and the preliminary dating determined by an artist-restorer, it is this particular saint who should be considered the patron saint of Church No. 2 dated to the 14th c.

**Conclusion:** Church No.2 in the citadel of Kokalyanski Urvich was built in the early 14th c. and functioned until the end of that century, when it was eventually abandoned. At that time, the late medieval monastery around the Church of St. Elijah the Prophet was founded at the foot of the citadel. Church No.2, located in the citadel of Kokalyanski Urvich, is one of the single-aisle churches with a pitched roof typical for southwestern Bulgaria during the 12th–14th centuries. In the early years it functioned as a parish church for the inhabitants of the citadel, and it was presumably converted into a commemorative church for the rulers of Urvich in the mid-14th c. According to its specific architectural design it should be referred to the tomb-churches but featuring not vertical but horizontal arch-shaped markings in the pavement. In the second construction stage of the church, arches were added in the ceramic pavement, and in the third construction stage a narthex was added on the west. The few mural fragments and especially those found on the west give grounds to date the church to the 14th c. and to ascertain that its patron saint was St. Nicholas the Wonderworker, Bishop of Myrlica.

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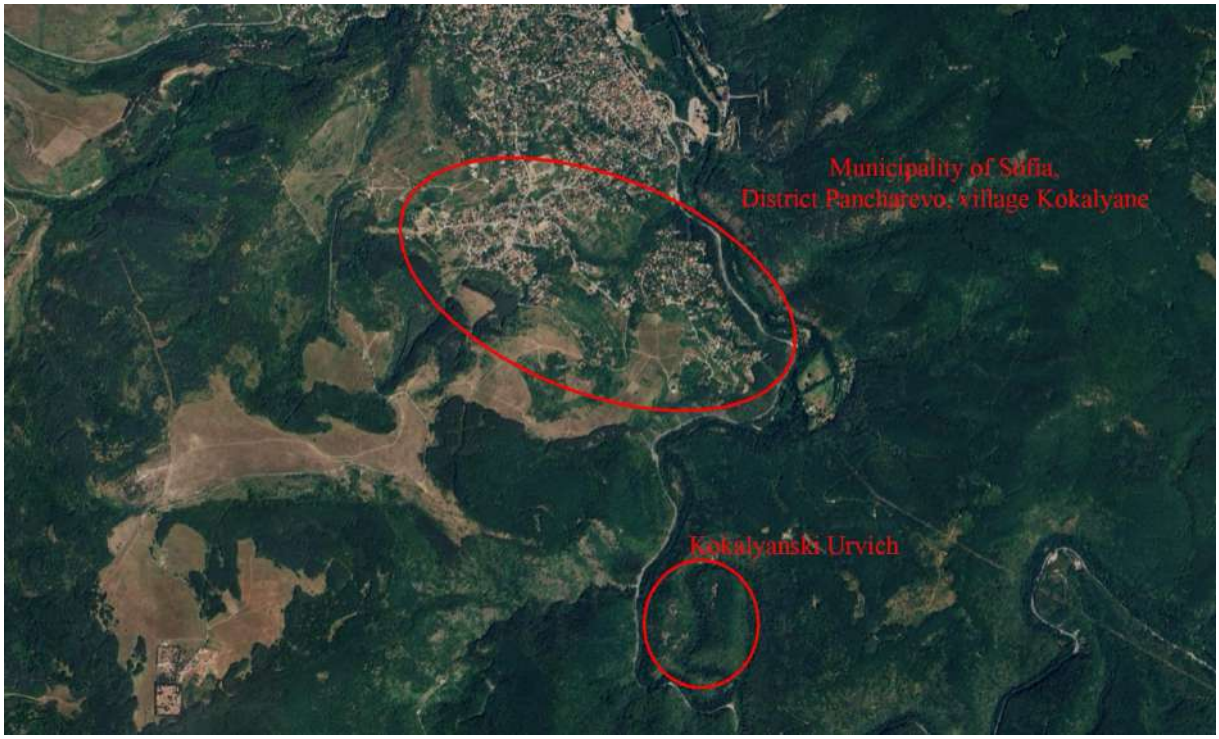



**Fig. 1 - Site location**



**Fig. 2 - Stage of archaeological research**

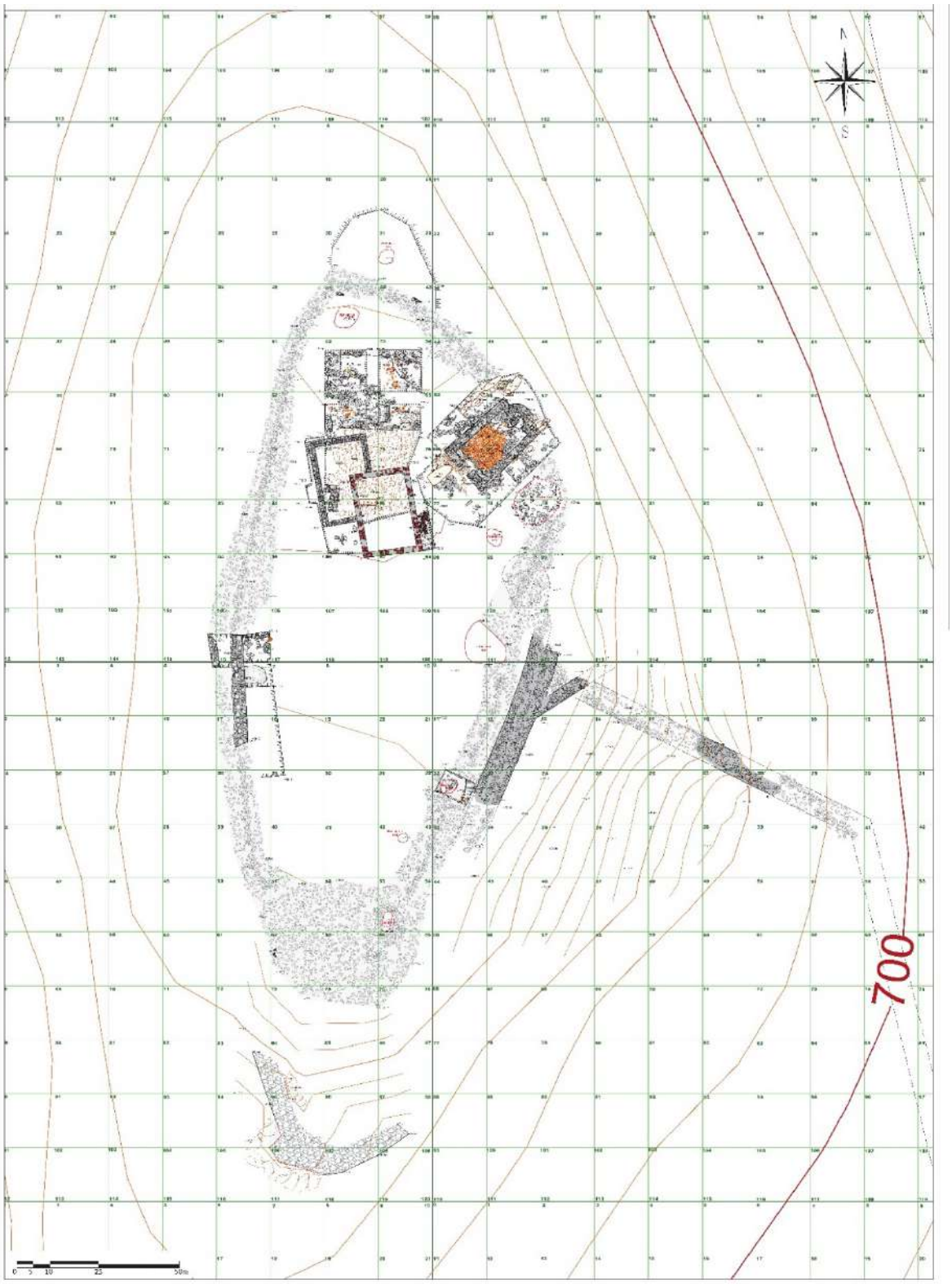



**Fig. 3 - General plan of the citadel**

**Coordinate system BGS2005 – cadastral, Altitude system – Baltic**

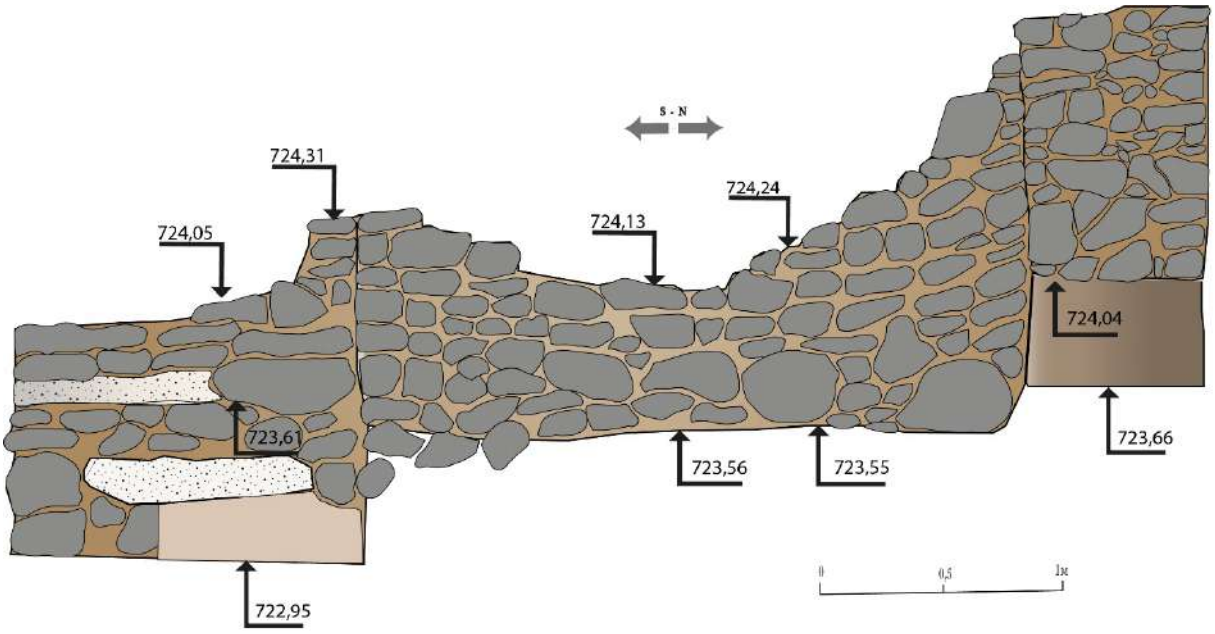



**Fig. 4 - Profile of Church No. 2 from the east.**

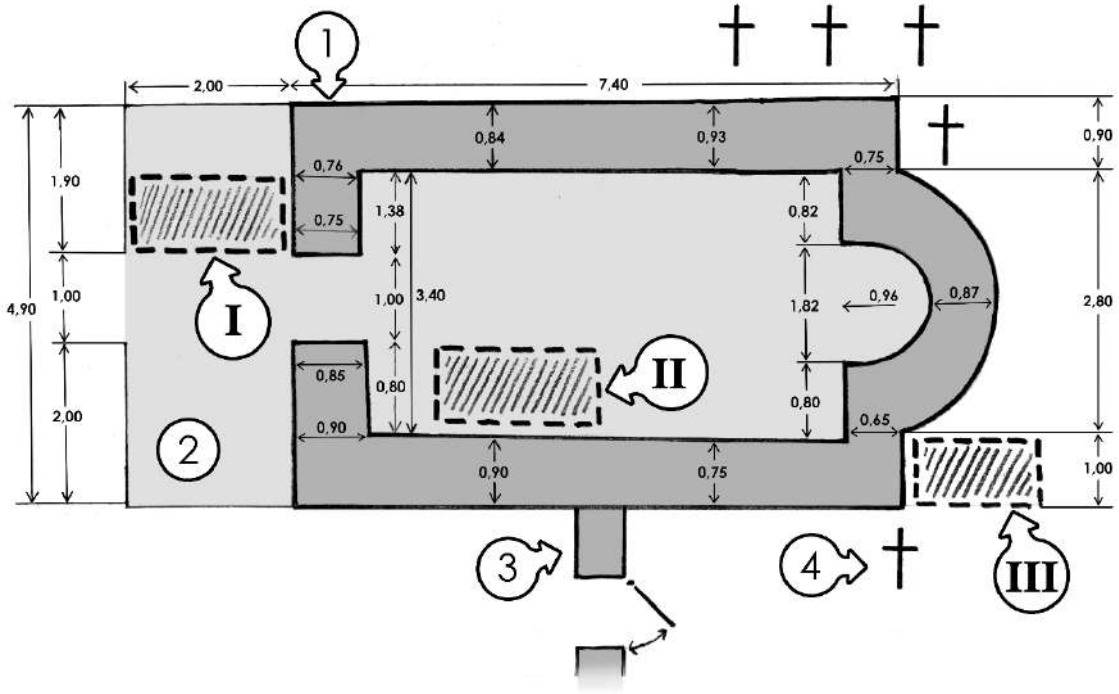



**Fig. 5 – Plan of Church No. 2; Legend: 1. Church No. 2 – St. Nicholas, Bishop of Myrlica. 2. Exonarthex – Gazebo. 3. Southern wall and passageway. 4. Necropolis – 14th century. I – Grave No. 9. II – Grave No. 7. III – Grave No. 11.**

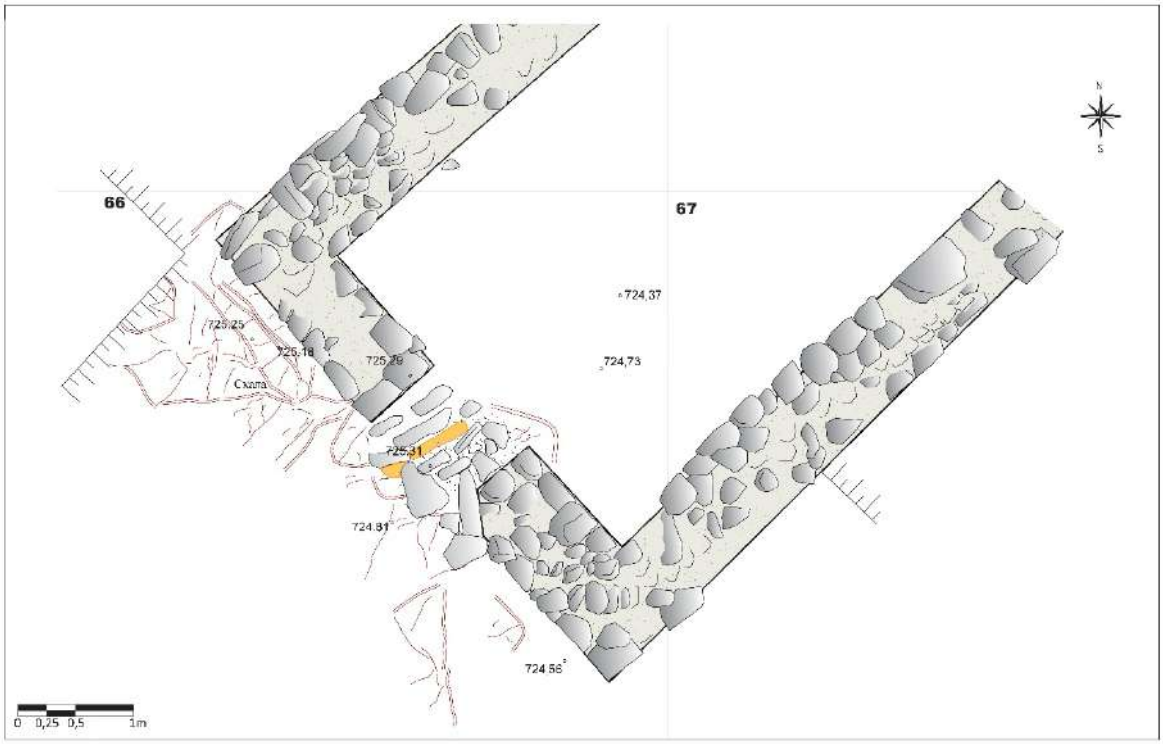



**Fig. 6 - A passageway of Church No. 2.**



**Fig. 7 - Mural paintings presenting polystavrion.**

# STOREFRONTS OF FORMER CRAFTING AND TRADING SHOPS IN VLASOTINCE AS ELEMENTS OF ARCHITECTURAL HERITAGE: MAKING OF TECHNICAL DOCUMENTATION USING PHOTOGRAMMETRY

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***Abstract**: In the present day, it is observed that in smaller towns in southeastern Serbia, the transformation of spaces has led to significant changes in the appearance of former crafting and trading shop fronts. Despite this, a number of preserved storefronts with architectural, cultural, and historical significance remain. It is crucial to protect these from potential further alterations, whether due to human intervention or the effects of time. This paper focuses on a case study of the storefront of the building located at Dušanova Street No. 12 in Vlasotince. The objective of this study was to produce both existing and improved technical documentation for the storefront of the building using photogrammetry method: one depicting its current condition and the other providing a detailed digital reconstruction of its historical appearance. Considering that the conservation of cultural and historical heritage is essential for preserving the historical integrity of communities, this study contributes by developing technical documentation that may serve as a basis for the potential restoration of the storefront.*

***Key words**: architectural heritage, conservation of cultural heritage, photogrammetry method, technical documentation, storefront*

## 1. Introduction

The urban environments we inhabit today are shaped by past transformations, reflecting the historical events and cultural influences of past generations. In recent decades, transformations in economy, society, demographic structure, political dynamics along with human ignorance and negligence have significantly impacted architecture and built heritage of small towns leading to a complete change in their aesthetic impression and deterioration of their cultural identity [1] [2].

Regardless of the current circumstances, numerous once-significant built structures continue to exist in small towns, particularly in Southeastern Serbia, and their preservation is of great importance. Smaller towns in Serbia have a rich history that has shaped the way of life of their inhabitants, who often relied on crafting and trading. This tradition led to the

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construction of shops specialized in artisanal products and trade activities [3]. As a result of this commerce-oriented lifestyle, storefronts play an integral role in the architectural heritage, alongside residential structures. One of these smaller towns with a rich history of craftsmanship and trade is Vlasotince, located in southeastern Serbia. It lies within the municipality of Vlasotince, near the city of Leskovac, and is part of the Jablanica District [4]. Vlasotince is a town rich in both tangible and intangible cultural assets, many of which are protected or require protection. The town contains a significant number of buildings recognized as cultural monuments, predominantly dating back to the early 20th century [5] [6]. Many of these structures were, or continue to be, used for residential purposes, often followed by commercial functions on the ground floor. The storefronts of these crafting and trading shops have frequently been altered or, in some cases, destroyed over time. The invention of new technologies, such as the use of modern materials and modern construction techniques, has led to the replacement of many original storefronts with entirely new designs, often lacking cultural or aesthetic significance. However, a substantial number of these shopfronts have survived in their original form, though often in deteriorated condition due to the effects of time. These facade elements, often characterized by their distinctive and unique appearance, merit greater attention, as they not only represent a reflection of a historical era but also reinforce the cultural identity of towns like Vlasotince.

Modern technologies such as digital technologies offer new solutions and opportunities to preserve and revitalize cultural heritage in many different ways. The digitization of cultural heritage aims to protect and ensure the long-term preservation. This process focuses on making information about cultural heritage accessible, facilitating data exchange among preservation institutions, developing new documentation while enhancing existing records, promoting and presenting cultural heritage, increasing user engagement, creating new content, and introducing innovative services [7]. The digitalization of cultural heritage involves the creation of multimedia databases that enable the preservation and presentation of cultural assets, making them accessible to both experts and the general public through cultural institutions and the Internet [8]. The creation of 3D and 2D technical documentation plays an important role in preserving cultural heritage, specifically in the conservation of the buildings and the objects that represent cultural monuments. The photogrammetric method is technique that can be used in the documentation of cultural heritage sites. Photogrammetry enables the most detailed representation of the current condition of built objects and cultural monuments which is why this method is used in this paper.

The aim of this research is to produce both 3D and 2D technical documentation of the existing storefront located at Dušanova street No. 12 in Vlasotince, as well as a proposed improved version, to serve as an independent contribution to the field. Furthermore, it is aspired to enhance our collective understanding of cultural heritage preservation and to elevate awareness regarding its significance. Through this initiative, this research seeks to emphasize the importance of preservation of cultural heritage and to inspire ongoing dialogue and action in this crucial domain.

## 2. Methods

At the outset of this research, a comprehensive collection of literature relevant to the topic has been gathered, followed by an extensive analysis of the gathered materials and information. Various types of analyses were employed, including exploration of the cultural-architectural heritage of Vlasotince, examination of its historical context, analysis of the architectural stylistic characteristics of storefronts, and an evaluation of their cultural significance. Subsequently, the photogrammetric method was applied in Agisoft Metashape software, leading to the creation of 3D Model and technical documentation of

the existing condition of the storefront. To ensure that the technical documentation was created at an appropriate scale and with accurate dimensions, site visit was necessary to collect more data about dimensions of the storefront using a measurement method.

Based on the technical documentation of the existing condition of the storefront, an improved condition was created. This enhanced version was developed by analysing the geometric characteristics observed and considering the expected geometric regularities during the construction of the portal in general. In conclusion, through the synthesis of data, an evaluation was conducted to demonstrate the significance and contributions of the work, along with recommendations for further research concerning the preservation of architectural heritage.

### 3. Cultural Heritage of Vlasotince

Crafting and trading were already developed to some extent in Vlasotince by the early 19th century, but witnessed substantial advancement toward the end of the century, accompanied by a notable increase in population. The area currently referred to as the "Old Bazaar", or “Stara čaršija” in Serbian, accommodated the majority of commercial shops, while the rest of the population lived in distinct neighborhoods called mahalas. The development of Vlasotince (Figure 1), including the establishment of buildings that are now considered cultural heritage, can be divided into three key periods: the time before World War I, the period between the two World Wars, and the post-World War II era [6].

The first historical period can be divided into three phases: the first phase, which relates to buildings constructed during the 18th and 19th centuries and the development of Vlasotince; the second phase - transitional phase between the 19th and 20th centuries; and the third - final phase, which covers the period right before World War I [6].

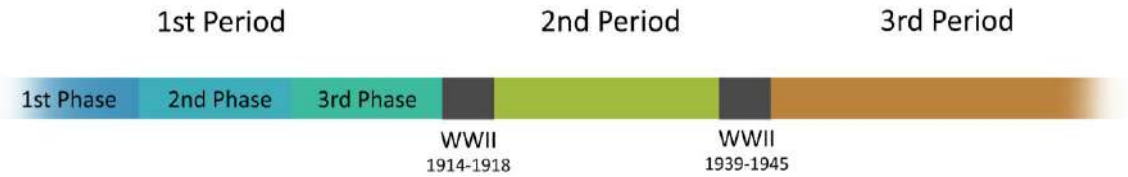



**Fig. 1**. Periodization of Vlasotince’s development, source: authors

In the first phase, the majority of culturally and architecturally significant buildings were built in area presently called "Old Bazaar" (Stara čaršija). This area encompassed today's Liberation Square (Trg Oslobođenja) and the following streets: Nemanja Street (Nemanjina ulica), Dušan Street (Dušanova ulica), 12th Brigade Street (Ulica 12. brigade), Vineyard Street (Vinogradarska ulica), and 22nd Division Street (Ulica 22. divizije). While few buildings from this phase remain, the ones that have been preserved include: the Turkish Tower (Turska kula), the house of Stojan Stoilković, also known as Giga's House (Gigina kuća), the Church of the Holy Spirit (Crkva Svetog Duha), Spaska's House (Spaskina kuća), and the Old Mill of Petar Popović (Stari mlin Petra Popovića). Additionally, a few shops in Nemanja Street and a small number of houses have also been preserved [6] [9].

The second phase, which represents the transition between the 19th and 20th centuries, is characterized by several important buildings, including the two constructed by Taša Valčić - one on Liberation Square and the other on Dušan Street. These, along with other buildings from this period, were built in the academism style, adhering to established architectural elements of massive construction [6].

Within the third phase of the first historical period, the decorative street facades along Nemanja and Dušan Streets acquire a unique appearance. Noteworthy examples from this phase include the house of Petar G. Popović on Dimitrije Stojanović Street, the

house of Ilija Krainčanić on Nemanja Street, and the house of Golub Aranđelović, also on Nemanja Street. These buildings, along with others from this phase, are distinguished by their monumentality, massiveness, symmetry, representativeness, and academic design. Besides this style, Vlasotince also saw the emergence of the Secessionist style, with Zaharia Hadži Stamenković's house standing as a prominent example. This building is characterized by its richly decorated facade, precise craftsmanship, and well-balanced proportions. Additional Secessionist-style structures in Vlasotince include the house of Vlajko S. Takić on Nemanja Street and the building of the Sejović brothers [6].

The second period of historical development of Vlasotince, period between the two World Wars represents a time of remarkable growth and development. Beyond Liberation Square, Nemanja Street, and Dušan Street, the entire settlement underwent significant expansion during this era (Figure 2). Improvements were made to side streets and alleys called "sokaci" as well. Numerous dual-purpose buildings were constructed during this period, featuring public functions on the ground floor and residential spaces on the upper floor. This period is distinguished by architectural diversity and a range of urban forms, with a variety of house shapes and sizes, along with a substantial number of villas and family homes being constructed. Russian architects made notable contributions during this time, leading to the construction of buildings in the Russian academism style. Notable cultural monuments constructed during this time include the Valčić Palace, the monument to the Liberators, the house of Spiridon Bošković, the house of Proka Mijajlović, the house of Dimitrije Popović, and the house of Gavrilo Manić [6] [9] [10].



**Fig. 2**. The former appearance of the Old bazaar, Liberation Square, Vlasotince, source: https://bibliotekavlasotince.org.rs/

After World War II, various political changes took place, which led to the demolition of a large number of older buildings to make way for new constructions that were intended to symbolize the state's new regime, system, and progress. This process is commonly known as "total reconstruction." Everything that did not align with the ideals of social-rationalist views was destroyed. On the eastern side of Liberation Square and in Nemanjina Street, a total of seven multi-story residential buildings were constructed for collective housing. The majority of the buildings constructed during and after this period lack architectural significance and frequently detract from the authenticity of the broader architectural and environmental setting. Few of the modernist structures were originally designed to blend into the surrounding environment; however, the majority underwent additional construction in the 1990s. The only exception in terms of aesthetic distinction is the work of Bogdan Bogdanović, particularly the memorial complex - Monument to the Start of the Revolutionary Struggle also called Sanctuary of fallen fighters (Svetilište palim borcima), completed in 1971. [6] [11]. Over the past 30 years, a considerable number of

buildings have been either improperly altered or demolished due to the needs of the owners, as well as their lack of expertise and understanding of importance of cultural heritage. This devastation is illustrated in Figure 3, which highlights the difference between the former and present appearance of the street front on Dušanova Street. (Figure 3). Consequently, the visual identity of Vlasotince has been progressively diminished, and in some areas, entirely lost.



**Fig. 3**. left: former appearance of the Dušanova street front, right: present appearance of Dušanova street front, source: Heritage Preservation of Vlasotince: Protection and Preservation of the Old Bazaar [6]

Although history has brought many challenges, a significant number of buildings have survived to this day and require to be preserved and protected in the future. The Institute for the Protection of Cultural Monuments Niš published a study titled "Heritage Preservation of Vlasotince: Protection and Preservation of the Old Bazaar" [6] in which these buildings, recognized as cultural monuments, have been mapped.

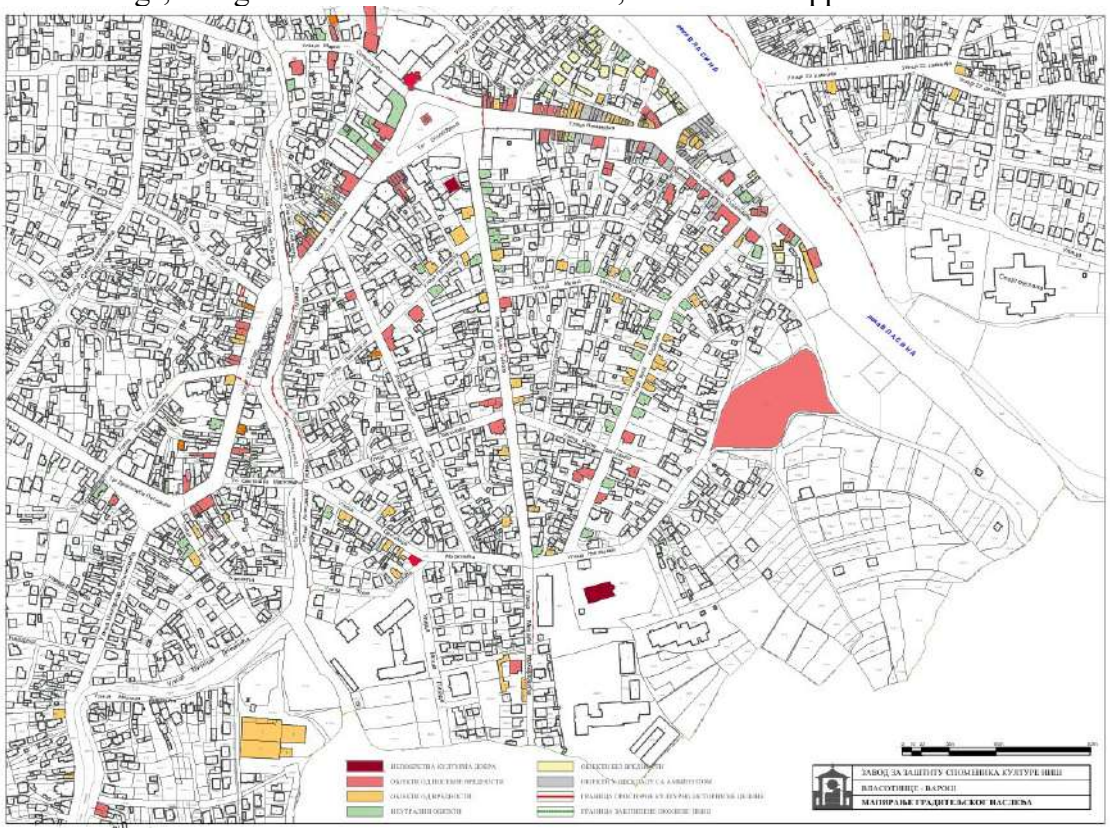


**Fig 4.** Mapping the Architectural Heritage, source: Heritage Preservation of Vlasotince: Protection and Preservation of the Old Bazaar [6]

In the accompanying graphic, "Mapping the Architectural Heritage" (Figure 4) buildings are assessed based on cultural importance. Dark red denotes immovable cultural assets, light red indicates buildings of particular value, bright yellow shows valuable buildings, green represents neutral buildings, pale yellow indicates buildings without value, and grey shows buildings that do not align with the environment. The study also outlines proposed boundaries for the protection of a spatial cultural-historical ensemble, which includes several smaller units within streets such as 12. Brigade, Dušanova, Liberation Square, Marko Oresković, Ive Lole Ribara, Nemanjina, Dimitrija Stojanovića, and sections of Vuk Karadžić and Njegoševa near the old mill. The study on heritage preservation covers numerous significant buildings, recognized as cultural monuments. It outlines general protection and conservation measures for Vlasotince's cultural heritage and offers suggestions for eliminating existing degradations.

### 3.1. Old Crafting and Trading Shop fronts of Vlasotince

In small towns such as Vlasotince, the primary reason of its development was trade - specifically, craftsmanship and commerce that began to flourish in this region even before World War I. The success of local artisans led to the emergence of specialized shops that catered to various needs, highlighting the diversity of trades within the community. The period between the two World Wars was particularly crucial for trading and crafting as it saw the construction of many structures that are now considered cultural monuments [9]. The streets were often bustling with life, showcasing a rich tapestry of goods and services. This era was marked by architectural innovation, as craftsmen sought to incorporate intricate details into their facades and storefronts, enhancing the visual appeal of the town.



**Fig 5.** The former appearance of the Old bazaar, Nemanjina street, Vlasotince, source: https://vlasotincekojenebledi.weebly.com/

The Old Bazaar, during its development, served a dual function; each plot was required to accommodate both commercial and residential uses. The buildings along the main streets were typically two stories high, comprising both houses and shops. The careful design of these buildings not only provided functionality but also allowed for artistic expression, with detailed decorations that reflected the cultural identity of the town (Figure 5). These shops were primarily used for the creation and sale of various products, while the upper floors typically served as living space for artisans or merchants, and their families [6] [9]. This architecture not only reflects the daily lives of people in these towns but also testifies to the significance of craftsmanship and trade in the economy and social structure of small towns in Serbia.

Storefronts in Vlasotince were more than just shop entrances; they served as vibrant representations of the town's cultural identity and economic vitality [12]. The external facade was the most important part of the building, meticulously designed to be both

representative and appealing, showcasing the storefront in a manner that would attract customers to enter, while the residential quarters were typically developed on floor above or deep within the plot. At their peak, these storefronts showcased the craftsmanship of local artisans, each with unique designs that represented the value of trades and products offered inside [9].

In contemporary times, many of the storefronts face significant negative changes in appearance. This issue commonly arises from the inappropriate placement of advertising elements on building facades, as well as the use of new, often unsuitable materials and proportions that are not in harmony with the original design. This not only undermines their historical significance but also jeopardizes the visual coherence of the streetscape. The second issue is that many of the existing storefronts are not in optimal condition due to their age, and the materials from which they were constructed have limited lifespan, influenced by the passage of time and environmental factors. To address these issues, it is essential to establish guidelines that prioritize the preservation of original architectural features and advocate for the use of appropriate materials. Restoration efforts should focus on enhancing the authenticity of these storefronts, preserving their cultural and architectural values, while also adapting to contemporary needs [13] [14]. By doing so, we can ensure that these vital components of Vlasotince's cultural and architectural identity are preserved for the appreciation of future generations [15].

## 4. Analysis of the Existing Condition of the Building and its Storefront located at Dušanova Street No. 12 in Vlasotince

The building, whose storefront is the focus of this research, is located at 12 Dušanova Street, on cadastral parcels 1145/1 and 1145/2, in the central part of Vlasotince, within the Old Bazaar area. It has a rectangular footprint, occupying nearly the entire area of these parcels (Figure 6). It is part of a row of buildings, with its side facades mostly attached to adjacent structures. The building's rectangular layout shows that its depth, extending into the parcel, is much greater than its front facade.

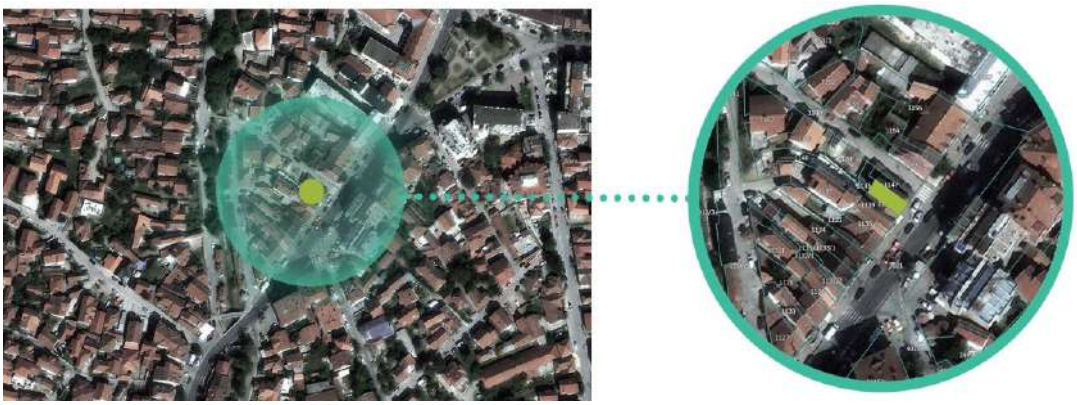


**Fig 6.** The position of the subject building in relation to the surroundings, source: GeoSrbija, authors' processing

Based on its stylistic features, and by examining historical photographs (Figure 7), along with a comparison of the surrounding buildings with more documented history, it is presumed that this building was constructed between the two World Wars. Figure 7. depicts a row of houses on Dušanova Street, with the second building from right to left representing the subject of this study. The building includes two above-ground floors and a basement. Although access to the interior was not possible, the front facade suggests its function: the ground floor likely housed a shop or workshop with a public purpose, while the upper floor rooms served as private living spaces. The basement was most probably used for storage or as a warehouse.



**Fig 7**. The former appearance of Dušanova street, Vlasotince, source: Graditeljsko nasleđe Vlasotinca (drugo dopunjeno izdanje) [9]

According to the study "Heritage Preservation of Vlasotince: Protection and Preservation of the Old Bazaar" [6], the building is classified as a valuable building, indicated in bright yellow on the graphic representation titled "Mapping the Architectural Heritage" (Figure 4). The study outlines specific protection measures, emphasizing the need to maintain the building's original appearance and dimensions. Restoration of any missing architectural elements should be based on available historical records and align with established preservation guidelines. Additionally, alterations to the building's dimensions, especially regarding its height, are strictly prohibited.

The analysis of the building's facade reveals several vertical divisions: the basement, ground floor, first floor, and roof (Figure 8). The first area, being the lowest section, represents the basement space inside the building. This section, also establishes a direct connection to the ground, specifically the sidewalk, through the inclusion of two steps that facilitate the transition between the ground and the ground floor. The presence of the basement is confirmed by a modest window opening located centrally on the facade. Visible construction material for the basement part is made of stone blocks. The ground floor and first floor are distinguished as the two most significant sections of the facade. The ground floor features three openings - two doors and one window, crafted from wood and single-layer glass, embellished with intricately designed wooden details that enhance the overall aesthetic of the facade. The first floor is characterized by two proportionately designed windows and is decorated with Neoclassical elements. The triangular surface of the hipped roof represents the highest part of the frontal facade.




**Fig 8.** Vertical divisions of front facade of the building in Dušanova Street, 12, source: https://sketchfab.com/3d-models/de15d1647dd04efbabc2fdb6d84f6b42 , authors' processing

Each section is effectively divided by visual barriers (Figure 8). Between the basement and the ground floor, the intermediate structure acts as a visual barrier, while a cornice element separates the ground floor from the first floor. It is presumed that the actual physical separation is facilitated by an intermediate structure positioned slightly lower. Finally, a gutter serves as the visual barrier between the first floor and the roof, outlining the building and fulfilling the essential function of water drainage while also visually distinguishing the structure from adjacent buildings.

The storefront features three distinct openings on the facade (Figure 9). Each opening consists of a main section and an upper section known as a transom. Each of these openings is very similar in size. The height of each element is consistent, while the widths show only minimal variation. The subsequent text delineates the structure of the main components of these elements, followed by an explanation of the transom's appearance. The central opening served as window, while the two lateral openings functioned as doors. The purpose of the window was to facilitate the entry of light into the building and to establish a visual connection between the exterior and the interior. Larger part of this window is glass surface, which is divided into two sections. This window was designed in a simpler manner compared to the other openings. Both doors are raised and fielded, characterized by a stylized design. The main section of the door on the left is divided into two distinct parts: the operable section and the fixed section. The fixed section is situated above the operable section and is glazed, providing transparency and the transmission of light. The lower part of the operable door is solid, while the upper part consists of glazing. The door exhibits a vertical division in the centre, ensuring a symmetrical appearance. The main section of the door on the right is also divided into two distinct parts: the operable section and the fixed section positioned in similar way. The fixed section above the operable part of the door is solid and it has small vertical part that divides it symmetrically. Operable part of this door is divided into three equal parts. The bottom one looks similar to the other door, the top one is glazed, and the middle one is divided into two non-equal parts with the bar-like wooden element. This element is composed of two different parts. The first one is a bracket-like structure mounted on the door to support the second part which is flat, horizontal shelf.




**Fig 9.** The storefront of the building in Dušanova Street, 12, source: autors

Each opening on the sides features a pilaster designed in the Neoclassical style. The upper section of the pilaster, referred to as the capital, is cylindrical with profiling,

designed as a generalized convex surface. The lower section, known as the plinth, exhibits a more complex construction; it incorporates a similar generalized convex surface (Figure 10; left), a flat section in the shape of a prism, and an additional smaller element located at the very bottom of the plinth. The door on the right side does not have the plinth treated in this manner.



**Fig 10.** Details from the storefront of the building in Dušanova Street, 12, left: part of the pilaster's plinth, right: details from transom, source: authors

The upper section, referred to as the transom, exhibits a consistent design across each of the elements. Its treatment on the side can be viewed as a continuation of the pilaster's capital. Two of the three central panels from the transoms have been removed; however, the remaining panel located above the right door suggests that the original panels were wooden rather than glazed. At its upper part, the transom showcases a finely detailed crosshead which includes a row of interlinked oval beads that follow a rhythmic pattern throughout its entire length. The remaining panel has a drilled circular section, likely due to some modifications made during the last period of the building's use (Figure 10; right). Above these three openings is a flat, finished surface of the wall called fascia which is believed to have served as a location for an advertising sign or may have remained unutilized throughout its existence. Positioned above the fascia is a cornice that serves to visually delineate the public and private areas of the facade.

Currently, this building is not in use and is exhibiting considerable neglect; the elements of the facade are deteriorated and have sustained some damage. The wooden components have decayed due to effects of time and weathering. Based on the physical appearance of the building, it can be concluded that it has not been utilized for years. The inscription on the glass portion of the facade indicates that its most recent function was as a pizzeria, while a former illuminated box sign further reflects its previous use. Nevertheless, the current storefront's state of disrepair detracts from the overall aesthetic appeal of what was once a successful commercial or craft business.

## 5. Making of 3D Model of the Storefront of the Building using Photogrammetry Method

Photogrammetry is a highly effective method for creating detailed three-dimensional models from two-dimensional photographs [16], playing an important role in the preservation of cultural heritage. This method has become an essential tool in the documentation, evaluation and preservation of historic sites and artifacts. It allows for the detailed recording of every feature, from large architectural elements to intricate decorative details, all of which are captured in a digital format [17]. By using only photographs and knowing at least one dimension of the cultural heritage site, a highly precise three-dimensional model can be produced, resulting in detailed technical documentation. This approach is far more reliable than sketches or drawings made on-site, as it enables the

collection of a significant amount of accurate data within a relatively short timeframe. A photogrammetric model serves as a form of digital preservation of architectural cultural heritage, while also supporting future restoration of the subject [18].

To create a 3D model of the building's storefront, Agisoft Metashape software was used. During on-site work in Vlasotince, approximately 150 photographs were captured. Some images were taken to cover the entire portal area, while others specifically focused on architectural details of the storefront. The photos covered the storefront from various perspectives in order to ensure the model was as detailed as possible in the software.

The first step in working with Metashape software involved the creation of masks, allowing for the exclusion of unwanted and problematic areas of the photographs. This step was carried out to ensure the model was clean and free of unnecessary elements that did not belong to the object.

The second phase (Figure 11) utilized the "align images" function, leading to the generation of the point cloud. This step was essential for determining the perspective of each photograph and identifying the specific point from which each image was captured. The accuracy setting was configured to high, while reference preselection was set to sequential, as the photographs were taken in a consecutive order. For the purposes of this research, key points were set to 40 and tie points to 10, although generally higher values are preferred. These settings resulted in the creation of a point cloud.

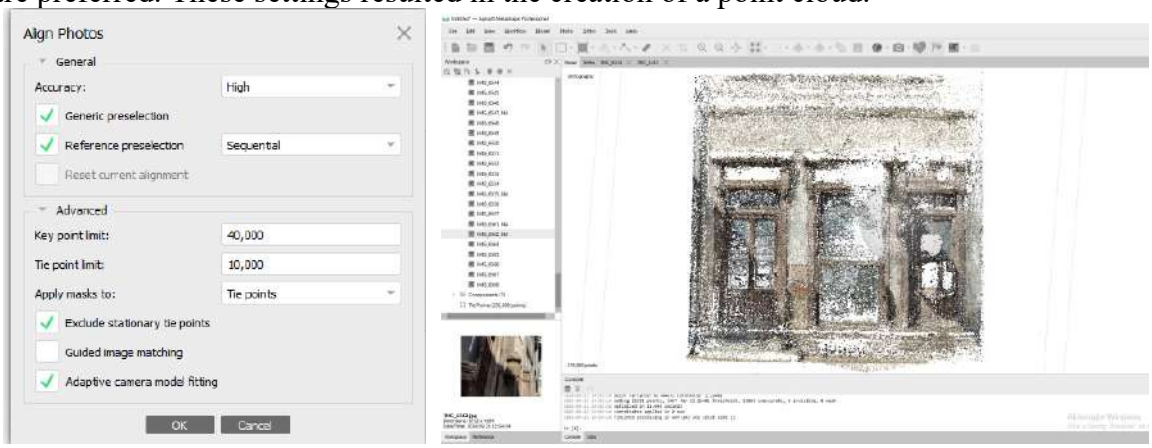



**Fig 11.** The second step: Aligning images and creation of a point cloud in Agisoft Metashape software, source: authors

The third step (Figure 12) involved the creation of the dense cloud. The quality and depth filtering were set to high, and the options to calculate point colours and point confidence were enabled. This produced a dense cloud of high resolution.

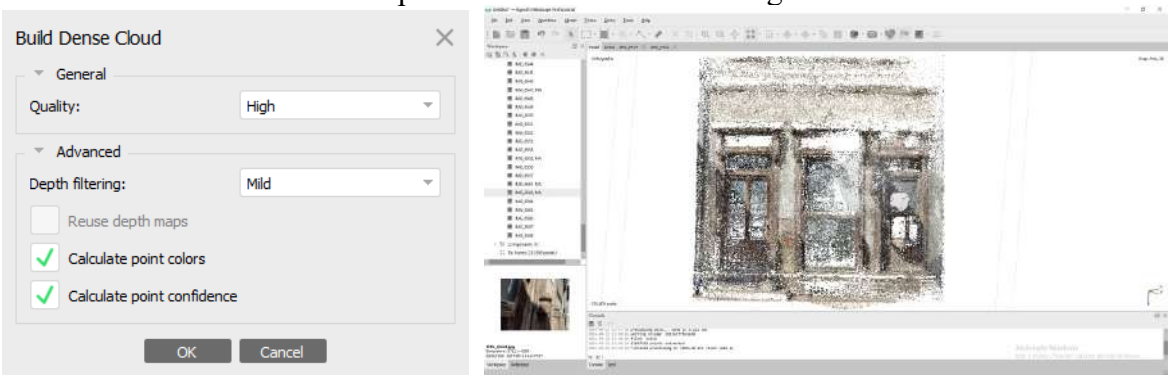



**Fig 12**. The third step: Building a dense cloud in Agisoft Metashape software, source: authors

The fourth step (Figure 13) involved creating the mesh. The settings for building the mesh were as follows: the previously generated dense cloud was selected as the source data, and the surface type was set to arbitrary 3D. Quality was adjusted using face count to high (12,000,000). Interpolation was enabled, and the option to calculate vertex colours was checked. This resulted in the creation of mesh model.

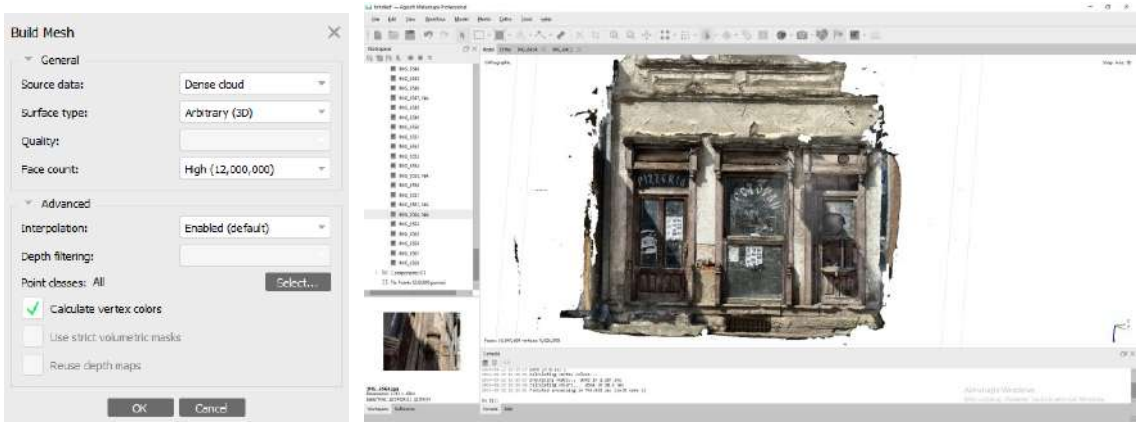



**Fig 13.** The fourth step: Building a mesh model in Agisoft Metashape software, source: authors

The fifth step (Figure 14) was creating the texture. The settings for building the texture were: texture type set to diffuse map, source data set to images, mapping mode set to generic, and blending mode set to mosaic. The texture size/count was required to be as large as possible, so it was set to 8192x3. The options to enable hole filling and enable ghosting filter were also checked. This produced the final textured 3D model of the storefront of the building.

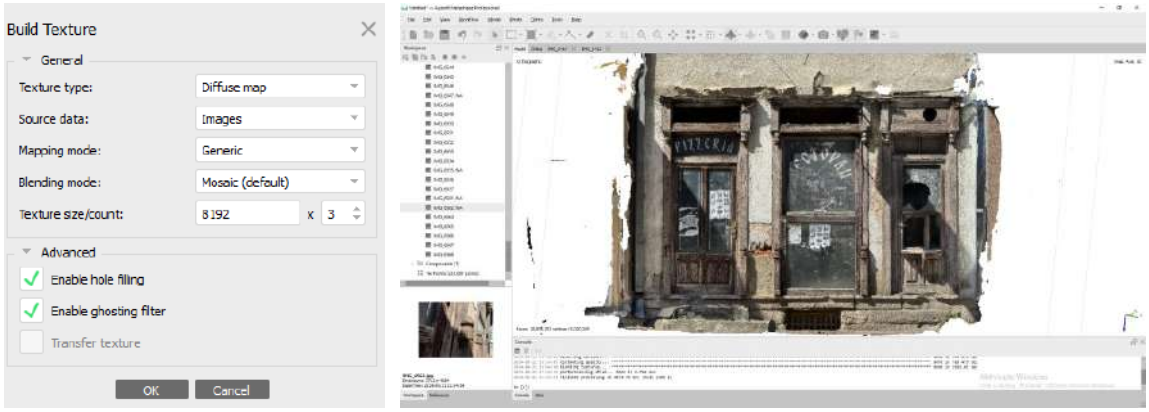



**Fig 14**. The fifth step: Building a final 3D model with texture in Agisoft Metashape software, source: authors

This model is highly detailed and accurately reflects the current condition of the storefront with precision and quality. On the Figure 15, these details are presented in three-dimensionality, effectively illustrating the depth and intricacies of the portal. The 3D model provides a comprehensive visual record, showcasing both the architectural features and any visible signs of wear, making it an invaluable tool for further analysis and restoration planning.



**Fig 15**. Details from final 3D model in Agisoft Metashape software, source: authors

## 6. Making of Technical Documentation

Technical documentation is essential for the preservation, restoration, and analysis of cultural architectural heritage, enabling a precise understanding and safeguarding of its characteristics. Additionally, it assists in ensuring compliance with legal standards and facilitates research work on heritage. In the subsequent section of this paper the process of creating technical documentation and the results obtained will be presented. Technical documentation of the existing condition of the storefront of the building located at 12. Dušanova Street, was created, followed by the development of a reconstructed version.

### 6.1. Existing Condition of the Storefront of the Building

To create technical documentation based on the three-dimensional model obtained from Agisoft Metashape software, it was essential to produce a two-dimensional model, more precisely to built orthomosaic and to export it into another drawing software. For the purposes of this study, a PNG file of the orthogonal representation of the storefront facade was created, which was later exported to AutoCAD software, where technical two-dimensional drawing was created (Figure 16).




**Fig 16.** The graphical representation of existing condition of the storefront, source: authors

The graphical representation of existing condition has been drawn exactly as it appears in reality. The geometric forms of the storefront are not idealized but are depicted in complete accordance with their current condition. The damages observed on the wooden elements have been meticulously drawn, and every detail has been represented with a high degree of accuracy in alignment with the reference model.

### 6.2. Reconstructed version of the Storefront of the Building

The reconstructed version of the storefront aims to provide a faithful representation of the original appearance of the craft workshop or commercial establishment. Considering that the structure has not undergone substantial alterations throughout its historical timeline, the graphical depiction of the enhanced or reconstructed condition is drawn to closely align with the existing state of the storefront, thereby exhibiting minimal differences.

The reconstructed version (Figure 17) was achieved in the following manner. The damages have been removed. The existing elements that had damages have been idealized within this representation. Any geometric irregularities have been corrected and drawn in an idealized manner. To ensure that the storefront aligns with its original appearance, certain parts of the elements have been added, changed or removed. This notably applies to the wooden panels illustrated within the transom above the left door and the centrally located window. In the existing condition, these panels are absent; however, they have been incorporated in the reconstructed version to align with the appearance of the panels on the transom above the right door. The more significant changes in the reconstructed version of the storefront, as opposed to its current state, are reflected in the removal of the shelf-like element and the vertical division in the middle of the right door. These elements do not harmonize visually with the overall design and are believed to have been added during the period when the building functioned as a pizzeria.



**Fig 17.** The graphical representation of reconstructed version of the storefront, source: author

### 7. Conclusion

The preservation of cultural heritage, especially cultural architectural heritage is of great importance, as it embodies the historical and aesthetic values of a community, providing insight into its evolution and identity. Architectural heritage not only enhances

the character of urban environments but also contributes to local economies through tourism. Buildings which represent cultural sites, serve as tangible links to the past, fostering a sense of continuity and belonging among local residents. The cultural heritage of a small town like Vlasotince in southeastern Serbia reflects the rich history of entire population of a country, highlighting its significance not only for the local community but also for the broader culture of the region and the nation.

The preservation of storefront facades, reflects not only local craftsmanship but also the broader architectural and cultural narrative of the region, highlighting the need for comprehensive preservation efforts. This paper explores the significance of crafting and trading shops as an often-overlooked aspect of cultural architectural heritage, particularly in Serbia. The historical overview of the development of cultural heritage in Vlasotince presented in this paper illustrates the ways in which the population has created, evolved, and navigated various historical changes. Social transformations are particularly reflected in the architecture of the area, and this comprehensive analysis successfully illustrates the context in which structures were constructed, demolished, modified, restored, and preserved, ensuring that the architectural language of the past continues to communicate with the present. In the small town of Vlasotince, the town's history, shaped by craftsmanship and trade, is reflected through the preserved storefront facades, safeguarding both the town's identity and its historical way of life.

Non-invasive nature of photogrammetry ensures that the integrity and authenticity of historical sites are maintained, ultimately helping to protect and conserve our cultural heritage for future generations. The digitalization of heritage, particularly through the use of photogrammetry, contributes to the preservation of cultural monuments primarily in digital format, and later, if needed, these digital archives will enable the restoration of monuments to their most authentic state. This approach not only aids in safeguarding physical structures but also facilitates deeper research and documentation, providing invaluable resources for future conservation efforts and ensuring that these cultural landmarks remain a testament to their historical significance.

Contemporary time testifies that society has increasingly disregarded the importance of architecture, heritage, and the historical moments that have shaped our present. Negligence and lack of awareness have contributed to the erosion of aesthetic values in modern architectural practices, particularly over the past thirty years in small towns across southeastern Serbia. By preserving and presenting this cultural monument, this work aims to raise awareness about the importance of cultural architectural heritage emphasizing that its preservation is not exclusive responsibility of an individual, but rather a shared obligation among all who observe and interact with it. Cultural heritage, although rooted in the past, represents something we have today and something we can preserve for future generations. The present moment is the only time in which we can take action, placing upon us the responsibility to determine what will endure, what will be preserved, and what will inevitably be forgotten.

**Acknowledgement**

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# THE HISTORY OF STRUCTURES. SEARCHING FOR EQUILIBRIUM

# (ИСТОРИЯ НА КОНСТРУКЦИИТЕ. ИЗСЛЕДВАНЕ НА РАВНОВЕСИЕТО)

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**Abstract:** *An attempt has been made in the report to give a brief description of the History of Structures(Searching of equilibrium) during last 500 years.*

***Key words:*** *masonry arch bridges, space structure, load-bearing capacity***,** *MFE*

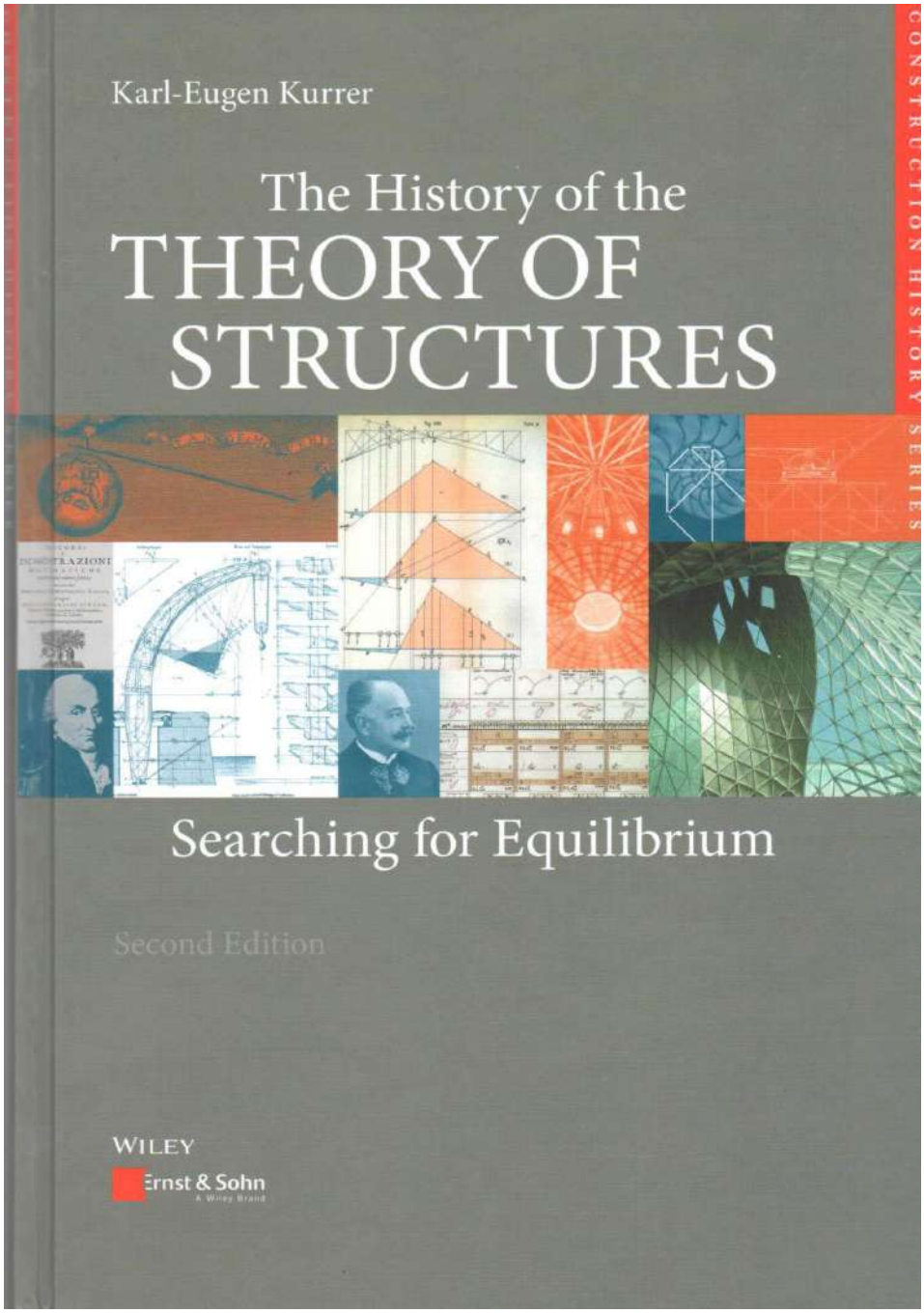
**KURRER Karl-Eugen**

Ernst & Sohn, A Wiley Company, 2-ро Английско издание, 1212 страници, повече от 970 илюстрации, твърди корици, цена 149 Евро, ISBN 978-3-433-03229-9, юни 2018. Книгата е достъпна и в електронна версия(Фиг. 1.).

Авторът на този уникален труд е Dr.-Ing. Karl-Eugen Kurrer, който е бивш главен редактор на списанието *Stahlbau* в периода: 1.1.1996-28.2.2018 а от 2008 год. е главен редактор на списанието, *Steel Construction – Design and Research.*

С историята на „Теорията на строителните конструкции", в различните и контексти, авторът на книгата се занимава повече от 40 години. В тази област той е публикувал повече от 180 статии и няколко монографии. Тази интересна и убедителна със своята вековна истина книга представлява второ английско издание, отпечатано две години след второто немско издание, 10 години след първото английско и 16 години след първото немско издание. Новите теми тук се явяват в: теорията на земния натиск, теория на черупките, изчислителна статика, FEM, CAD, анализ на учебници посветени на историята на строителните конструкции и др.

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Фиг.1. Оформяне на корицата на книгата

Предговорът написан от автора на книгата е предхождан от предисловието, написано от prof. E. Ramm от TU Stuttgart. Книгата се състои от 15 глави. Предхождащите първото издание публикации са композирани от 10, респ.12 глави. Наименованията на отделните глави са: 1. Задачи и цели на Историята за Теория на конструкциите; 2. Поуки от тази история са изложени в 12 уводни есета, анализиращи периода 1575-1825, включително до нашето съвремие през 1975. Освен в информацията от Германия, Австрия и САЩ тук са упоменати и значимите висящи мостове на територията на Чехия и Морава; 3. Теория на конструкциите и Приложна механика като първа инженерна научна основна дисциплина; 4. От зидания дъгов мост до еластичната дъга; 5. История на теорията за земния натиск; 6. Начало на теорията на конструкциите; 7. Период на формиране на дисциплината - Теория на

конструкциите; 8. От железните към стоманените строителни конструкции; 9. Статика на прътите получава трета димензия: пространствени прътови конструкции; 10. Влияние на стоманобетонните строителни конструкции върху Теорията на конструкциите; 11. Период на консолидиране на Теорията на конструкциите; 12. Развитие и приложение на изчислителната статика; 13. Тринадесет научни контраверсии в Механиката и в Теория на конструкциите; 14. Перспективи за историята на Теорията на конструкциите; 15. Кратки автобиографии на 260 протагонисти на Теорията на конструкциите. В заключение на книгата са на 127 страници фотографиите и автобиографиите на 260 починали личности от цял свят, които значително са допринесли за развитието на Теорията на конструкциите.

Възможно е в книгата да се открият имената на личности от Русия( Бубнов, Кирпичев, Новожилов, Папкович, Рабинович, Тимошенко, Власов, Журавски- описани от Д. Михайлов от Москва). От Чехия са упоменати следните имена: Бажант, Дашек, Фалтус, Колоушек, Шолин-описани от проф. Фриба от Прага. От Словакия са дадени имената на двама известни научни специалисти: Аугустин Мразик и Арпад Тесар- описани от проф. Иван Балаж.

Тук е мястото да се отбележи, че авторът на книгата възнамерява да увеличи броя на Словашките учени с имената и автобиографиите на Аурел Стодол и на Йозев Дюбек, които със свойте плодоносни резултати и приноси по преценка на автора на тази рецензия биха заслужили напълно своето място между световните личности в областта на Теорията на конструкциите.

Книгата завършва с богат списък на използвани литературни източници(93 стр.) списък на имената на учените работещи в областта на механиката и строителните конструкции(12 стр.) и съответния веществен регистър (17 стр.).

Съдържанието на книгата е по - скоро тематично, отколкото хронологично. Във всеки случаи става въпрос за много сериозен обем събрана информация от сведения и факти. Книгата съдържа и множество полезна информация, мотивиращ анализ и разсъждения на самият автор. Тази сполучлива книга представлява завършен труд, посветен на развитието на Теорията на строителните конструкции през последните 500 години. Този труд може да се приеме не само като притегателен магнитен център за строителните специалисти, интересуващи се от тази област, но и като извор на ценни знания, даже и за активни до този момент проектанти. Книгата спокойно може да се препоръча за ползване от научните работници, лектори и студенти в университетите у нас както и на действащите в строителния бизнес инженери.

# ASSESSMENT, REHABILITATION AND RECONSTRUCTION OF RELIGIOUS BUILDINGS IN VOJVODINA - EXAMPLES FROM PRACTICE

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***Abstract:*** *Recognizing the importance of preserving architectural marvels, scholars, engineers, and conservationists have devoted considerable efforts to establish methodologies for the assessment and repair of historical structures. Through two case studies, one Orthodox and one Catholic temple, this paper presents a synthesis of historical insights, technical expertise, and practical considerations, pointing full complexities involved in preserving these sacred spaces. The analysis of the two historically significant churches, both designated as cultural heritage sites, reveals a set of common structural damages that can be mainly attributed to the specifics of the chosen architectural-constructive system.*

***Key words:*** *Condition assessment, repair, maintenance, masonry structure, damage, deterioration.*

## Introduction –

Throughout history, religious buildings have served as testaments to human faith, craftsmanship, and cultural identity. However, as guardians of our cultural heritage, these structures face the relentless passage of time, enduring the effects of natural forces, wear, and occasionally, neglect. In response, the assessment and repair of masonry structures within these churches emerge as vital endeavours, ensuring their longevity and continuous contribution to our shared heritage. Recognizing the importance of preserving these architectural marvels, scholars, engineers, and conservationists have devoted considerable efforts to establish methodologies for the assessment and repair of masonry structures. These approaches integrate a blend of traditional craftsmanship, advanced technology, and interdisciplinary collaboration, reflecting a deep respect for both the historical significance and the technical challenges inherent in such endeavours. Through two case studies, one Orthodox and one Catholic temple, this paper presents synthesis of historical insights, technical expertise, and practical considerations, highlighting full complexities involved in preserving these sacred spaces.

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## 2. The church of the descent of the holy spirit in Ruma

### 2.1. Description

The Church of the Descent of the Holy Spirit in Ruma, also known as the Greek Church, was constructed during the first half of the 19th century. Its design features a single nave layout with a semi-circular altar apse situated to the east, and a commanding bell tower positioned on the western side. The prominent western facade is distinguished by imposing paired columns topped by a tympanum, a towering gabled wall, and an Art Nouveau-inspired bell tower in the shape of a hat, designed by Herman Bole. The church was originally constructed as a rectangular masonry structure, measuring 14x36m at its base. The ceiling reaches a height of 12m, while the bell tower stands tall at 39m. The vault is supported by 120cm-wide arches of varying heights. The walls vary in thickness, measuring 196cm at the pilasters, 100cm between the pilasters, and 45cm under the windows in the altar area. In the early 20th century (1902), the Orthodox church community in Ruma requested permission to build a family tomb next to the Church of All Saints. The reconstruction was entrusted to the Austrian architect Herman Bole, a well-known restorer of architectural monuments, who happened to be living in Ruma at that time. Works under Bole's leadership began in 1902, and by 1905, the construction was finally completed. The circular tomb extends 3.5m beneath the altar, and features entrance constructed as an attached building with a semi-circular wall. The ornate facade is adorned with shallow pilasters that accentuate vertical division, a recessed semi-circular niche, and an adorned zone of attic wreath spanning the entirety of the church.

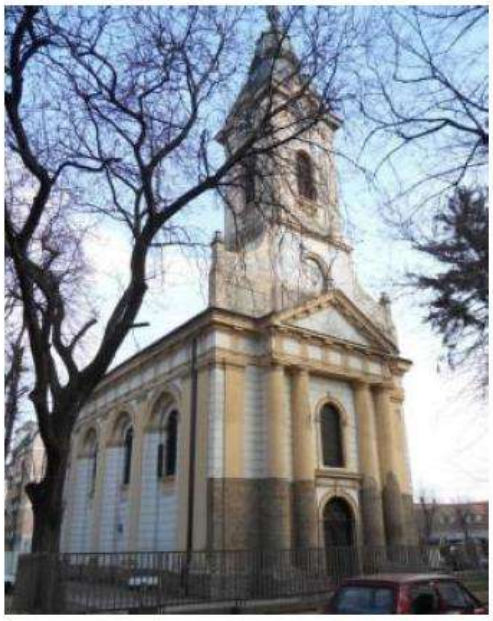




**Fig. 1.** West and North façade
F**ig. 2.** The entrance to the tomb on the East side of the church

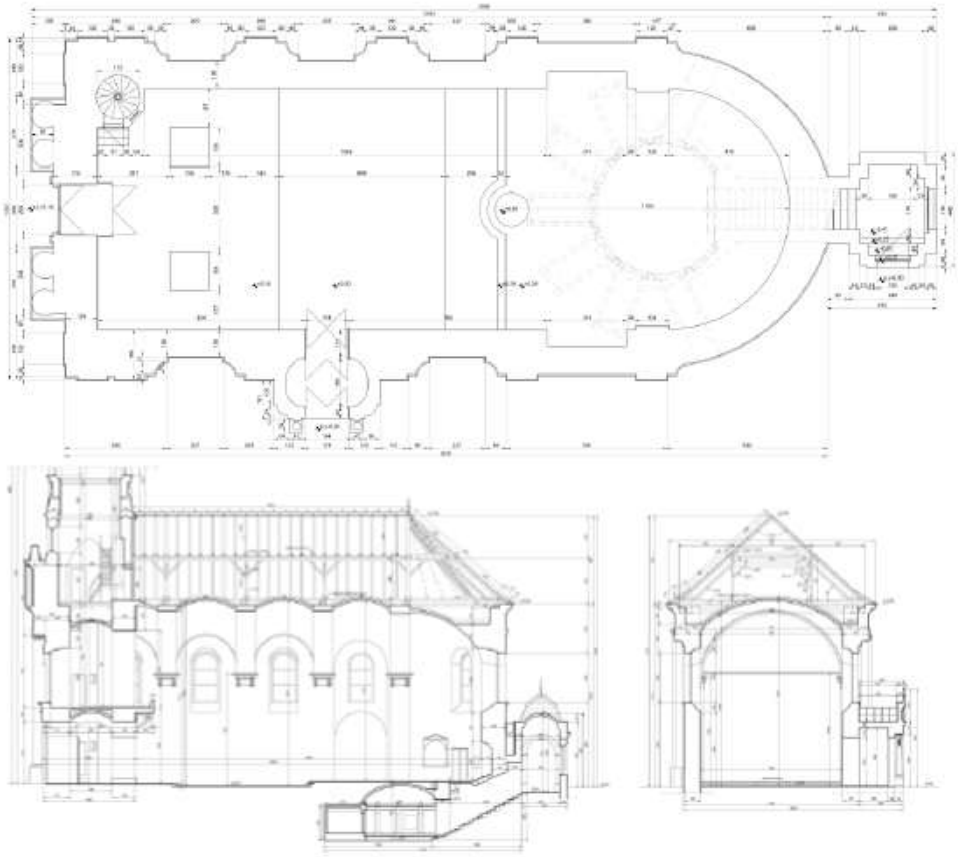


**Fig. 3.** Plan view and cross section of the church structure

**2.2. Assessment of the condition**

Several thorough visual inspections of the church structure were conducted during 2012 and 2013 [1,2], revealing various damages common to buildings of this type, as well as some that were unique and caused by long-term negligence. Characteristic damages identified on the walls include spalling and mortar disintegration, crumbling bricks, cracks and fissures in mortar and walls (particularly around arches and openings), foundation settlement under the tower's pillars, mechanical damage, and soot residue. During the subsequent construction of the tomb, sections of the walls were dismantled, and later, after the completion of construction works, rebuilt. However, achieving continuity between the new wall and the existing structure was not successful. Consequently, cracks appeared due to the settlement of the building. A selection of these damages is illustrated on the following pictures.



**Fig. 4.** An overview of typical cracks observed on the church walls



**Fig. 5.** Surface flaking of bricks, crumbling of deteriorated mortar from joints, and detachment of masonry elements



**Fig. 6.** Cracks in the areas of arches and openings



**Fig. 7.** Peeling and detachment of plaster and paint

Based on a detailed visual inspection of the church it has been concluded that the church's structure is in a considerably poor condition, necessitating urgent rehabilitation to prevent further deterioration. The primary cause of the damages on the structure is uneven settlement. This settlement has resulted in the opening of cracks and fissures in the vaults, arches, around openings, and within the walls. The origins of these damages are manifold:

- Subsequent construction of the tomb required excavation beneath the eastern part of the church.
- After the church roof was repaired in the seventies, vertical gutters were stolen, exposing the soil beneath the foundation directly to atmospheric precipitation.
- Differential weight distribution within the structure led to the sinking of the tower pillars several centimeters deeper into the ground compared to the load-bearing walls of the church.

Among other damages, the most notable is the degradation and deterioration of materials, particularly in areas directly exposed to weather conditions. At the end of the last century, mortar was removed from the facades around the perimeter of the building to expedite drying after winter, with the intention that it would be a temporary measure. However, the building remained bare and exposed for the next two decades, significantly accelerating its deterioration by increasing vulnerability to weathering of the external facade. Moisture and frost have primarily contributed to the loss of mechanical properties of materials. Inadequate performance of the drip channels and precipitation drainage systems has also worsened the condition of the building. One positive indicator in assessing the stability of the structure is the absence of widening of existing cracks over an extended period, as confirmed by survey measurements conducted from 2012 to 2016. After considering all defects and damages to the structure, it can be inferred that both the global and local stability of the construction are compromised, consequently affecting the overall load-bearing capacity of the structure. The durability of the structure is particularly at risk, especially considering the protection of cultural heritage and ornaments, and must be kept from deteriorating further.

### 2.3. Repair solution

A series of repair and rehabilitation measures were proposed and works started in 2016. All works were divided into several phases [3]: roof structure and roof cover repair, execution of horizontal hydro-insulation, repair of masonry structure, finishing works

(plastering, painting, iconostasis rehabilitation). By the end of January 2022, the church had been completely rehabilitated. Only solutions to a few major structural issues will be given here.

**Roof structure repair**

Repair works of the roof structure included the following operations:

- Removal of the roof covering;
- Removal of existing roof battens and the rafters;
- Strengthening of the purlins and tie-beams;

Repair of local damage on top-plates and principal rafters; • Setting the new rafters, collar ties, roof battens and roof covering.

Static analysis was performed in accordance with current regulations and some of the elements of the roof structure did not meet the criteria of capacity and/or usability, as determined by the visual inspection. As the Institute for the Protection of Cultural Monuments stipulated that the primary elements of the roof structure cannot be removed, the following approach was used: strengthening existing purlins and tie-beams by increasing their cross section. In addition, the problem of setting and leveling of new rafters was solved. Another problem with purlins included large deformation in the horizontal plane, occurred as a result of the large horizontal load from rafters and large spans, unusual for this type of roof structure. To minimize horizontal load from rafters, each pair of rafters was interconnected with collar beams. Details and appearance of the roof structure, after the repair, are shown in Fig. 8.




**Fig. 8.** Repair and strengthening of the roof structure

**Rebuilding of wall construction joints**

The chosen repair solution involved the stitching method, where steel rods are inserted into the bed joints. The procedure and details of the repair works on connecting the wall with pilasters are illustrated in Figs 10 and 11. Materials based on limestone, specifically "MapeWall Inject & Consolidate" and "Mapewall Render & Strengthen" by MAPEI, were chosen as injection material and repair mortar.

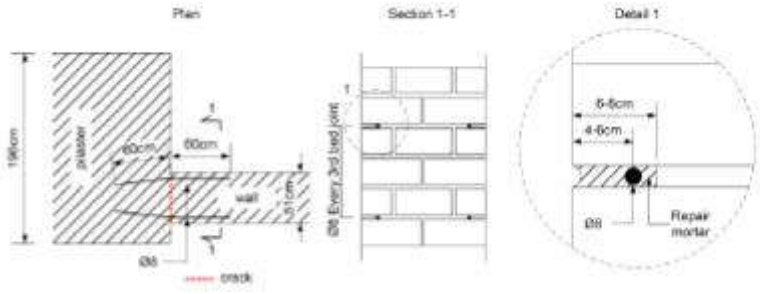



**Fig. 9**. Construction joint rebuilding design



**Fig. 10.** Executed construction joint rebuilding

**Cracks in vaults**

During visual inspection, two types of cracks in the vaults in wall openings were observed. Cracks in vaults below windows spread from the base voussoirs to the lower corner of the window, while in vaults above windows, cracks were located in crown zone. Since all these cracks were caused by uneven settlement, and there were no signs of further settlement, selected the repair solution was designed only to restore the integrity of the masonry in the zones of cracks. Repair of the cracks below the window included drilling Ø30mm holes for anchoring 2Ø12 reinforcement bars bended and welded into a "T" shape. Holes were drilled at an angle of 60-90 degrees to the crack, cleaned and filled with anchorage material (ADESILEX PG1 – Mapei). After preparation, "T" shaped anchors were put into anchorage holes (Fig. 11).

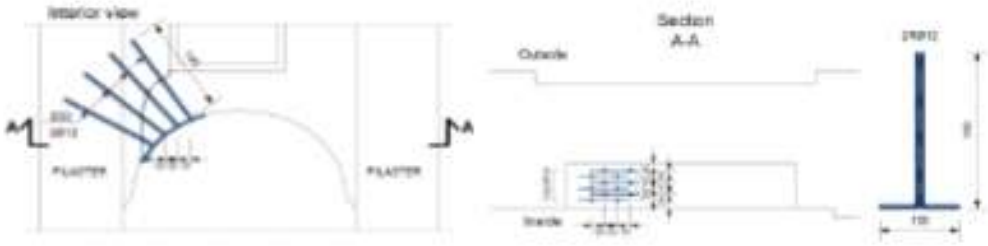



**Fig. 11.** Repair solution for cracks in vault below window

Similar techniques were used to repair cracks in the vaults above the windows. Reinforcement bars were placed in the bed joint at the angle of 30 degrees to the wall surface. The minimum length of bars was 120cm in the first line and 200cm in the second line. Bars were alternately placed symmetrically on both sides of the crack in bed joints. Surface reinforcement bars were placed in bed joints extending 50cm on either side of the crack. After execution of the reinforcement of the cracked vaults, final phase was injection of existing cracks with the same material and procedure as for all injection works. Details of reinforcement of the wall are presented in Fig. 12.

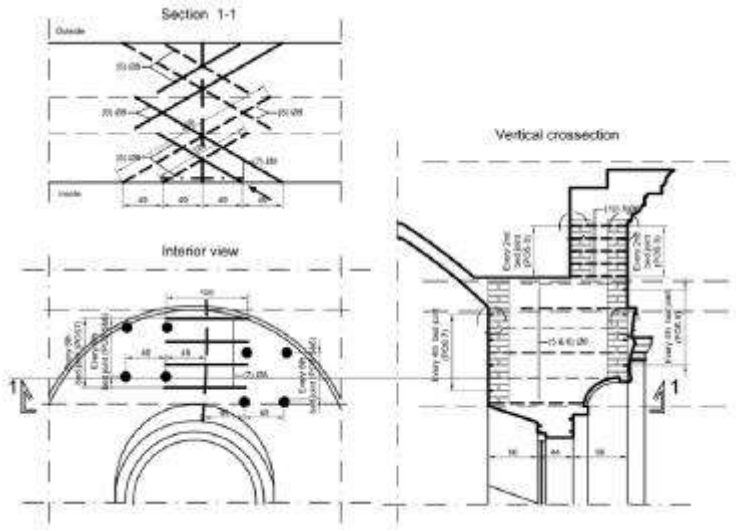



**Fig. 12.** Repair of cracks in vault above window

**Design of new tie-rods**

Ceiling of the church was constructed as a masonry domical rib vault with the ribs on the extrados side. Initially, for balancing lateral thrust in arches, inclined ties anchored in base of arch and hung on the roof tie were used. After roof renovation in the 1950's, new ties were added (old were left but without connection to roof tie), with same structural concept, but this time, instead of hanging new ties on roof structure, new "I" beam was introduced (Figure 8). Since this solution is not very effective, it was decided to balance lateral thrusts with standard, horizontal steel tie rods.

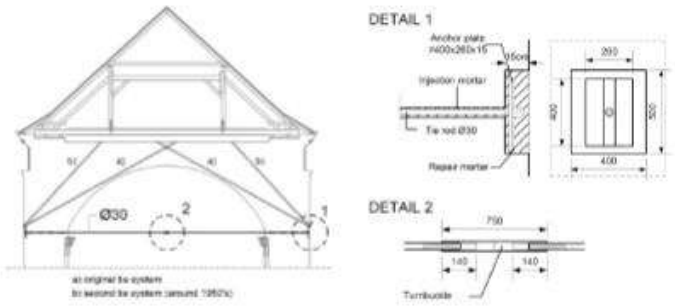



**Fig. 13.** Design of new tie-rods



**Fig. 14.** Old anchors, new anchor plate and tie rod with turnbuckle in the middle of the span

**Strengthening of flat masonry lintels**

Flat masonry lintel was strengthened by placing three steel frames made of UPN140, to accept load from the wall above the opening. The works for the construction of new lintels involve local "grooving" of walls from the inside for installing the steel structure, drilling holes/channels for installing anchor bolts, placing anchors, and filling the channels with anchoring compound (e.g., STABILCEM, MAPEI, or equivalent), placing and securing steel profiles in the designed position, anti-corrosion protection by applying a base coat in two layers and a final coat in the desired color as per the investor's preference. Later on, the steel frame was used as a part of the entrance door structure.

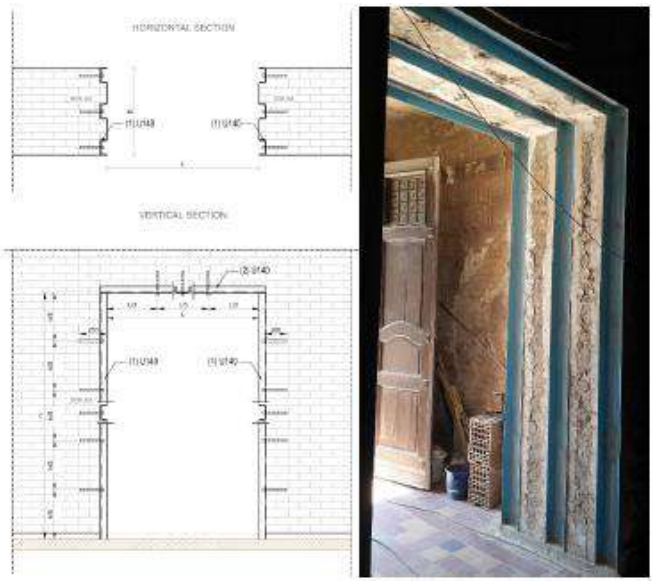


**Fig. 15.** Strengthening of door opening with flat masonry lintel

## 3. Catholic church of the immaculate virgin mary in Bačka Topola

### 3.1. Description

The Roman Catholic Church of the Immaculate Virgin Mary in Bačka Topola belongs to the Subotica Diocese of the Roman Catholic Church. The church was completed in 1906 according to the plans of Ferenc Rajhl, in the neo-Gothic style. It is among the most impressive buildings of sacred architecture in our country, with a tower height of 72.7m and a capacity of 5,000 people. The appearance of the church is shown in Fig. 16.



**Fig. 16.** The appearance of the South facade of the church

The church is essentially in the shape of a Latin cross, with dimensions of approximately 23.5x70m (Fig. 17). It consists of three longitudinal and one transverse nave (transept). The span of the main longitudinal nave is 10.8m, while the side naves are 6.33m wide. The span of the transverse nave (transept) is 10.76m. The structural system of the church is a massive skeletal system, which belongs to the neo-Gothic architectural style and consists of a combination of reinforced concrete and masonry elements.

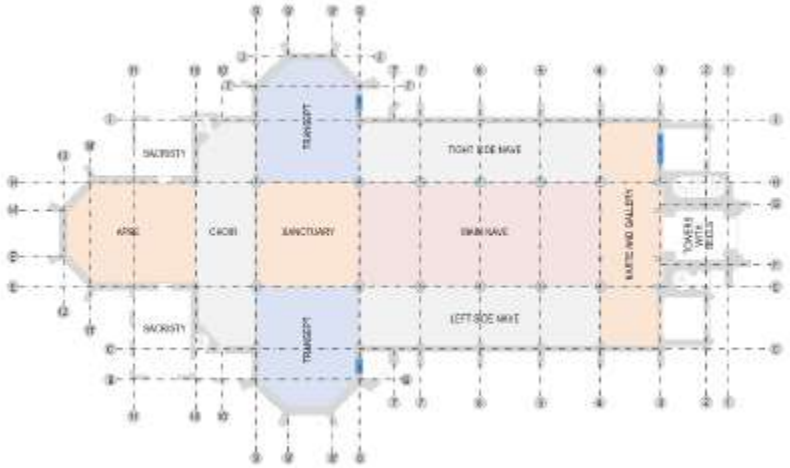



**Fig. 17.** The basic parts of the church with adopted labels for axes

The facade walls are founded on masonry strip foundations, which have the same thickness as the facade walls. The depth of the foundations is approximately 2m. Reinforced concrete columns are founded on isolated foundations, which are

interconnected by counter-arches in both the transverse and longitudinal directions. In the part of the building between axes 1 and 3, there are two sides and one central - main tower (Fig. 18). The supporting structure of the towers is predominantly masonry and consists of masonry columns with buttresses in the longitudinal and transverse directions, masonry arches above openings. Floor strucutres at elevations +4.87m and +15.12m are constructed as masonry cross vaults, at elevation +30.62m there is a solid reinforced concrete slab with reinforced concrete beams supported on steel I300 profiles, while at elevation +35.38m the floor structure is constructed as a Prussian vault. The thickness of the tower walls varies, from approximately 130cm at the ground level to 50 cm at the last level (elevation +34.38m). The main reinforced concrete elements of the naves (between axes 3 and 12) are: internal columns, ribbed cross vaults, and longitudinal and transverse broken and rounded arches (Fig. 1). Masonry elements of the naves include external columns with buttresses and masonry facade walls with broken arches above windows. The main intermediate construction of the church consists of ribbed and stellar vaults, and broken and rounded arches, which are placed in the transverse and longitudinal directions. Masonry walls are constructed above longitudinal and transverse arches, forming "boxes" within which ribbed vaults are located. Steel tie rods are installed on transverse and longitudinal masonry walls. These tie rods connect the facade walls and pass through the reinforced concrete columns in the central part, attempting to reduce the flexibility of the church at the level of the intermediate structure.

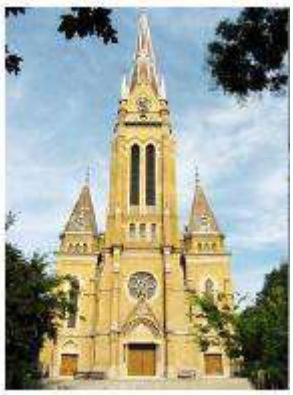




**Fig. 18.** The appearance of the front (west) facade of the church with its towers
**Fig. 19.** The appearance of the church interior with reinforced concrete structural elements

Vertical communication occurs via two spiral staircases, with one (staircase in the G-H/1-3 field) leading to the gallery level (elevation +4.59m), while the other (staircase in the E-F/2-3 field) leads to the levels of +15.12m and +20.62m in the tower. From elevation +20.62m to +34.38m, a new four-flight staircase made of Glulam is constructed. The church has a sloped roof of complex geometric shape, with two gable roofs dominating above the main nave and transept. The primary roof structure is wooden, resting on the facade walls and the tops of central columns. The roofing material consists of fiber cement panels. Above the sanctuary, a tower with a pointed top, called a spirelet, is constructed. The roof structure of the central tower and two side towers is also wooden. Previous works have been carried out to repair the roof structure of the central tower, including the installation of a new reinforced concrete ring to replace the existing supporting structure of the tower. The masonry facade of the church is adorned with a large number of different architectural elements, executed in plaster, facade bricks, stone, or concrete.

**3.2. Assessment of the condition**

In order to prepare the groundwork for a visual inspection of the structure, a detailed survey of the geometry of the building was conducted. Considering the period of construction, the existing project documentation was quite limited. Preparation of graphical backgrounds was done through photogrammetric scanning, which resulted in a point cloud from which a 3D model (digital twin) of the building was created (Figure 20).
Following the preparation of the backgrounds, a detailed visual inspection was carried out [3]. Accessible interior and exterior elements were inspected from ground level, as well as from the floor levels of the church and the gallery, internal staircases and platforms, while for higher exterior elements photographs taken by a drone were used. The subsequent images depict characteristic damages to the structural elements.



**Fig. 20.** Digital documentation preparation: building, point cloud i digital twin

**RC coulmns**

No structural damage that could affect the load-bearing capacity and stability of the reinforced concrete (RC) columns has been registered. Only non-structural damages such as vertical and diagonal cracks in the plaster coating of the plinth and local detachment of parts of the plaster coating have been registered.

**Masonry columns and walls along with pilasters and buttresses**

Structural damage to the masonry columns above the buttresses has been noted. The damages are local in nature and have manifested as widened vertical joints and/or displacement of bricks beyond the plane of the wall, indicating inadequate tension in the load-bearing structure of the church at the level of the intermediate construction. Cracks have been detected in the masonry facade walls on both the external and internal sides, and they differ from one another. Characteristic damages on the external side of the ongitudinal walls are intermittent step-like and vertical cracks, which have occurred due to the widening of vertical joints between facade bricks. There are intermittent vertical cracks on the external side located approximately in the same places as vertical or slightly angled cracks on the internal side. In areas of these intermittent cracks, there are locally cracked bricks. Cracks on the internal side of the walls are more dominant, mostly vertical or slightly angled, with some diagonal cracks. They are wider than 1mm and located in the central part of the wall, mostly below windows and in the angled parapet wall. In the transept walls, angled cracks wider than 3mm have been registered, belonging to the group of damages requiring structural repair. Characteristic damages on the tower walls are angled cracks, mostly above and below openings, as well as cracking and bulging or

detachment of bricks on the buttresses. Considering the disposition of the registered cracks in the lateral naves of the tower, the damages likely occurred as a result of earlier settlement of the central part of the tower. Additionally, on the frontal sides of all buttresses of the central tower, widened and partially washed joints have been registered, with pronounced signs of biological corrosion, most likely due to long-term exposure to atmospheric influences. In some places, there has been bulging and detachment of a larger number of facade bricks.



**Fig. 21.** Expanded vertical joints and partial displacement of bricks outside the plane of the wall, vertical crack in the frieze and roof cornice
**Fig. 22.** Facade bricks falling out, mortar detachment from the cornice, locally detached edges of the fence and terrace slab

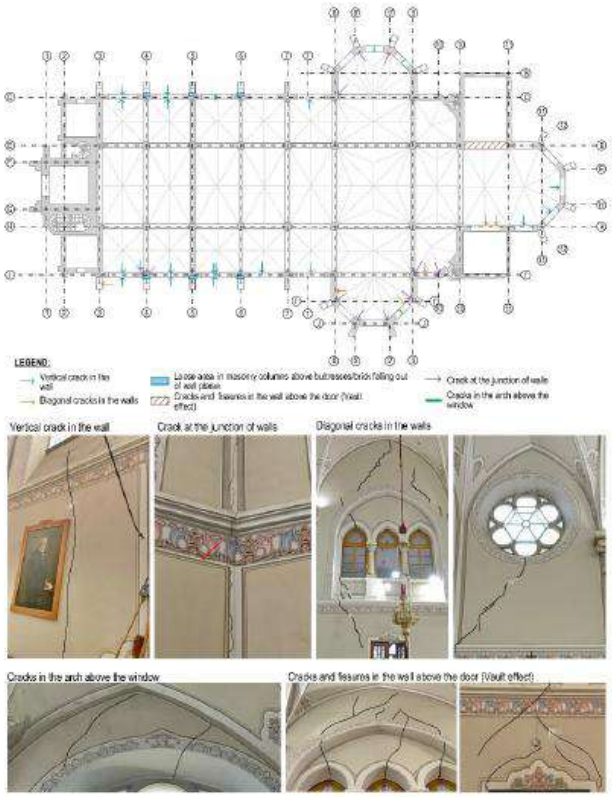



**Fig. 23.** Schematic representation of the distribution of cracks in masonry walls, masonry columns, and buttresses

Above the longitudinal and transverse arches are walls on which steel tie rods are installed. These walls exhibit damages in the form of horizontal and diagonal cracks, disintegrated (loose) parts, and areas where bricks are missing. Diagonal cracks in the walls likely appeared due to insufficient rigidity of the load-bearing structure in the plane of the intermediate structure. Horizontal cracks are most commonly registered at the level of the lower row of steel tie rods. The steel tie rods are loose, locally affected by corrosion, and do not provide adequate connection between the load-bearing structure of the church nave and the facade walls. Since the steel tie rods have lost their primary function, the load-bearing structure lacks sufficient rigidity in the plane of the intermediate structure and, consequently, has reduced capacity for lateral loads (horizontal forces).
The load-bearing capacity of the masonry lintels is reduced both due to the applied structural solution (masonry lintels with steel flanges) and due to the resulting damages (corrosion of steel flanges and transverse cracks).

**Reinforced concrete ribbed vaults and reinforced concrete transverse and longitudinal arches**

There are cracks on the ribbed vaults of the church naves on both the lower and upper sides. The characteristic damage includes cracks visible on the lower - ceiling side of the longitudinal nave and transept, at the junction of the vaults with the supporting transverse and longitudinal reinforced concrete arches. Cracks and fissures along the junctions with the supporting arches are most likely the result of the flexibility of the intermediate structure (vaults and arches) and/or shrinkage and flow of concrete.
There are transverse cracks and fissures on the reinforced concrete arches. They are more prevalent on the lower side of the transverse arches in the side aisles of the church. The cracks are mainly located in the central part of the arches and are the result of insufficient tension in the load-bearing structure in the transverse direction in the plane of the intermediate construction. By comparing the positions of the cracks on the lower and upper sides of the arches, it is concluded that the cracks do not penetrate the entire thickness of the arches.

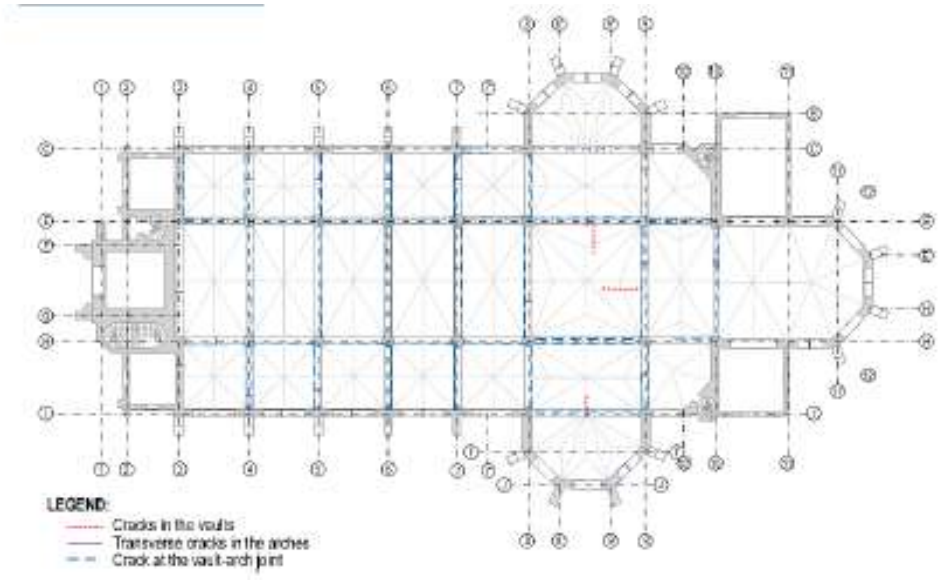



**Fig. 24.** Arrangement of cracks on the bottom side of the vaults and arches




**Fig. 25.** Appearance of characteristic cracks on the bottom side of the vaults and arches

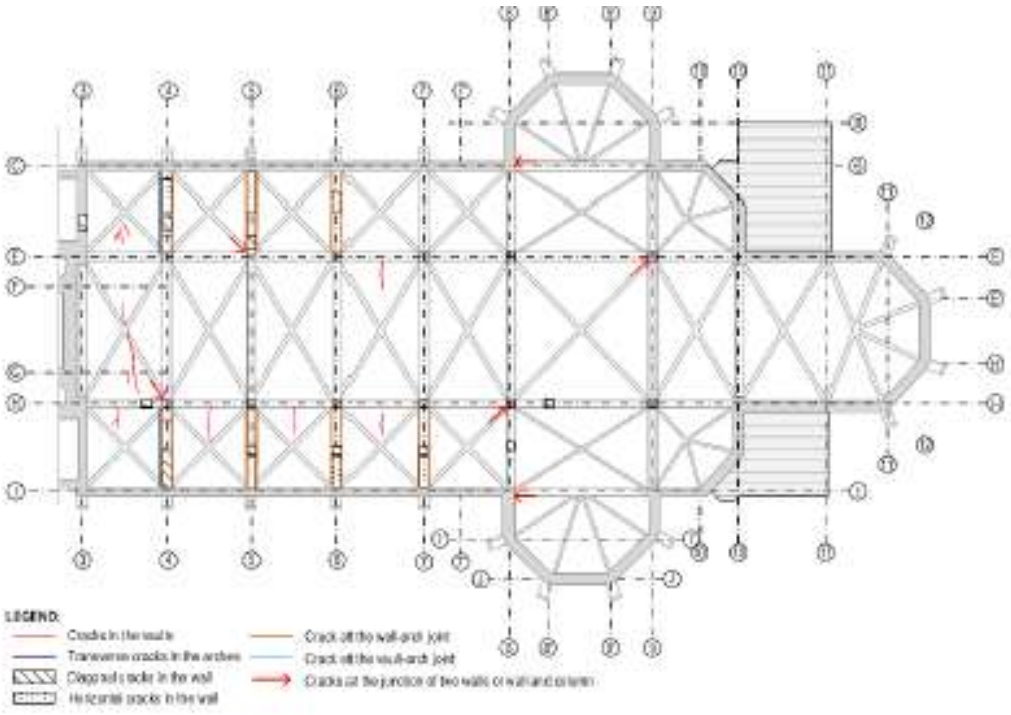



**Fig. 26.** Arrangement of cracks on the top side the vaults and arches




**Fig. 27.** Appearance of characteristic cracks on the top side of the vaults, arches, and walls

**Other registered damages**

Other registered damages are a result of atmospheric exposure, material aging, and biological corrosion. These damages have manifested as surface erosion of bricks and stone copings, the appearance of moss and lichens, worn-out, cracked, and washed-out mortar joints in facade walls, cracking and detachment of plaster in plaster friezes, sloping parapet walls, and base courses of facade walls, as well as in other areas where facade "plastic" is applied. Inside the church, these damages have manifested as damp stains, flaking, and detachment of plaster and decorative paint.

**General conclusion**

Based on the condition of the registered damages, the following conclusions might be drawn:

- The functionality of the church is not compromised.
- The load-bearing capacity of the structure is locally reduced for lateral loads, especially in the plane of the intermediate structure of the nave and the central tower.
- The load-bearing capacity of the lintels is reduced, while the stability of the walls above the openings in the apse is compromised.
- The facade walls, where larger cracks are registered, have locally reduced stiffness in the plane of the wall.
- The durability of the building is partially reduced, predominantly concerning facade elements.

The general condition of the church's structural elements is such that appropriate structural and non-structural measures can ensure the necessary load-bearing capacity of the structure for lateral loads and satisfactory durability.

**3.3. Repair solution**

The structural rehabilitation solution for the church encompasses all defects and damages identified during the visual inspection, and the following works are planned [4]:

**Rebuilding parts of masonry elements**
This repair technique is envisaged at locations where parts of the masonry columns/walls are loose, with individual bricks protruding from the plane of the built column/wall, or where cracks are evident in the buttress (clear separation of the wall mass).

**Repointing deteriorated and missing mortar joints in facade elements**
This remedial measure is planned for the church's facade walls, including the tower, in all areas where mortar is missing from joints deeper than 2cm or where the joint is filled but the mortar is deteriorated and cracked.

**Strengthening parts of masonry walls with significant cracks (stitching technique)**
This repair technique is intended for masonry walls with cracks, identified in the church's condition analysis as walls requiring structural rehabilitation.

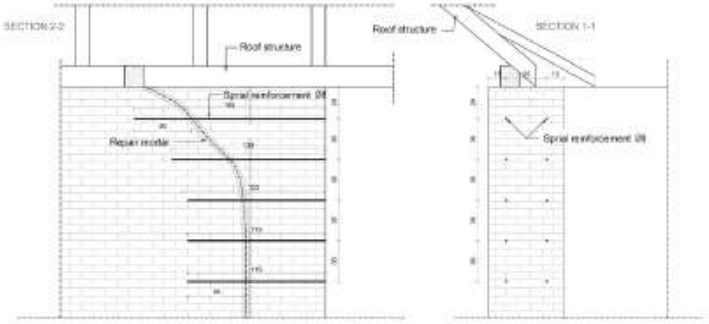



**Fig. 28.** Rehabilitation of masonry walls with cracks using the stitching technique

**Stiffening of reinforced concrete arches with RC ties**

This repair technique involves installing RC ties in level with existing steel tie rods above the arches and along the facade walls.

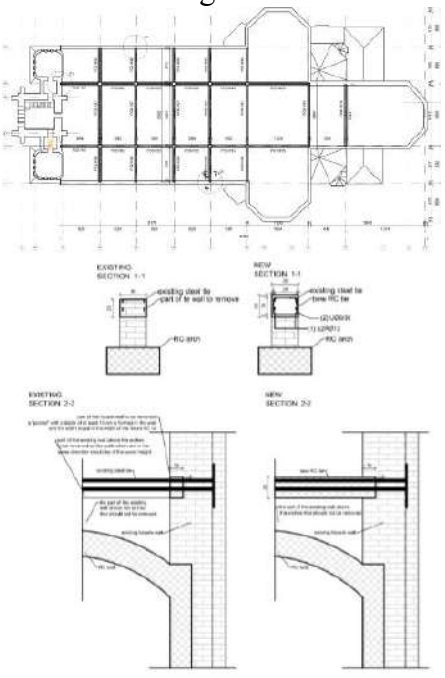


**Fig. 29**. Stiffening of reinforced concrete arches with RC ties

**Bracing of the walls of the central tower between levels 3 and 4**

Considering that the central tower is constructed as a slender masonry structure with large openings in the walls, reducing the overall stiffness of the structure, and that the height between the rigid floor of levels 3 and 4 is approximately 17m, new steel bracings are designed to reduce the length of deflection of the masonry walls/columns.

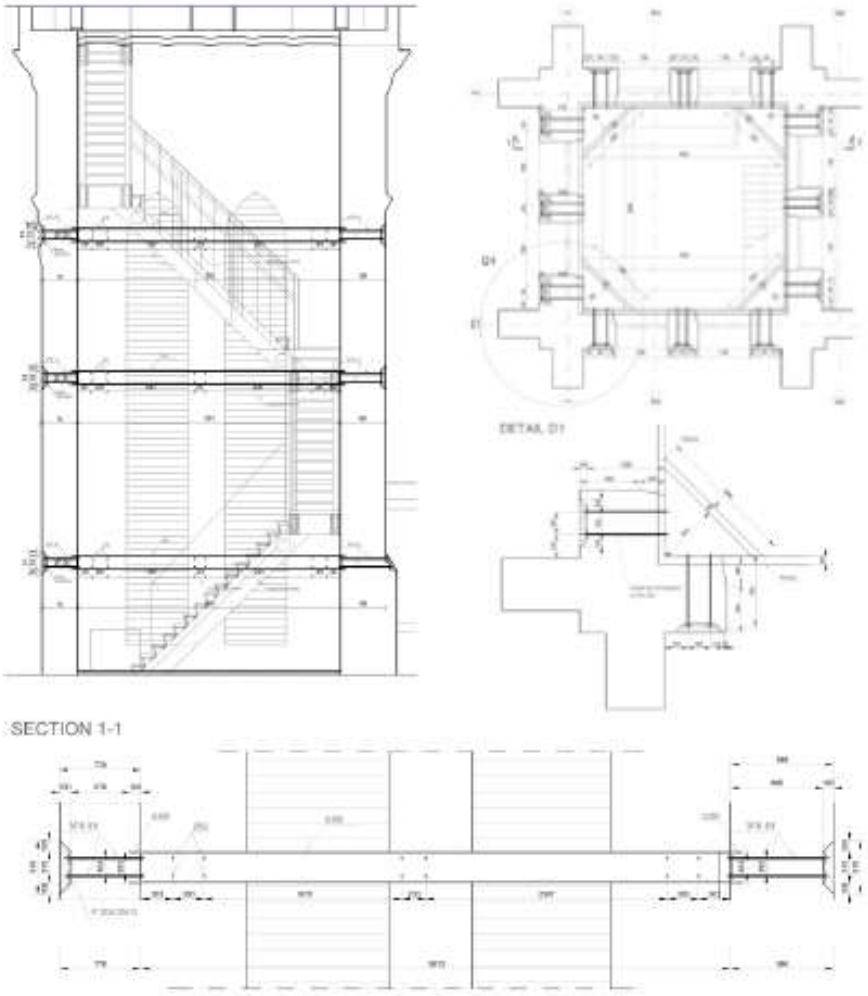



**Fig. 30**. Bracing of the walls of the central tower between levels 3 and 4

**Strengthening of lintels**

The installation of a new lintel is planned for lintels that have been damaged in the area of openings due to the insufficient load-bearing capacity of the current lintel system and compromised durability (same principle as explained on Fig. 14).

**Repair of cracks and fissures in reinforced concrete arches and vaults**

Injecting cracks, as a structural rehabilitation measure, is envisaged for the joint of reinforced concrete arches and vaults. This repair technique is chosen because it allows for the restoration of the compromised integrity and ensures the joined functioning of these structural elements.

**3.4. Note**

Assessment and repair solution are part of a restoration project issued by the Roman Catholic Parish of the Immaculate Virgin Mary in Bačka Topola. The project is done by consortium between the Institute for testing, assessment, and repair of structures LTD Novi

Sad (responsible person: prof. dr Vlastimir Radonjanin), Design and Supervision Bureau for Building Construction "Rind Project" Bačka Topola (resposible person: Anzelm Rind), „Perfekt Elektro doo Subotica“ (resposible person: Zoltan Berta) and Art Workshop „Restauro“ Nova Crnja (resposible person: Karolina Biači).

## 4. Conclusion

The analysis of the two historically significant churches, both designated as cultural heritage sites, reveals a set of common structural damages primarily attributable to their inherent architectural vulnerabilities. Although they have different structural systems, one built as a massive masonry structure and the other as a combination of masonry and reinforced concrete structure, the recognizable and most vulnerable elements of the structures are common to both. In both structures, the common issue is that the vaults were constructed without horizontal ties in the zones where the arches rest on the vertical supporting elements (walls and columns). This has led to the spreading of the walls at the top and the appearance of cracks and fissures due to the lack of lateral rigidity. It has emerged as a significant issue, compromising the overall integrity of these structures. Additionally, characteristic damages include cracks and fissures in the areas around openings, as well as weathering-induced deterioration that further aggravates the condition of these buildings, highlighting the cumulative impact of environmental factors over time.
Based on the conducted survey, it can be concluded that the global as well as the local stability of the structures is endangered, and hence the load-bearing capacity of the structures is jeopardized. Also, the durability of the buildings is particularly vulnerable, considering the importance of protection of cultural goods and ornaments whose further decay must be prevented. The findings underscore the necessity for a targeted restoration and preservation strategy that addresses these specific vulnerabilities. Overall, this study provides a critical foundation for informed conservation efforts aimed at preserving the structural and historical integrity of these irreplaceable architectural treasures.

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# VARIABILITY OF THE URBAN CONCEPT IN THE 18th CENTURY IN VOJVODINA

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***Abstract -*** *The extraordinary strategic position of the Panonian plane was the reason why this part of the Europe turned into hands of many rulers. Such was the case with many settlements of this territory through history. The consequences were drastic, several times the complete changing of the building and urban conception of those towns. At the end of 17th and during the 18th century, there were several wars of variable success between Turkey and Austria*

*After the second decade of the 18th Century Turkey had lost forever the territory of the Panonian plain between the Sava and Danube Rivers. The border between the two empires was very fragile and established with great difficulties. The time of war always brings the changing of the building and urban structure of the settlements exposed to the military destruction.*

*What was the image of such a town in the Panonian plane with all this changing of rulers, demographic migrations, urban structure and architectural appearance? General conclusion is that during the 18th century, cities in Vojvodina changed the oriental settlement structure to the European one in different, faster or slower ways. Although the baroque principles of urbanism prevailed in the 18th century, it could not be fully applied in the area of Vojvodina, precisely because of the conceptual discontinuity in settlement planning, i.e. the differences between oriental and European social organization.*

*The paper deals with the different types of oriental town planning in Vojvodina, which can be recognised from the very scarce material data, descriptions by travel writers, the contemporary and latter plans and engravings. Even those data are very poor it is possible to reach certain conclusions about the remains of the oriental characteristics of the towns in Vojvodina before they were completely reorganised after the town planning principles under the Austrian rule.*

***Keywords –*** *Vojvodina, 18 century urban planning, oriental planning, city planning transformation*

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## 1. Introduction

In the geographical and cultural terms, Vojvodina consists of three parts, Srem, Bačka and Banat. From the beginning of the Common era, the territory of today's Vojvodina, which is part of the Pannonian Plain and the Carpathian Basin, was the final destination of the steppe peoples from Eastern Europe. Srem was part of the Roman Empire civilization for almost five centuries, and Bačka and Banat were a part of the Terra Barbaricum at that time. The Christianization of newly arrived peoples began in the 10th century, and thereby began the period of feudalism that led to the creation of the nucleus of future cities. First of all, they represented administrative and religious centers at strategically important points. During the 14th and 15th centuries, a specific Western European civilization with a mixture of Western and Eastern culture and numerous settlers developed in this area. This is how cities of the *civitas (city) and oppidum (fortified city)* types arose [1].

The wars of the Kingdom of Hungary with the Turkish Empire that followed, as well as the internal conflicts, did not favor the development of cities, and then the wars between the Austrian and Turkish Empires completely devastated and laid waste to this area. Vojvodina then gradually began to develop again and the cities were partially built on the basis of the medieval matrix of cities, and this is an integral part of the urban heritage that is today in the domain of archaeological research.

At the end of the 17th and during the 18th century, significant historical events took place on the territory of the present day's Vojvodina, which significantly influenced the change in the population structure and the urban design of cities. Getting to know the way of action in space by creating new forms of the built environment transcends ideas about the architecture of that era.

Presenting the facts about architecture, despite the difficulties encountered during a research, has its own understandable course. Considerably more complicated, however, than what the buildings in a settlement looked like, is the search for the origin and inception of the settlement itself. These researches cannot stop only at ascertaining the physical characteristics. Namely, the material traces do not provide information about a whole series of other spiritual, immaterial peculiarities that constitute a settlement. That is why concepts about the cities during the 18th century in Vojvodina are still insufficiently defined and somewhat romantic.

In the desire to gain knowledge about a settlement and an idea of what it looked like in a certain period of its existence, as a rule, one starts from the current data, and by looking back into the past and decomposing, breaking down the factors that make up the settlement fabric, one arrives at those that were of an importance to the settlement at certain time stages. In the case of settlements in Vojvodina, the 18th century is undoubtedly one of the most significant periods when there were changes in the urban structure and the formation of the one that is still recognizable in the old city centers of most cities.

There is a different way of looking at the 18th century in different parts of Europe. For the Italians, it was the time when they eventually lost primacy in arts and the beginning of the preparations for the unification of the states on the Apennine peninsula. For the English and the French, it is a significant period in which the mature baroque expression was completed and the principles of the baroque city were realized, but also when the classicist architectural expression was defined. In German-speaking countries, influences from Italy, France and England were absorbed and the foundations of the scientific archeology were laid. All together, they reveal the immense beauty of the ancient Greek art, which preceded the Roman art, which until then was considered the most important one. In all those areas, the evolutionary process of the development of cities took place.

In the area of Vojvodina, the situation was different. The entire territory of today's Vojvodina was subordinated to the Ottoman Empire until 1552. In rural areas, there was a predominant Serb population, while in cities, the population was ethnically and religiously mixed. There lived Turks, Islamized Serbs, Arabs, Roma, Greeks, Aromanians, Jews, Bunjevci. The last, so-called Great Turkish War was fought on the territory of Vojvodina from 1683 to 1699. It ended with the peace signed in Sremski Karlovci, when a large part of the area was liberated, except Banat. Banat came under the rule of Austria after the war fought from 1716 to 1718 between the Ottoman and Austrian empires [2].

In the Pannonia Plain, the transformation of an oriental-type city into a European city, which, in a specific way, is still ongoing in some cities, began in the first decades of the 18th century, and this process later spread to other parts of the Balkan Peninsula. According to Radovan Samardžić, the first modern civil society on the soil of the former Kingdom of Hungary and the Austrian Empire was created in this area at that time [3]. These people were direct participants in the formation and use of urban and architectural factors that marked the development of architecture in the 18th century. The question arises, what was the environment in which people lived at that time? It is difficult to come by even a partial answer, while the entirety probably cannot be completely reconstructed.

The cities of Vojvodina represent the only non-agrarian oases in an otherwise distinctly agrarian region, making a striking contrast in terms of the development of this territory. Status charters of cities were mostly granted during the 18th century, but even without this act of obtaining a kind of autonomy, the cities underwent a very interesting process of physical transformation.

## 2. Urban heritage of Vojvodine at the beginning of 18th century

During the 16th and 17th century, the area of the Pannonia plain was under the rule of the Turkish state. The previous, medieval forms of settlements were successively replaced by new structures. In contrast to villages, cities quickly acquired the character of oriental-type settlements [4]. In this period, cities are formed and upgraded according to the rules of oriental urbanism, which recognizes a certain degree of spontaneity in using the natural conditions of the immediate environment. The medieval fortresses that were not destroyed during the conquest campaigns were being adapted to the defense needs of the Turkish army, and new fortifications were built according to the principles of the oriental military strategy. In the oriental urbanism, the zoning of city functions is pronounced, so that the central city zone is intended for commercial and craft activities, that is, *čaršija* (bazaars) are formed, while residential clusters, *mahalas*, are created around the perimeter. The architectural program was adapted to the needs of the oriental city, mosques, inns, hammams, madrasas and maktebs were built, as well as characteristic forms of enclosed residential buildings.

The people of Western Europe breathed a sigh of relief at the end of the 17th century, after 1683, when the Turks were defeated at Vienna, but in the Pannonia Plain the two great powers, Austria and Turkey, continued to wage the war with fluctuating fortunes. Although since 1718 the Turks no longer ruled even the remnants of their conquest across the Sava and Danube rivers, Eastern Srem and Banat, the border between the two empires was fragile and difficult to establish. As a rule, times of war change the structure of settlements in an area exposed to destruction. This was also the case during the 18th century, but in cultural terms, the Turkish influence will be felt for a very long time even after the withdrawal of the Turkish army and

population. So what could a settlement that changed owners, population structure, urban structure and physical appearance look like?

For the area of Vojvodina, which was under Turkish rule for many years, these were certainly the so-called oriental type settlements. There is much more written than graphic data about the appearance and character of those settlements. Nevertheless, the general rules of urban planning of oriental settlements are better known nowadays than before, and that is why it can no longer be defined as it was the case in the older researches, in short, as "spontaneous construction". On the contrary, there were defined, even codified rules in the urbanism of the oriental type, but the logic of that urbanization, i.e. the settlement process, is foreign to us today, and its study was also marginalized for justified reasons.

Religion and administration in cities where the Muslim faith was dominant are interwoven to such a degree that most modern researchers believe that one can speak of an Islamic type of city. Considering the concept partially inherited in continuity from the antiquity as well as certain elements taken from early medieval Christian cities, the term ‘city of the oriental type’ used here was also adopted for the same form.

Islam as a religion emphasizes the enclosure and secrecy of private and family life. The settlement was therefore an aggregate of houses that, outwardly, do not manifest a clearly defined form or meaning. In such a fabric, endowment complexes with mosques as a central motif had the greatest value. The city becomes a compact organism, often enclosed and differentiated in different zones.

The narrowest, central zone of the city is usually occupied by the trade and craft center. Each ethnic group or religious community inhabits a separate quarter, a *mahala*. The area around the city gates served as a gathering place for citizens from all over the city. Immediately behind the gates that led into the city, a network of tangled streets and alleys emerged where gathering was not possible, and was even forbidden. The winding nature of the streets arose from the logic of tracing the shortest route to a specific location, and not from any carelessness of the concept.

Considering the dynamic older history of this territory, the Oriental-type city in the area of the Pannonia Plain probably arose from an older type of settlement conquered or gained in war, which continued to live and develop after the conquest by Muslim forces. Such a city further had three possibilities for survival.

The first option was to restore and further develop the model of the city that had been conquered.

Another way was to adapt the inherited model in order to adapt it to specific Islamic requirements. This particularly applies to the construction of Juma-mosque (for worshiping on Fridays) and central administrative buildings.

The third option was bridging or connecting two previously different but not distant city entities (existing and new) in order to achieve better governance.

If the city was built from scratch, then it could have been created in two ways. The first way was without a prior plan or model, except for the well-considered and carefully chosen location of the Juma-mosque and the Dar al-Imara.

The second group is represented by cities built according to a predetermined plan or model. There, one can distinguish three subgroups that mark the further development of Islamic cities:

a. - Fully planned additions to the already developed older cities, whereby the newly created combination possesses many features of the cities from the aforementioned classification. The older parts of such a city are usually examples of spontaneously created units, in which it is not possible to make administrative or religious buildings stand out, so this is achieved in better

planned segments. In such cases, the old part of the city, often neglected, still manages to maintain its commercial importance.

b. - Gradual renovation within the planned additions and/or removal of parts of the city that were developed according to the older model.

c. - Establishment of new residential districts on certain gaps that remained undeveloped within the defined city; then, the formation of suburbs directly next to the city walls or in sight outside the city, along determined road routes [5].

This general typology of oriental cities indicates the inherited differences: building forms and functions were inherited or adapted from old conquered centers; others were created or developed on the basis of purely Islamic experience, new physical conditions, of manifested temperament and taste. Based on the diversity of these factors, it is possible to create a physical profile of many cities, a profile that, when completed, shows the essential characteristics of each city individually and what makes it distinct from others.

The social profile can reinforce, but cannot contradict the purely physical, because social norms can be acted upon, while the physical form of the city is based on true indicators.

Therefore, if urban settlements of the oriental type are discussed, they can be classified into open and closed, that is, fortified. The open settlements were further divided into *varoš*, *kasaba* and *šeher*, and fortified ones were *palanka, hisar* and *kale*, with corresponding sub-structures, which could also be of the *varoš, kasaba* or *šeher* type [6].

If this division is checked on Vojvodina settlements from the period when they were under the Turkish rule, then it can be seen that they completely fit into such a classification that was specified by the law.

When reading the descriptions of Evliya Çelebi and other Turkish travel writers, one notices that they know the classification of the settlements of their country and present them according to that classification. Evliya Celebi describes Banoštor, Subotica, Sombor, Pančevo, Futog, Kovilj, Martonoš, Tovarnik, Sotin, Senta, Bečkerek, part of the Banatska Palanka and a number of others as *palanka*, but he speaks of Bač as a fortress (*kale*) with an outer *varoš* (town), Vojka is presented as a village; Irig was a *kasaba*, as was Novi Bečej, while Sremska Mitrovica, Grgurevci, Slankamen, Karlovci, Petrovaradin, Čerević are mentioned as *šeher*.

### 3. Transformation of the urban structure in Vojvodina during 18th century

The Ottoman Turks controlled the area of today's Vojvodina from the early 16th century, while from the end of the 17th and during the 18th century, this territory gradually came under the rule of another great power, Austria, whose development was delayed in relation to the duration of the Turkish Empire. In order to discuss this major change, which reflected in the development of settlements, it is necessary to firstly briefly consider the principles of urban development in this large country, those same principles that would directly affect the transformation of Vojvodina settlements.

After the wars with Turkey, Austria experienced a sudden urban boom, which incorporated European experiences, especially those of Italy and France. Vienna became the capital of the country, and began to spread its cultural influence on all the Danubian, Pannonian and Balkan peoples. The capital itself is experiencing a demographic increase accompanied by urban systematization and general architectural decoration of the city. In the first decades, a second protective line of fortifications (Linienwall) was built, which encompassed the suburban extensions formed along the directions of the main communication arteries. The suburbs were then often grouped around the summer residences of the nobility whose monumentality is still

striking today (Belvedere, Schwarzenberg, Convent Salesiani, etc.). The second building impulse took place in the middle of the 18th century due to the industrialization encouraged by Empress Maria Theresa and Joseph II. It is characterized by the construction of civil and commercial buildings. With this method of construction, Vienna took on a recognizable baroque appearance. And the Baroque city is considered one of the most influential city models in history.

During the 18th century, that is, already at the end of the 17th century, there was a marked development of absolutism in the state management. Since the 16th century, the Church has been in the Counter-Reformation, so the confirmation and symbolism of such authority was reflected in the urban development and architecture. Recognizable features of urbanism that meets the requirements of such an authority are:

- formation of very clear and recognizable architectural entities;
- the dynamic, undulating wall mass of individual buildings is also implemented in the concept of the whole city, there are, first of all, circular, elliptical, complex squares, etc.;
- large, long axes are introduced, which end with a prominent, eye-catching motif. These principles express the desire for urban monumentality, regardless of the actual size of the city.
- large squares are created that are formed as negative spaces, i.e. voids that are used to join the aforementioned axes. In the Baroque, this empty space has the same value and importance as the positive (built) space;
- the orthogonality of the street directions and the resulting construction of blocks is inherited from the times of antiquity. In the Renaissance, the orthogonality was only theoretically considered and only partially empirically tested, and in the Baroque it was codified in the form of regulatory plans and various construction regulations.
- the relationship to nature is such that it is subjugated (gardens and all greenery is cut and shaped), and natural traffic routes and waterways are also subjugated [7].

In the area of the Pannonia Plain, two models of the city, oriental and baroque, occurred in succession, and their mutual relationship was expressed in a large number of variants. That relationship was not always physical, it was not expressed through demolitions and new construction, through erasing the street matrix and planning a new one. It was the fluid of the oriental spirit that, during the 18th century, hovered over the newly built city fabric for a long time.

Until 1699, that is, until 1718, the greater part of the Pannonia Plain was within the Turkish state for over 150 years. The oriental civilization, which was destroyed in the wars of the late 17th and early 18th centuries in these parts, lasted for a long time in the habits of the people, social nature and the appearance of the country.

Such development was complemented with the influence of the immigrants from the Balkans, who arrived mostly with the same or stronger habits, which they were very reluctant to relinquish. The colonization of other nationalities from various parts of Europe brought a completely different social organization and way of everyday life.The new government, considering the many years of exhaustion in the wars, could not change the everyday way of life and the entire architecture of the conquered cities overnight. It was only during the reign of Empress Maria Theresa (1740 - 1780), when a series of reforms were introduced, that the influence of oriental civilization and its concept of the city was more seriously diluted and removed.

The area of today's Vojvodina was for centuries on the frontier between the powerful states of Turkey, Austria and Hungary. During the 18th century, such a position diminished the importance of its extremely fertile soil, which is the main reason for the settlement of ordinary

residents. Regulating watercourses requires longer periods without war disturbances, so such an undertaking could hardly have been realized before the 18th century. The river bank training, the construction of canals and other amelioration works, in addition to the frequent struggle against the water element, are related to a new form of planning and urbanization during the 18th century. For the same reason, the settlements did not develop to their limit of their possibilities, but in most cases, due to the complexity and layering of different influences, they appeared unfinished or incomplete.

Urbanism of the 18th century can therefore be seen as a conflicting process of two different approaches to building. What, for example, is called spontaneity in oriental urbanism is, in fact, the result of deep consideration whereby everything that nature has given, strategy and material, is used to the maximum. A winding street is not like that by chance, it is winding, because that is best way of overcoming the obstacles on its route. A planned layout of the settlement, however, breaks and neglects many natural effects, justifying it with the organizational plan or brings them into an unnatural position.

The middle of the 18th century is very important for Vojvodina towns, because it was mostly the period when they got their status privileges. Obtaining the city charter, in addition to a number of other determinations, means the planned introduction of order and the direction of the development of the settlement in the manner prescribed administratively by the Austrian authorities. The regulatory foundations, the cadaster and building regulations were also adopted in the 18th century. They introduce an orthogonal street matrix, horizontal and vertical alignment and a number of other elements characteristic of the baroque model of the city. The specificity of the area of Vojvodina is the division introduced at the beginning of the 18th century into a civil and a military territorial-political administration. The military administration represented a part of the wider Military Border, while the civil administration was within the counties.

Although the planning and urbanization of cities in the 19th century and the first half of the 20th century are considered the most dynamic processes that defined their present-day structure, yet the transformations that occurred during the 18th century represented the stem of all future spatial and urban plans. Basic communication routes, gathering centers as well as the orientation of most settlements, if they are not of an even older origin, can be glimpsed in the rudimentary forms created during the 18th century. This can be seen in several examples that show in the most illustrative way the process of transformation of the urban structure during the 18th century [8].

For the longest time, the word *varoš* remained as the term that connects both settlement models. This Hungarian word in the Turkish urbanism was primarily used to designate a suburb of a town, and the second, more common meaning was a town-type settlement that is exclusively or predominantly inhabited by Christians. When in such a settlement the inhabitants converted over time to the Muslim faith, the name *varoš* was retained to only one or several Christian *mahallas*, i.e. residential districts. The same word is used in the urbanism of the Austrian state to mark parts of the city where the population is of different nationalities. When it comes to such a division, in an oriental-type city it corresponds to the division into *djemats* and *mahallas*. The djemats were organized according to religion (Muslims, Christians, Jews), and the mahallas had an appropriate place of worship, primarily a mosque, but also a Christian church.

Settlements of the oriental type consisted of two parts, the *čaršija*-bazaar (craftsman and trade part) and the mahallas, residential parts. That division persisted for a long time even though architecture itself was undergoing a transformation. A good example is cited by Ivy Kugli Lentić for Sremska Mitrovica: in 1729, the so-called Imperial House was the first one-story brick

building in the bazaar. Until then, the bazaar was all about wooden "chardaks", which were only replaced by walls towards the end of the 18th century, as confirmed by the inscriptions in the stone over the gates of those houses [9].

It is difficult to enumerate, analyze and explain all the peculiar forms in which the oriental and baroque model of the city were intertwined, it can only be stated that it is an interesting area of research that is the best testimony of the strength and vitality of a settlement once built to persist in various spatial forms and to survive different architectural concepts. According to research throughout the history of the development of Vojvodina, there were a large number of settlements that were extensively developed during the period of the Turkish rule, but over time they fell behind or were abandoned, and some began to develop as cities in the town planning sense only during the 19th century. In the paper, through the briefest descriptions, only certain cities are presented. Even today, those cities represent significant centers of urban development in Vojvodina.

Today's Sremska Mitrovica is a town and pier on the left bank of the Sava in Srem, built on an alluvial plain with dry beams. The area was inhabited in pre-Roman times, then there was Sirmium, the capital of the Roman province of Pannonia Secunda, and during the time of Diocletian it was one of the four capitals of the Roman Empire. During the Middle Ages, the city was ruled by the Huns, Gepids, Avars, Byzantines, Bulgarians and Hungarians. The city was under Turkish rule from 1521 to 1718, and in the middle of the 18th century it became an important center on the military border between Austria and Turkey. The greatest changes to the city fabric were made during the 18th century, but in the city matrix, in some parts, the remains of the Turkish urban planning layout are recognizable [10].

In addition to the extremely valuable remains of ancient and early Christian Sirmium, whose stock is being constantly enriched with new forms in the course of the archaeological research, today the most significant examples of church, public and residential architecture that have been preserved are those from the 18th and 19th centuries. Under the Austrian rule, Sremska Mitrovica belonged to the Military Frontier, and from the period of the 18th century, an interesting example of a transitional form from oriental to western European urbanism has been preserved. It is the Square called the Grain Market. This area has the characteristics of a Turkish urban structure, it is triangular in shape, with irregular sides, the streets meet on the slopes, and the surrounding streets are winding and narrow, with several passages and dead ends (blind alleys). However, during the 18th and then the 19th centuries, commercial-residential type buildings were built around the perimeter of the square. Some have arched gable ends, the so-called "Nuremberg" gables, indicating a German influence, probably of the settlers. Military buildings have mostly been preserved in this city, such as the military border building, the headquarters of the Petrovaradin Ninth Border Regiment, known as the "Lieutenant Colonel's Apartment" from 1747, and the Main guard building from the second half of the 18th century. On the banks of the Sava, one of the economic buildings, the Granary or Vojarna from 1774, with a very distinct Baroque style, has been preserved. The granary on the Sava, Vojarna, is one of the rare preserved economic buildings from the 18th century, of large dimensions, with a ground floor, two floors and a high attic space that was also in the use. It was built according to designs that were typical and made in Vienna. Among the residential buildings, the House of the Bajić family, built at the end of the 18th century, but outside the urban context of the 18th century, is very well preserved (Fig. 1, Fig. 2) [11].




Fig. 1. Grain Market in Sremska Mitrovica with findings from the Roman period and buildings from 18th and 19th centuries (after https://radiofruskagora.com/?p=33037)



Fig. 2. Military-frontier house, Granary, the Bajić family house
(after https://zavodsm.rs/spomenici-kulture-u-sremu/)

**Vršac** is the second town that was located within the Military Border during the 18th century, built on very fertile and high-quality land This city was developed by the Turks below the medieval fortified city, on a very fertile soil. A quadrangular *palanka* made of rammed earth with a supporting wall was first built there, and then a town developed outside the *palanka*. Evliya Celebi mentions that Inside the rammed earth fortification he saw a modest mosque with a wooden roof and a minaret and eight wooden houses for the accommodation of soldiers. He mentions about three hundred buildings in the town, some of which had a storey over the ground level. There was one mosque and two masjids, a madrasa, a tekye, two maktebs, a hammam, two inns and a bazaar with over a hundred shops [10]. Today's names: *Čukur mala, Požarevačka mala, Irig mala, Radakova mala* bear witness of the settlement of the residential areas of Vršac at that time. Serbs from Peć and Dečani from Kosovo and Metohija began to settle in 1690, after the Great Migration of Serbs under the Patriarch Arsenije III Čarnojević. Their life in their new habitat was still very precarious and it is recorded that in 1698 the Turks massacred the villages around Vršac. The Turkish population that also lived in this territory was expelled in 1716. Since then, German settlers have become very important and influential in the field of construction. They built the "German" Vršac next to the Serbian settlement created at the end of the 17th century, next to the vineyards [12]. At the end of the 18th century, the Jews also organized their municipality with the land they received to build a place of worship, and they also began to form their own cemetery.

At the end of the 18th century, in 1794, a map of Vršac was created, which very illustratively shows the remains of settlements that have the character of oriental urbanism, and it

is contrasted to the forms created under the influence of Western European urbanism, with neat, orthogonal street directions (Fig. 3, Fig. 4) [13]




Fig. 3 The map of Vršac from 1794 and the modern plan of Vršac with the old names of the districts (*Iriška mala and Radakova mala*) (after htp//www.facebook.com/stari.vrsac/photos/1794/2770728929654426/?locale=ar_AR)

Fig. 4 The two oldest houses in Vršac: the Pharmacy on the staircase (mid-18th century) and the inn "Kod dva pištolja" ("At two pistols" (end of the 18th century) (after http://spomenicikulture.mi.sanu.ac.rs/spomenik.php?id=1051)

Individual buildings created in the 18th century have survived, but they have been drastically changed, both in the interior and exterior, so that only archival data exist about them. One such example is Vladičanski dvor (Bishop's residence), which is known to have been built between 1750 and 1757. This extremely imposing baroque palace was radically renovated in 1904. Vršac only became a free royal city at the beginning of the 19th century, in 1817 [14].

The third town developed on the line of the Military Border is **Pancevo**, was created on a loess plain. The history of settlement in the area of Pančevo is very long, because that position has always been strategically important. It was conquered by the Turks in the 15th century, and was liberated in 1716. From then until 1764, it was a logistical point, and from 1764 to 1794, it was a military frontier trading post. During the 18th century, the town was inhabited by Serbian families from Timisoara and its surroundings. Then came the Germans from Franconia, the historical region in the north of present-day Bavaria. During the colonization, a large number of settlers died from various diseases, because the area was swampy and gradually dried up into fertile soil. It is also recorded that there were major conflicts between the indigenous population and the settlers [15]. During the 18th century, a large number of buildings were built in Pančevo, the most interesting of which are those intended for the military administration. However, it is curious that some parts of the National Brewery, built as early as 1722, have survived. It is a significant industrial building that testifies to the development of a settlement with urban content. This complex was later continuously extended, and it consists of a series of additions and it is difficult to imagine its original modest appearance. Among the religious buildings, the Minorite monastery with the church of St. Carlo Borromeo built in 1757 has been preserved. Together

with the smaller square, it is the oldest urban entity in Pančevo [16]. Military buildings that were built for the needs of the defenders are the Provision Store from the first half of the 18th century, and for the needs of the administration of the Military Frontier, the Baroque Red Warehouse was built for grain storage, built from 1785 to 1787, and the Border Guard's House from 1792, which shows a pronounced Baroque influence (Fig. 5, Fig. 6, Fig. 7). Many more buildings that have defined the present day's urban matrix of Pančevo were built in the 19th century [17].




Fig. 5 Map of Pančevo of 1766 and Cadaster map of Pančevo of 1769 - 1972.
(after https://staropancevo.wordpress.com/author/epo7011/page/8/)



Fig. 6. Pančevo: Minorite abbey (after https://www.catholic-zr.org.rs/language/sr/pancevo-2/) and the Red Provisions storage (after https://www.start013.rs/crveni-magacin-nije-u-pitanju-samo-boja-spomenik-trgovacke-istorije-panceva/)

Considering the position of today's **Novi Sad**, the history of its settlement is very long, complicated, and therefore interesting. The city developed in complex natural and urban

conditions. It is located on the banks of the Danube, but with a different development context. The geomorphological conditions were different. Directly next to the riverbed on the right bank of the Danube is the Petrovaradin rock. The terrain along the left bank of the Danube was marshy and was not the most favorable terrain for settlement. As a result, the development had to be different. Traces of life have been recorded on the Petrovaradin Rock since the Paleolithic, while sporadic settlement on the left bank can be traced back to the Neolithic.

The area on the plateau and around the Petrovaradin rock has an extremely important geographical and strategic position. The Hungarians had a medieval fortress on the top of the Petrovaradin rock, where they allowed the formation of a Cistercian monastery. This fort gained importance when the danger of Turkish conquests appeared. In 1501, Archbishop Peter Varadi rebuilt the fortress. It did not help for long, since during the time of Suleiman the Magnificent, and under the command of the Grand Vizier Ibrahim Pasha, the fortress was conquered in 1526. In the description of Evliya Čelebi, it is stated that the fortress, which had a hexagonal shape, rose to the sky under the clouds, it had seven large towers, two hundred houses covered with wooden shingles, without fences and gardens. The obligatory Suleiman Khan mosque, two smaller mosques, and an ammunition warehouse and granaries were also built there [10]. That description indicates a very modest way of life and weak fortification. The reason was undoubtedly that the Turkish state then extended to Buda, so this fortification no longer had a strategic importance. The Austrian army conquered Petrovaradin in 1688 and it was then decided to strengthen the fortress. Again, the reason was strategic, because now the Petrovaradin fortress was once again on the border between Austria and Turkey. The demolition of the old medieval Turkish fortress began and the construction of a modern fortification based on the Vauban's system started. In that unstable time, the Turks unsuccessfully tried to recover the fortress in 1694.

On the other, left side of the Danube, there is an alluvial plain with dry soil beams. On the other, left bank of the Danube, most of the settlements from the Middle Ages and the era of Turkish rule have disappeared and are known only from archaeological and archival data. At the end of the 17$^{th}$ century, when the Petrovaradin fortress with its baroque town came under the rule of the Habsburgs, the Orthodox and other non-Catholic population was forbidden to live in that town. This was the main reason that the Serbs, along with Greeks, Aromanians and Jews, started to establish a settlement in 1694 across from the fortress, near Mostobran, which had already existed there (Fig. 7). Because of the majority of the Serbian population, it was called *Racka varoš.(Rascian town)* [18]

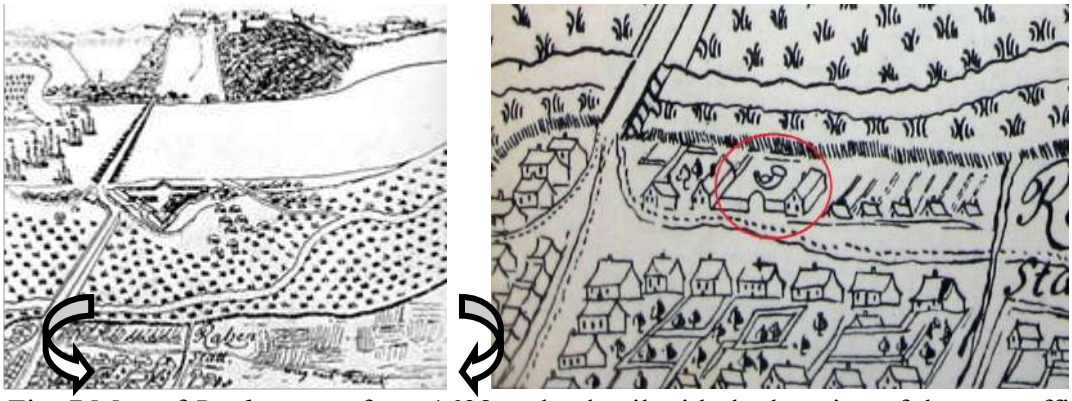


Fig. 7 Map of *Racka varoš* from 1698 and a detail with the location of the post office (https://graditeljins.wordpress.com/karte-grada/)

The painstaking backfilling of the swamps began to create conditions for construction. The backbone of the future settlement consisted of three streets on a relatively solid ground and led in the direction of Futog and Szeged. One of the three oldest streets in the city still bears the name Ulica Zlatne grede (Golden strip street), as a memory of a part of the solid ground on which houses could be built (Fig. 8).

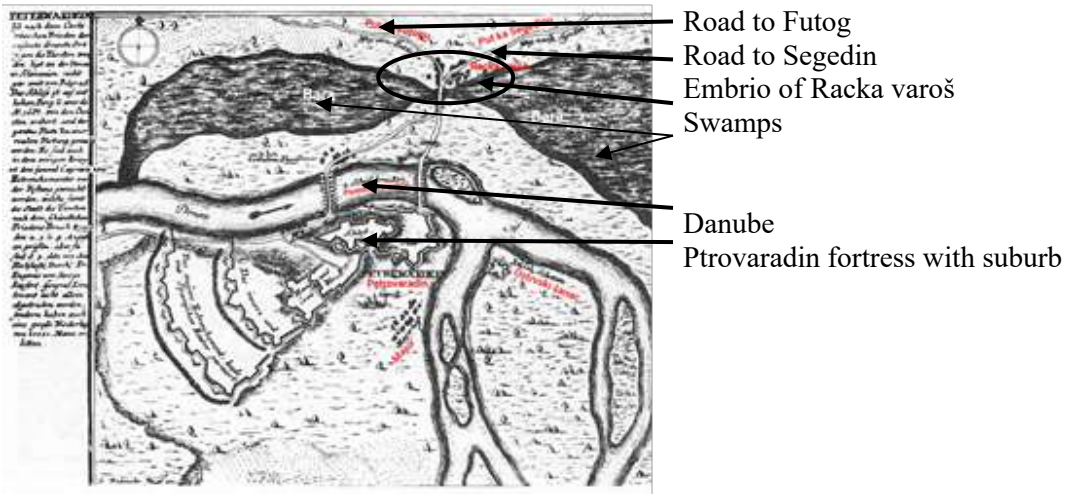



Fig. 8 The position of the Rascian town behind the marshy area and Bridgehead on a plan from around 1700 (after https://graditeljins.wordpress.com/karte-grada/)

The embryo of today's Novi Sad was therefore Racka varoš, and the name Petrovaradin ditch was also used. That there was a certain link with some form of settlement from the time of Turkish rule is indicated by the name of the street that led in the direction of Szeged, and which today is called Pašićeva Street. On the plan from 1745, this street is marked as Velika Čaršija (Great Çarshi) (Fig. 9). It is also possible that the settlers, who lived under Turkish rule for a long time, continued to use some Turkish words for some time.

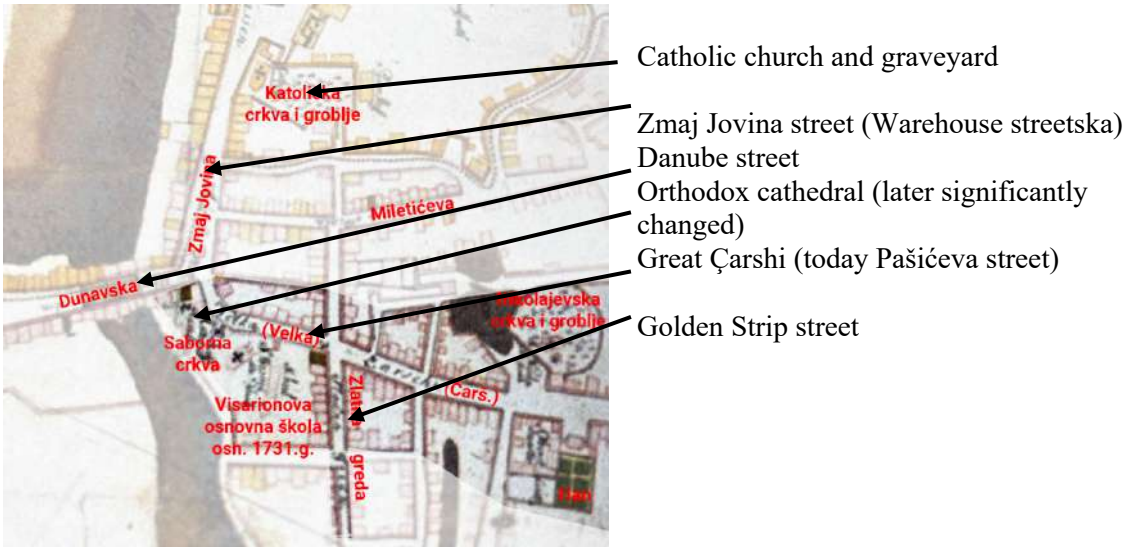



Fig. 9 Segment of the map of Racka varoš from 1745, containing the modern inscription of the already formed network of the oldest streets and buildings

The families of soldiers, frontier guardsmen, as well as the builders of the Petrovaradin fortress, various craftsmen, merchants and innkeepers lived in the settlement that was created (Fig. 10) [19].



Fig. 10 Church of the Holy Three Hierarchs (Almaška) from 1797 (the first in the same place in 1718, the second in 1733); One of the oldest houses "At the White Lion" from the 18th century was in the baroque style, while after reconstruction in the 19th century it is predominantly in the classicist style

In the 19th century, in 1848, there were numerous national revolutions across Europe. In that period, the Serbian revolution took place in 1848-49. The calamitous events also affected the urban structure and buildings already built in the 18th and early 19th centuries. The heavy bombing and the resulting fire destroyed a large part of the city fabric. Nevertheless, the main street directions that had already been established survived and very damaged houses around them from the 18th century were repaired very quickly, which then received a new stylistic expression. Since then, the progress of the city has been faster, and the urban network has expanded on the dried-up terrain.

The cities of Subotica, Sombor and Zrenjanin, which today are located in the north of today's Vojvodina, closer to the border with Hungary, had a slightly different development in the 18th century [8, 20].

**Subotica** is located on a wider area, the loess plain, which has been inhabited since prehistoric times. Some form of settlement existed after the Tatar invasion of the Balkans. The name Zabatka was first mentioned for this settlement in 1391. Since then, the settlement has changed its name several times. After the tumultuous historical events after the Battle of Mohács in 1526, Subotica found itself at the center of important battles for territorial supremacy over Bačka, Banat and part of Srem. The Turks finally conquered Subotica in 1543 (Fig. 11).




Fig. 11 Zabatka (Subotica) on the Mercator map of 1583.

The city was then developed around a small fortification made of hard material. Turks settled colonists from the Balkans, as well as families of Serbian mercenaries as part of the Turkish army. Subotica became the center of *Nahija*, the lowest administrative unit, so it housed the judicial, administrative and military authorities. Descriptions from that time mention about 150 houses covered with straw or wicker panels. There were gardens around, and vineyards were numerous due to the suitable soil for vine growth [10]. The Turkish rule lasted 150 years.

At the end of the 17th century, the fortunes of war changed and the Austrian army won a great victory at Senta. The map made by the military cartographer of the military leader Eugene of Savoy is very important as one of the documents of the layout of the Sabatka settlement in 1697. E.N. Sparr included a large part of the area around Lake Palić, where the army rested, and in the distance he registered a settlement dominated by two massive structures, presumably the castle of the city (Fig. 12).



Fig. 12 A veduta of Subotica (Sabatska), detail of the wider veduta of lake Palić and surroundings (https:/gradsubotica.co.rs/prva-slika-subotice-i-palica-veduta)

The stable settlement, Subotica, was first formed as part of the Potisje military frontier. The location of this place was attractive to a large number of settlers, especially the Bunjevci people. The

beginning of the 18th century was quite unfavorable for faster and better development, they survived the Rakoczi Rebellion (1703-1711), plague epidemics (1709, 1738), smallpox (1713, 1720). Diseases threatened the population even at a later date, typhoid fever was in 1760, and spotted typhus in 1768 and 1780. These were certainly not the most favorable conditions for urban development. Various political decisions caused a change in the composition of the population, Serbs moved out, then returned, a larger number of Hungarians settled in, but the Bunjevci were a stable population. The city strived for the higher tax exemptions and managed to obtain them The town was granted the status of a privileged free royal city in 1779 under the name Maria Theresiopolis. The name of Subotica was returned as late as in 1845. The privileges attained by the status of a free city enabled the enrichment of the city administrations and population by holding fairs, market days and collecting taxes. The core of Subotica was located in the wasteland, which was wisely used to divide the wasteland into parcels and sell the plots for construction. Thus, an urban city in the flatland slowly began to emerge [21].

On the map made by Kaiser in 1747, the future city is still shown as a scattered settlement, without regulated streets. The inhabitants arbitrarily erected their houses on two dry high ground areas, between which flowed a stream (Fig. 13).

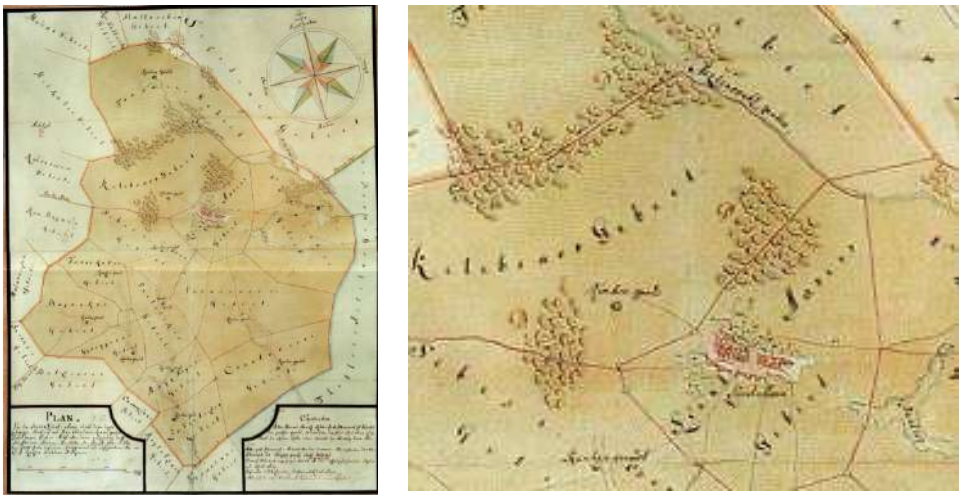


Fig. 13 Kaiser map of Subotica of 1747 and the city core detail
https://suistorija.wordpress.com/karte-i-mape-od-xviii-do-xxi-veka/

The urbanity is gradually reflected in the establishment of institutions characteristic of the city. The secondary school (later the grammar school) started working in 1747, the town hall was built in 1751, and the home for the elderly was built in 1766. Religious architecture is better preserved and recorded. The Chapel of St. Rock, the protector against the plague, was built in 1738, rebuilt in 1753, but in the 19th century it was almost completely changed [22]. The Church of St. Mihajlo was built in 1730 on the site of a fortress that was built in 1439 for defense against the Turks. It was created by the expansion of a Franciscan chapel of 1695, which was inserted into a large hall on the ground floor of the Subotica tower. The rest of the premises were converted into a Franciscan monastery in 1716. The first elementary school was opened at the monastery in 1713, and later a school of rhetoric and philosophy worked at the monastery. The Roman Catholic Church of St. Teresa of Avila was built between 1773 and 1798 in the late Baroque style. As is the case with most baroque buildings, i.e. those from the 18th century, this one also underwent additions and certain changes during the 19th and 20th centuries (Fig. 14).

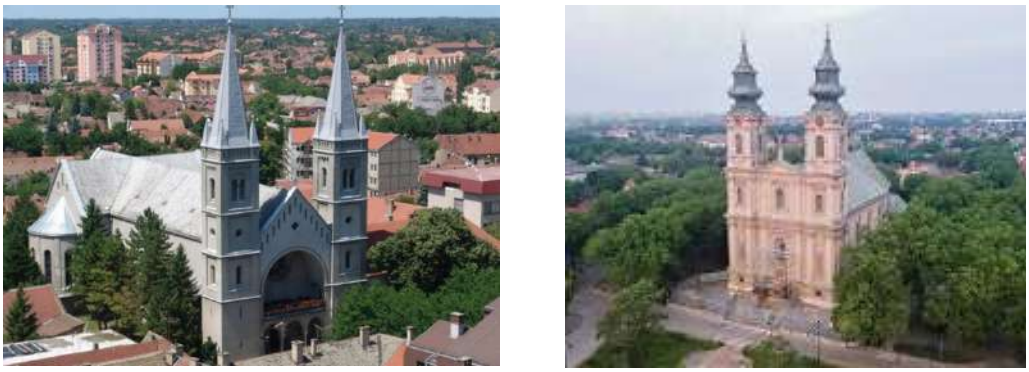


Fig. 13. Franciscan monastery and church of St. Teresa of Avila in Subotica
https://visitsubotica.rs/sta-videti/sakralni-objekat/franjevacka-crkva/
https://www.planplus.rs/katedrala-svete-tereze-avilske/1891

Karl Leopold Kovač made a handwritten map of the settlement in 1778. It shows that the settlement was developed on a large area, but still without a prominent urban character. In the core of the settlement alone, there are about seventy houses that appear to be urban, made of masonry and with a long front facing the street side. The map undoubtedly shows that systematic, planned regulation has not yet been carried out [23]. In the Statute of the free royal city, there were also provisions that determined the construction method and the arrangement of the territory. In order to accomplish the most important task and create solid ground for construction, it was necessary to drain ponds and regulate watercourses. For a very long time, the names of Dolova greda (Dol strip), Rogina bara (Roga pond), Jasi bara (Jasi pond), Ciganska bara (Gipsy pond) and Vrbov potok (Willow stream) survived for certain parts of the settlement (Fig. 15). The regulatory plan was drawn up towards the very end of the 18th century, in 1799, and it is considered that it was very extensive and thoroughly done. Today, however, only its central part, which shows the city center, has been preserved (Fig. 16) [24].

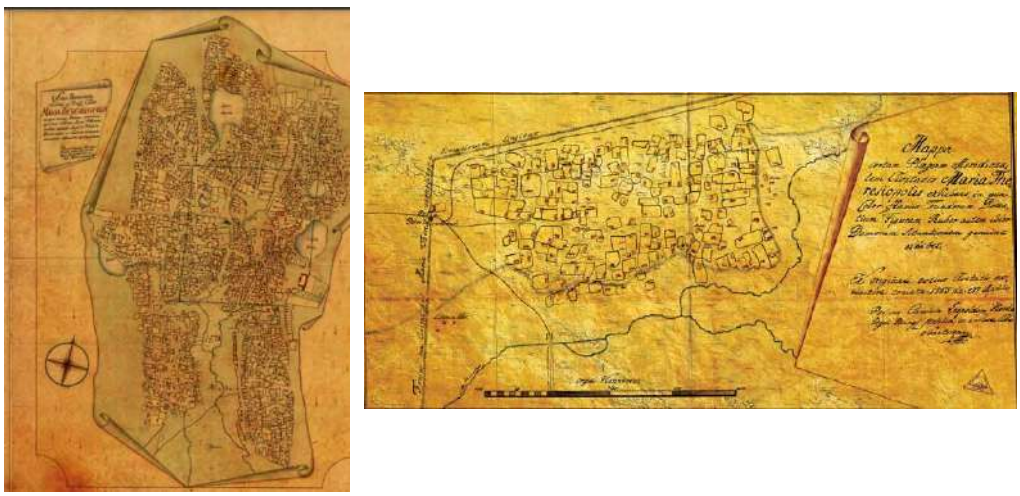


Fig.15. Handwritten map of K.L. Kovač, 1778. https://subotickaistorijagroup.wordpress.com/nas-grad-na-karti-iz-1778-godine-tada-maria-therisianopolis-danas-subotica/): Detail of Ker, oldest part of the city of 1785. (https://suistorija.wordpress.com/karte-i-mape-od-xviii-do-xxi-veka/)




Fig. 16 Part of the Regulation plan of 1799
(https://www.suarhiv.co.rs/files/katalozi/subotica-na-starim-mapama.pdf)

The urbanization of Subotica throughout the 19th and especially at the beginning of the 20th century testifies to the great rise of that city, which at one point had as many as 100,000 inhabitants, but also to its marginalization after the First World War

The beginning of the present-day city of **Sombor** was a small settlement on one of the numerous small islands, in the marshy terrain of the Mostonga River, which was located on the vast estate of the Cobor Sent-Mihaly lords since the 14th century.The later name of the city, Sombor, comes from the name of the landlord. The shape of this settlement already indicated that later development and urbanization would take place so that the city core would later be located on a dry area with a square base [25].

The Turks occupied this estate and the settlement in 1541. Then the Turks found an already developed town with a city citadel. Evliya Celebi calls Sombor a well-fortified *palanka*, with a quadrangular base. Outside the ramparts there are residential houses, mosques, madrasas, tekyes, inns, a bazaar with shops and a hammam. That layout is mostly visible in documentary sketches from that time. The records indicate that at that time the goldsmith shops were the most numerous, which reflects the developed craftsmanship. Although it was a Turkish town, the largest number of inhabitants were Serbs, a slightly smaller number were Hungarians. On the plan of the Austrian siege of the Turkish Osijek, from June 1687, for Sombor, which loomed on the horizon across the Danube (with four minarets and a tower), an explanation was written in Italian: "*Sambor citta mercantile posseduta allora da Turchi" (Sombor, a mercantile city, still in the possession of the Turks)* [26].

The Austrians took Sombor in 1687 as a Turkish trading *palanka*, the seat of the *Nahija* and a military center. Since the liberation from the Turks, the citizens had tried very hard to collect enough money so that only in 1749 they received from the Empress Maria Theresa a charter of the status of a free and royal city. During the 18th century, Sombor became urbanized, gradually creating an expanding city core. In addition to obtaining the status of a free royal city, another significant historical event was the elevation of Sombor to the rank of administrative center of Bač-Bodroška County in 1786. The plan of 1783 clearly defines the placement of the main intercity roads that enter the city, through four oppositely placed gates. The roads intersect in the center, dividing the fort into four roughly equal parts. In this way, the core of the city known as the "inner town" was created (Fig. 17)

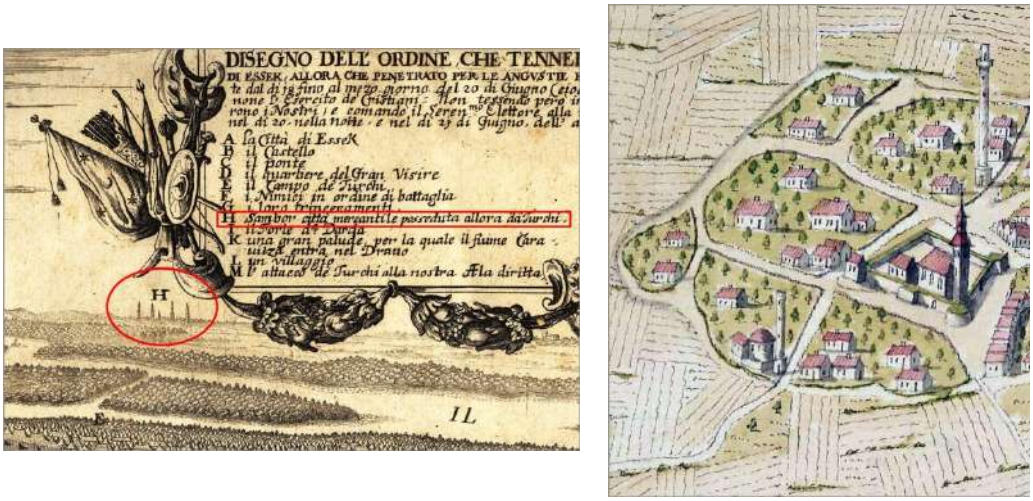



Fig. 17 Sombor with minarets on the plan from 1687 and colored veduta by F.N. Spar from 1697 with a formed center, partially regulated street fronts and the remains of Turkish mosques (https://www.ravnoplov.rs/panorame-starog-sombora/)

The plan of the Sombor magistrate called *Planum operationum commissinalum Bachonicum* was adopted in 1786. The urban matrix formed in this way dating back to the 18th century would become the basis for any further development of the city during the 19th century and beyond (Fig. 18) [27]

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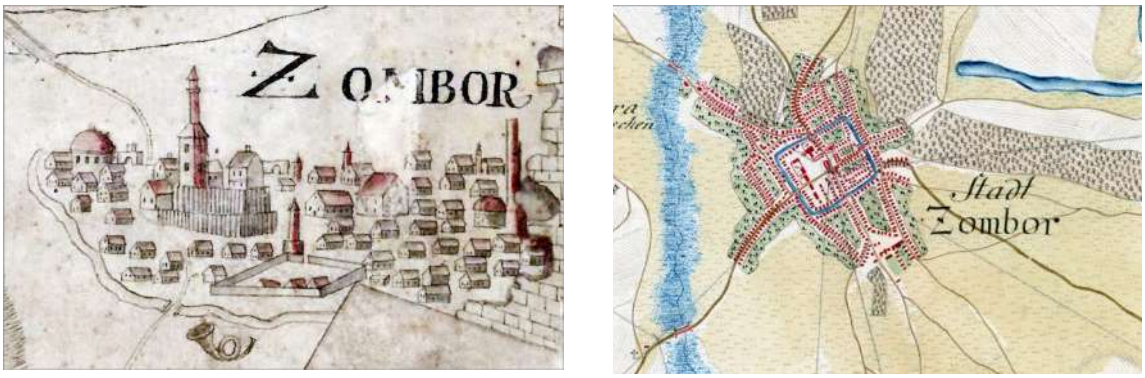



Fig. 18 Detail of the veduta of Sombor from 1700 (still with the remains of Turkish buildings) (https://www.ravnoplov.rs/panorame-starog-sombora/) and the plan from 1783 with the square and main communications clearly outlined (https://www.ravnoplov.rs/plan-sombora-na-mapi-iz-1782-85-godine/)

Sombor is one of the few towns in Vojvodina where numerous buildings from the 18th century, of various types, have been preserved. Unlike other cities where mostly the religious architecture is preserved, in Sombor there are also civil buildings, some of which were relatively very little modified in later eras. In the literature, the architecture of the 18th century in Vojvodina is called by different names, such as "provincial baroque" to emphasize the fact that certain characteristics of the European baroque were omitted, simplified or, in some cases, misinterpreted. Another characteristic of the urbanization of Sombor is the way in which the few remaining buildings from the Turkish period were

used with relatively minor changes. One example is Pasha's Tower, which was a part of the Turkish fortification (built on medieval foundations). The Austrian authorities estimated that it could be used and with the small renovation (installation of a new roof) the tower was used for the residence of scribes and cashiers. It has been preserved to this day and together with the Krušper's house forms the whole of the Historical Archive. In the second case, it was assumed that the chapel of St. John Nepomuk was built over the foundation of the former Turkish place of worship, which is known to have been near the Pasha's tower [28]. The importance of the urbanization of Sombor for the overall understanding of the cities of Vojvodina is reflected in the relatively consistent formation of the city core, which has survived to this day. The Baroque idea of homogenizing the central square with buildings of an administrative and residential character that formed its peripheral fronts, all within the former fortification or next to it, was realized to resemble, as much as possible, the type of a small Central European city (Figure 19).



Fig. 19 Orthodox church of Saint George of 1761.; Chapel of Saint John Nepomuk of 175 (https://www.zkvh.org.rs/aktualnosti-post/sakralni-objekti-backa/kapela-sv-ivana-nepomuka-najstarija-kapela-u-somboru).; Grašalković place erected between 175 -1763 http://spomenicikulture.mi.sanu.ac.rs/spomenik.php?id=1226); Krušper palace of 1774. https://www.ravnoplov.rs/krusperova-kuca-istorijski-arhiv/)

The present-day city of **Zrenjanin** in the Banat region of Vojvodina also had a similar development process of turning a Turkish settlement into an Austrian city during the 18th century. The position at the meander of the Begej river, at the contact of two units (loess plain and alluvial plain) and at the intersection of road directions, was well strategically placed.

Its historical development is specific, because it was created by connecting three islands in the wetlands of the Begej River. Researchers believe that the center of the settlement is on the ground where the Slavic-Avar hring existed in the early Middle Ages. Much later, in 1326, this settlement was mentioned for the first time under the name Bečkerek, later Veliki Bečkerek. Later, a fortress was built there. The entire wider territory, including the fortified city, was finally conquered by the Turks in 1551. Nowadays, on the site where there was the fortress even before the Turkish conquest, there is a City Hall building. Evliya Čelebi noted that by the order of the famous Mehmed Pasha Sokolović, the fortress was expanded and that the city had the rank of a *kasaba*. The same pasha founded a waqf and therefore there were mosques, a hammam, an imaret, a masjid, and mills on the river, as well as a port [10]. There was a large number of shops in the bazaar, and the residential houses were arranged around it. The only recorded representation of Bečkerek from the Turkish period is the city plan from 1697. It is still the central part of the city today, although nothing remains of the Turkish buildings. The fortification was of the *palanka* type, which means that the defensive walls were made of a wooden palisade on an earthen embankment. The mosque that was located in the area of the former fortress was demolished only at the beginning of the 20th century.

It also shows an independent village, Gradnulica, which also existed in the Middle Ages, on the dry terrain of a peninsula. This village will later be connected to Bečkerek and today represents one of the largest parts of the city. However, several uprisings against the Turkish government followed, but nevertheless, Bečkerek was freed from the Turks only in 1716. Although there were inhabitants of various nationalities during the Turkish era, the Austrian colonization was very dynamic and the settlement was developed by the colonization of Serbs, Germans, Romanians, Italians, and French. Particularly surprising is the settlement of the Catalans, who formed a part of the settlement that received the name "New Barcelona" (Fig. 20) [29]. By then, Veliki Bečkerek progressed in the hierarchy of Austrian cities, and in 1769 by the charter of Empress Maria Theresa it became a trading center. In 1779 it became the seat of the newly founded Torontal County, and in 1787 it received the privilege of holding monthly fairs [30]. This political and social rise of Veliki (Great) Bečkerek was accompanied by administrative, commercial and economic development. In her book, Olga Zirojević presents him as "the engine of the development of the whole of Vojvodina" [31]. The planned draining of swamps and the construction of the Begej canal (1728-1733), as part of the large Danube-Tisa-Danube canal network, certainly contributed to that development. Very early, already in 1722, the first elementary school was founded, the first brewery in 1745, the first hospital in 1763, and the first pharmacy in 1784. The printing house was founded in 1796. The only document of the town's development in the 18th century is the preserved ground plan from 1793 (Fig. 21) [32].

This successful development of the city was stopped by a great fire in 1807. At that time, almost the entire building stock was destroyed, and the already created urban matrix was erased by the new regulation of the streets. There are few buildings from the 18th century, they are mostly for religious use, and many were extensively remodeled during the 19th century. Two churches, one chapel and a residential building have survived (Fig. 22). The further development of Veliki Bečkerek can be traced back to 1935, when it was given a new name, Petrovgrad, and the current name Zrenjanin was given immediately after World War II.

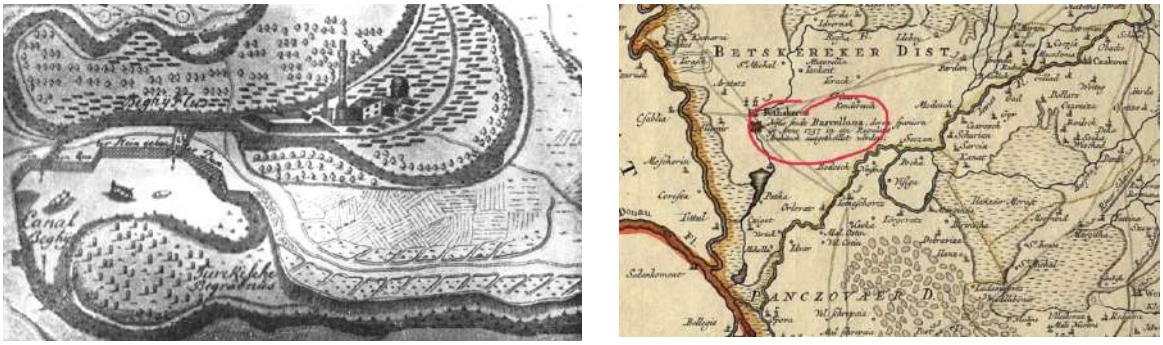



Fig. 20 Plan of the Turkish town drawn by Austrian engineers in 1697 (https://pescanik.net/veliki-beckerek-petrovgrad-zrenjanin/) and Grisellini's map of Banat with the Little Barcelona inscription written next to the Bethskeros settlement of 1740 (https://www.bbc.com/serbian/lat/srbija-59271898)

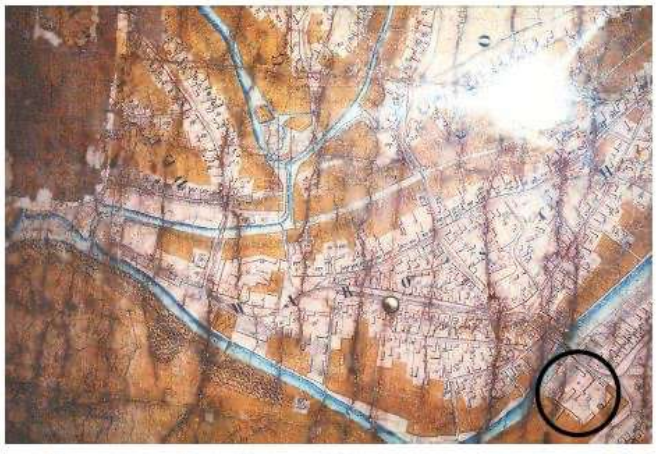


Figure 21 Ground plan of Veliki Bečkerek of 1793 (the brewery complex is circled)
(Istorijski arhiv Zrenjanina, sv.5, sv.7)

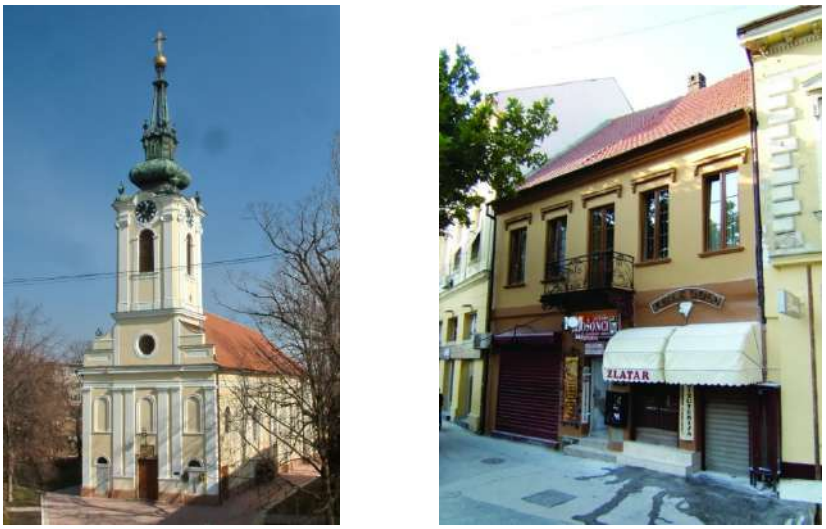



Fig. 22 The Orthodox Church of the Assumption of the Blessed Virgin Mary of 1746 and the house of Živko Vukov from the end of the 18th century (https://www.zrenjaninheritage.com/kulturna-dobra/spomenici-kulture/

## 4. Conclusion

Whatever the development of the settlements on the territory of Vojvodina since prehistoric times, it was at one particular moment defined by the oriental urbanism and social characteristics. The fall of all parts of Vojvodina under the Turkish rule ended with the capture of Banat in the war of 1552-1556. The campaign was led by Grand Vizier Mehmed Pasha Sokolović. Hungary was divided into three parts: Northwestern, "remnants of remains" or "Royal Hungary" in a personal union with the Habsburgs; The central part, where today's Vojvodina was located, was a part of the Turkish Empire, the Eastern part, Erdelj (Transylvania), remained under the rule of the Hungarian princes but in a vassal relationship to Turkey.

Srem, Banat and Bačka were included in the political, economic and social life of the Ottoman Empire for a century and a half. Apart from the Serbs, other Balkan populations also immigrated, Turks, Greeks, Aromanians, Bulgarians, and Sephardic Jews. In addition to Christians, a large number of Muslims also lived here. The most important economic branch at that time was animal husbandry, but military service was also represented to a large extent.

According to European travel writers, the towns appeared very neglected, while the famous Turkish travel writer Evliya Celebi, who was prone to exaggeration, gave a completely different, more beautiful picture of *palankas* and small towns in today's Vojvodina. External features of oriental culture were visible in the appearance of the cities, and in the clothing and habits of the people. The city population was engaged in trade and crafts. Roads were bad and almost impassable during the rains, so the traffic on the rivers, especially on the Danube, was very lively. Travel by both water and land was unsafe due to the large number of bandits.

In the constant aspiration to free these areas from the Turkish rule, a key victory was won in 1697 near Senta (Zenta) by the famous general Prince Eugene of Savoy. His role in pushing the Turks out of Southeast Europe, as well as in laying the foundations for the further development of this area, is of utmost importance. The "Great Viennese War" ended with peace in Sremski Karlovci in 1699. Bačka and the western part of Srem were taken by Austria, while Banat and southeastern Srem remained in Turkish hands. A new war followed, which ended with the Peace of Požarevac in 1718. Austria finally conquered Banat as well. State-legal and administrative divisions in the area of today's Vojvodina during the 18$^{th}$ century were very complex, due to the specificity of the relationship between Austria and Hungary.

During the 18$^{th}$ century, extensive works were undertaken, especially in the floodplains and marshes of Banat, to train the water courses and drain swamps with the aim of preventing floods, eradicating malaria, providing arable land and improving river traffic. Settlements, both small and large, were built according to strict rules that prescribed the layout and width of the streets, the area of the garden, the position and size of the houses, even the layout of the rooms in them, etc. Larger urban centers developed. Three towns purchased the status of a free royal city for large sums of money: Novi Sad (1748), Sombor (1749), Subotica (1779). There were also several urban settlements of a lower order such as logistical towns, free towns, free frontier communities. such as Veliki Bečkerek, Vršac, Sremska Mitrovica, Pančevo. Economically, the region progressed rapidly, at the end of the 18$^{th}$ and the beginning of the 19$^{th}$ century, Bačka and Banat were among the more developed provinces of Hungary. Craftsmanship, of the oriental type, gradually gave way to craft and manufacturing production based on the European model, the pioneers of which were, for the most part, Germans. During the 18$^{th}$ century, the area of today's Vojvodina acquired an ethnic and religious population diversity that has persisted to this day [7].

In this short overview of the urban development of several important cities of Vojvodina, the specific transformation of settlements from the oriental type to the Central European one (firstly baroque), is presented. This is particularly noteworthy, because the baroque matrix from the 18th century, today very faint or hardly discernible, laid the foundations for the urban development of these cities. Each of the example settlements experienced this transformation in a different way, sometimes faster and sometimes slower. The area of Vojvodina prospered from agriculture, the cities were mostly organic, that is, they were created and lived in harmony with their surroundings, and a high level of living culture was achieved. Contemporary tendencies of devastating the natural as well as the built environment, in the long run, may once again lead to the modern "barbarization" of the entire space, and thus society as a whole.

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# PROTECTION AND RESTORATION OF THE BUILDING HERITAGE OF MONUMENTAL HISTORICAL MONUMENTS OF CULTURE OF THE KOSOVO-METOHI SCHOOL

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***Abstract***:.
*The area of Kosovo and Metohija belongs to the regions of Europe that are extremely rich in cultural monuments, given that there are over 1,300 remains of Christian monuments. The most valuable are the medieval monasteries of the Serbian Orthodox Church, unique in that they bear witness to the meeting of Byzantine and Romanesque architecture. Since June 1999, 174 religious buildings have been demolished, damaged and desecrated in Kosovo and Metohija. The most important medieval heritage suffered serious damage, especially the Church of Our Lady of Ljeviška in the center of Prizren, after which UNESCO placed Serbian medieval monuments in Kosovo and Metohija (Visoki Dečani, Peć Patriarchate, Bogorodica Ljeviška, Gračanica) on the List of World Heritage in Danger. The main goals of this work are: to indicate the characteristics, European and world significance of the Serbian medieval heritage that belongs to the Kosovo-Metohija school; to present the current situation and problems in protection and restoration, starting from the highest institutional to specific and local ones; and to offer concrete solutions strategies for the protection and restoration of Serbian medieval heritage in Kosovo and Metohija*.

***Key words***: *Republic of Serbia, Kosovo and Metohija, Kosovo-Metohija school, Medieval heritage, Protection and reconstruction strategy*

## 1. Introduction

In the context of time, Serbian medieval architecture refers to the period from the middle of the 13th to the end of the 14th century, when the Serbian-Byzantine, that is, the Kosovo-Metohian style of architecture was developed. In a historical sense, it is the period of the reign of King Milutin until the time of Emperor Uroš, when the Serbian state was created and developed in turbulent times of the influence of the East and the West, so that monumental cultural monuments were created as a specific result of the influence of Byzantium and Western Europe.

In terms of style and typology, Serbian architecture from the second half of the 13th century and throughout the entire 14th century developed in accordance with the general trends of Byzantine art. It was built on similar or the same construction concepts with certain variations in realization that came under the influence of the architectural heritage of Western Europe of that era. A similar repertoire of forms and motifs characteristic of Byzantine art is used, stylization is emphasized, while the volume is relegated to the

background. In the beginning, the decoration was reduced, without striving towards the third dimension of observation and dematerialized, in order to get closer to the Orthodox Christian dogma. Over time, it gains in complexity and symbolism. Models are found in the ancient or Byzantine heritage, while at the end of the mentioned period there is a noticeable respect for Romanesque and Gothic and the influence that comes from the West.

From the relationship of architecture in Kosovo and Metohija to Byzantine and Western European architecture, it can be seen to what extent architectural forms were transferred to distant areas in Europe between the 12th and 15th centuries. Namely, there was no stylistic unity in Serbian medieval art, precisely because of the conflict between Eastern and Western influences, which is certainly a consequence of the political orientations of the rulers at the time. That is why the problem of the origin of forms and architectural solutions has always been an interesting topic in the research of the architecture of this period, and in the study an attempt was made to connect it with topics of general contemporary importance in terms of the protection of monumental cultural monuments and architectural heritage. The monometallic monuments mentioned in this paper have a huge, immeasurable value for Serbian history, architecture and culture. That is why it is important to emphasize their importance both in the individual and collective consciousness of the Serbian people. The medieval Serbian architecture in Kosovo and Metohija is the best proof of the greatness that the Serbian state has achieved and whose protection it should be dedicated to.

The Serbian medieval monuments of the Kosovo-Metohis school from an architectural point of view explain how the Serbian national identity and spirituality was created. They followed the historical movements, the ups and downs of the state, but were built continuously regardless of the state of the state, from the founder's personal affinities and the ruler's desire to continue the tradition in cultural material goods started by Stefan Nemanja. Although most, in fact all of the mentioned churches and monasteries no longer exist in their original form, because they were demolished, destroyed, burned, looted, they were never destroyed. It seems that the secret of the survival of the Serbian people itself lies in their construction and renovations.

## 2. Characteristics of the Kosovo-Metohija construction school

According to the long-accepted systematization of monumental Serbian architecture made by Mije as long ago as 1916 (Preradović, Marković, 2021), Serbian medieval architecture is classified into three units, which are called schools of architecture, namely: Raška, Serbian-Byzantine and Moravian schools. .

The architectural creation from the second half of the 13th to the end of the 14th century was called the Serbian-Byzantine school. Its main characteristic is lavish ideas and forms, which was supported by the economic enthusiasm characteristic of this period. From an economic point of view, it was a time of boom when, apart from the ruler, the orderers and founders of monasteries were the nobility and the clergy. Supported by extensive and continuous economic support from the founders, art and construction workshops developed around the courts of Serbian rulers, nobility and clergy.

The Kosovo-Metohija architectural school is associated with the reign of King Milutin (1283-1321), and continued during the reign of Stefan Dečanski (1322-1331) and Emperor Dušan (king 1331-1346, emperor 1346-1355).

King Milutin will remain known in Serbian architectural heritage as a ruler who helped build churches and monasteries that are among the most beautiful monuments of Serbian medieval architecture. The entire period of his reign is marked by the Byzantine influence, that is, Byzantium under the renewed Paleologus empire. Namely, Serbian medieval cultural and architectural art had role models and models for creative work in

Byzantine art. The Byzantine concept of space, structure, shape, style, colors and building materials was adopted.

The biggest difference compared to the architectural heritage attributed to the Raš school is the construction of churches with an inscribed cross with a dome. The dome was placed at the intersection of two half-shaped vaults above the arms of the inscribed cross. The tambours of the domes are round on the inside in most churches, while on the outside they are polygonal with semi-pillars on the edges that separate the window openings. In the more important monasteries, the type of church with an inscribed cross was developed, where four smaller domes were placed, which were worked in the same spirit, at the ends of the transverse arms, forming a more complex five-domed system. The cruciform base is surrounded by walls on the outside, which gives it an external appearance in the shape of a rectangle. The upper structure was supported by columns, not walls, so that inside the church acts as a single unit (Petković, Bošković, 1941). In order to achieve the effect of monumentality, there were often, even incongruous, increases in height that were supposed to emphasize the strength and size of the Serbian state (Ćirković et al., 1991). The very method of construction with bricks and hewn stones points to the Byzantine understanding of architecture. Each of the hewn stones is bordered by bricks on four sides and resembles cells in shape. This construction system was called cloisonne by Mije (Ćirković et al., 1991).

The facades are completely flat, finished with brick cornices that are sawn under the vaults. To achieve a greater exterior effect, brick was used and patterns such as a checkerboard, herringbone, and meander were made. Plastic decoration followed architecture and interior decoration. Over time, plastic decoration becomes independent from architecture, gains importance, and its interpretation greatly facilitates the process of assigning a building to a certain style or architectural school.

During Dušan's reign, stone sculpture became a recognizable style that was extended to the most isolated regions of the empire, so that in different areas of the vast empire, the same capitals, column bases, archivolts and door frames, and stylization of figures can be observed on churches (Šuput; 1989). Portals and space openings received significant decoration, especially in the case of monumental monuments.

The monumental historical monuments of the culture of the Kosovo-Metohija school stand out from other schools mainly because the influence of the exterior stands out: the domes are multiplied, the masses are distributed in a pyramidal manner, they strive for heights, new parts are added, narthexes, chapels, chapels, bell towers, and even whole new churches, thus creating new entities with completely new features, which is all in accordance with the spirit of the time of wealth and power, in which the Kosovo-Metohija school was born and developed.

### 3. Monumental historical monuments of the culture Kosovo-Metohija school

In the continuation of the paper, examples will be given that managed to nurture tradition and lay the foundation for the emergence of a characteristic Serbian style known in literature as the Kosovo-Metohija school, despite strong influences from the East and West and two great cultures - Byzantine and Western. This shows that Serbian rulers and endowments had a practical and open attitude towards ideas and cultural expressions from wide areas, adapting them to Orthodox beliefs and rituals.

In addition, it is impossible to interpret this architecture unrelated to the territorial context. The meaning of this elaboration is in an attempt to re-emphasize the awareness of the responsibility of the environment in the modern moment, through the obligation to restore and nurture the architecture, because it managed to be maintained within its natural territorial context and to be a testimony to future generations on the basis of which they will be able to to valorize national achievements in certain, never easy, historical epochs.

### 3.1. Monastery of the Virgin of Ljeviška

In the constructive solution, the church has a rectangular shape modeled on the church of the Holy Apostles in Thessaloniki. The basis of the church is an arrangement in the form of a developed inscribed cross with five domes. A ship is placed on the north, west and south sides. The central dome is the largest and is placed at the intersection of the vaults, while four smaller ones are placed at the ends of the arms. In the interior of the nave, two rows of columns stand out, giving the monastery the appearance of a multi-nave church. All domes have a square base, which is a feature of Byzantine temples. The western part stands out with a tall belfry tower in the middle.

The altar is a whole in itself, prominent in the external appearance and reduced by the calotte. This solution was also taken from Byzantine architectural practice (Nenadović, 1987). The facades are divided by numerous openings, according to late Byzantine examples, framed archiliths, blind arcades, couches, decorative niches. On all prominent surfaces of the walls there is a brick ornament in the form of meanders, toothed wreaths or specially made terracotta ornaments originating from the Byzantine regions (Šuput, 1989). The Virgin of Ljeviška brought something new to the Serbian architectural heritage of the Kosovo-Metohija school. It was preserved during the difficult times of the Turkish rule mostly because it was in the city center and because it was turned into a mosque. It was destroyed in arson during the pogrom on March 17, 2004 (Petrović, 2006).

### 3.2. Monastery Gračanica

The architecture of the Gračanica monastery is the most significant Serbian and Byzantine architectural work, but with a certain noticeable influence of the Western European architectural spirit. It was built by order of King Milutin in 1315, on the site of an older church that was dedicated to the Virgin (Milosevic, 1989). The concept for the construction of the monastery was taken from Byzantium. It is a five-domed building dominated by the main dome on four free supports, and stands out for its decorative decoration and height. The model of Thessaloniki's five-domed churches was changed in Gračanica by bringing the perimeter naves into the church space itself and receiving side chapels and a singing space. There is a three-sided apse on the east side, and an exoartesque on the west side that is not connected to the church. Contemporary Byzantine construction techniques and materials were used. The facades are finished in a manner characteristic of Byzantine architecture (Petković, 1982). The processing of wreaths, tambourines and windows is closer to Thessaloniki and Constantinople models (Maksimović, 1971), although there are also traces of local architectural traditions, as the altar resembles older Serbian solutions (Korać, 1987). The peculiarity of the Gračanica monastery is that it is significantly different from the churches created at the same time, especially by the emphasized vertical whole and the tightly grouped and closed overall space of the building. Its special feature, which gives it a special value, is the exceptional shape of the parts and their relationship to the whole (Ćurčić, 1979).

### 3.3. Pećka Patrijaršija

The Peć Patriarchate stands out among the construction monuments of the Kosovo-Metohija school, created at the beginning of the 14th century. It is known from written sources that in the second decade of the 14th century, Archbishop Nikodim built the Church of St. Demetrius on the north side of the Church of the Holy Apostles, and ten years later, on the south side, Archbishop Danilo II built the Church of the Virgin Mary. The monastery took its final form in 1330, when a common outer vestibule, a porch and a chapel were built in which Archbishop Danilo II was buried (Nenadović, 1987). With this construction, a unique complex was obtained where the new architecture was

harmoniously adapted and subordinated to the existing core, which gave it the characteristics of the Kosovo-Metohija school.

### 3.4. Monastery Banjska

The Banjska Monastery was built in the period 1213-1316, intended as the burial place of King Milutin. It was built according to the example of Stefan Nemanja's Studenica endowment. The exterior treatment is more adapted to the Romanesque style form, considering that builders from the west were engaged, who brought with them concepts and ideas from Romanesque architecture, but had to adapt them to the solution of the Byzantine concept. After major destructions, the mansatir of Banjsa can be reconstructed today only on the basis of the parts that remained after major devastations (Šuput, 1970). In terms of construction, the monastery was designed as a single-nave building with an emphasized central, domed part and chapels along the western aisle and chancel. It had two towers on the west side, which is characteristic of buildings with Romanesque style, as well as gradation in height and prominence of the central core and fewer openings on the outside. In everything else, it follows the achievements of architecture in Raš from the period after Stefan Nemanja.

According to the Raš model, the facades are flat surfaces made of hewn stone blocks in three colors, which were alternated according to the chessboard system, which reminds them of works of Tuscan or Eastern Adriatic Romanesque. Raška architecture was an immediate model for the choice of solutions for the lower structure, interior and stone decoration. It is assumed that the sculpture in Banjska was made by a group of masters from the workshop that King Milutin brought from the coastal cities to decorate his endowments.

### 3.5. Monastery Dečani

It is known from historical sources that the Dečani monastery was built as the burial church of Milutin's son Stefan Dečanski. It was started in 1327, but was completed in 1135 by order of Emperor Dušan. It is located near the Decani settlement between Peć and Đakovica. The builders were Franciscans, the name of Friar Vite from Kotor is well-known, so the similarity with Romanesque and Romanesque-Gothic cathedrals is pronounced.

In medieval Serbia, the Church of the Ascension in Decani was the largest and highest. The nave is five-aisled, and the altar space and chancel are three-aisled (Korać, 1965). It was built from marble slabs in two colors alternating in horizontal rows. Its form follows the local architectural tradition. But the influence of artistic creation from the West and its subordination to the Orthodox cult is best shown by stone sculpture, because the Dečani monastery is the richest with sculptural sculpture that is highlighted on the portals, window openings, cornices, and arcade friezes. This means that one artistic orientation was oriented towards conceptions characteristic of the Byzantine stylistic direction and the other towards solutions characteristic of the Byzantine style. This is how a combination of motifs was created that gave the church its specificity.

### 3.6. Monastery Sveti Arhanđeli

Emperor Dušan built a temple dedicated to the Holy Archangels near Prizeren in the period 1343-1352. as his burial church. Next to the temple there was also a smaller church dedicated to Saint Nicholas. The monastery was badly destroyed by the Turks and can only be interpreted on the basis of preserved fragments, some of which were used for the construction of Sinan Pasha's mosque in Prizren. Based on the preserved fragments, it is possible that Emperor Dušan built his endowment after the Constantinople Monastery of

Pantokrator, which served as the burial church of the Byzantine dynasties Comnenus and Paleologus.

The exterior of Dušan's endowment (treatment of facade surfaces, portals and windows) was built in the tradition of the Raška school, with which the architect wanted to repeat what Studenica and its builder represented (Maksimović, 1971). The interior (in terms of space layout and shape) was built according to the ideas of the Serbian-Byzantine school. It was a simple rectangular church with a base in the form of an inscribed cross, with four columns supporting the main dome. It also had four smaller domes at the corners of the arms of the cross. The effect that the whole presented was a harmonious relationship between facade volumes and surfaces (Bošković, 1967).

It is built with hewn and smooth blocks. It had rich sculptural plastic work done in white marble and a sumptuous mosaic floor. It was the largest, most expensive and most valuable construction project in the 14th century (Nenadović, 1987).

**4. The responsibility of international organizations and the contemporary specificity of cultural heritage in Kosovo and Metohija**

With its Conventions on the Protection of Cultural Property in the Event of Armed Conflict, UNESCO has established international standards for the protection of cultural heritage that require each country to take the necessary measures to establish a legal system of protection and enable the implementation of effective penal measures against persons who commit or order acts of intentional. The reasons for comprehensive international, and thus Serbian, protection and preservation of cultural heritage in Kosovo and Metohija are:

- They represent a unique cultural heritage whose valuable monuments have long been recognized as pan-European heritage;
- Protection, conservation and transmission to future generations of cultural heritage "belongs to the state on whose territory it is located" (Article 4 of the Convention on the Protection of Cultural and Natural Heritage, 1972). The Serbian heritage in Kosovo and Metohija after the war events of 1999 was under the administration of the Interim Mission of the United Nations UNMIK, and now under the administration of EULEX, so the responsibility for protection and conservation is directed to international bodies and organizations;
- They are indisputable criteria in determining the rights of the Serbian community on the territory of Kosovo and Metohija;
- Serbian cultural heritage and cultural monuments in Kosovo and Metohija represent a unique heritage which, even between the two world wars, was recognized as an inseparable part of European heritage;
- The Serbian cultural heritage and cultural monuments in Kosovo and Metohija preserve the architecture and art of the Roman and Byzantine empires, the medieval Serbian state, the Ottoman empire and the recent architecture of the Serbs and Albanians in the continuity of centuries;
- It represents the pinnacle of Byzantine architecture and art of its time;
- It represents a unique integration of Orthodox Byzantium and Catholic Romanesque architecture, which is a unique phenomenon;
- 8. It preserves monuments that bear witness to the centuries (from 1170 to 1371) of the development of the Serbian state as one of the most developed states of its era.

The main obligation of the international community with regard to the protection of the cultural heritage of the Kosovo-Meohi school and the cultural heritage as a whole is to preserve cultural monuments, monumental units and places, doing everything necessary for their maintenance, without negative influence such as handing over monasteries and

churches to the Albanian Orthodox Church outside Serbian enclaves, that is, where the people and the clergy were expelled.

## 5. The importance of spatial planning in the preservation of cultural heritage for the preservation of the identity of the people

The Spatial Plan of the Republic of Serbia is the basic planning document of spatial planning and development in the Republic, which determines the long-term strategic framework for directing and managing spatial development.

Serbia is distinguished by its rich cultural heritage. In Serbia, there are 12 localities (that is, 6 inscriptions) under the protection of UNESCO: the medieval complex of the Stari Ras monument and the Sopoćani monastery; four medieval monasteries of the Serbian Orthodox Church in Kosovo and Metohija (Visoki Dečani, Peć Patriarchate, Bogorodica Ljeviška, Gračanica), the remains of Felix Romuliana Palace (Gamzigrad) and three sites of medieval gravestones - stećaks.

According to the spatial plan of the Republic of Serbia 2021-2035. years, the most common development conflicts are uncontrolled construction in the vicinity of protected properties and urban expansion that disrupts the perception and integrity of cultural property, areas reserved for large infrastructure facilities and mining in the area of archaeological sites, etc. There is a lack of cultural property management plans that would provide significant guidelines for spatial and sectoral planning documents.

In the field of cultural heritage protection, the advocacy is for improving the valorization, presentation and use of cultural assets, and better organization, especially of cultural-historical entities, cultural monuments, archaeological sites and famous places and objects under previous protection. The concept is aimed at achieving the integral protection of natural and immovable cultural assets and the preservation of the cultural identity of the space and the specificity of the landscape of specific regions.

In addition to the objective obstacles in the protection and restoration of monocultural cultural monuments, the main procedural problems in the protection and planning of the restoration of cultural heritage in Kosovo and Metohija are:

- non-compliance of the institutional and legal framework of cultural heritage protection with international recommendations, conventions and ratified charters;
- long-term processes of determining cultural assets;
- inadequate treatment of immovable cultural assets in planning documents - lack of analysis and valorization of the construction fund, spatial checks of individual locations, as well as definition of specific protection measures;
- insufficiently recognized typology of urban structure in planning documents;
- in the planning and management procedures of urban development, insufficient recognition and differentiation of important features of the urban structure that represent elements of its identity and potential for development;
- insufficiently developed database on cultural assets;
- new typologies that disrupt the identity of urban settlements, due to the dominance of economic interest of investors - partial construction, illegal construction, etc.;
- economic underdevelopment of areas with important cultural potential;
- insufficient cooperation of professions involved in the protection, planning and management of cultural heritage - lack of practical guides and methodologies;
- insufficient capacities and financial support for the protection of cultural heritage;
- the decentralized system of immovable cultural heritage protection does not allow a uniform approach to heritage protection in accordance with the cultural and historical importance of certain areas;
- insufficient cooperation between institutions dealing with protection and planning and insufficient openness to modernizing protection and planning procedures;

- impossibility of equal participation of Serbia in international programs and projects.

Aring for cultural heritage is an indispensable sectoral area present in spatial plans, however, the specific situation in the area of Kosovo and Metohija cannot be treated in the usual way and by applying the established methodology of spatial planning, because it depends on the implementation of numerous agreements, starting with the so-called of Brussels, which should redefine the competences of the institutions in the area of Kosovo and Metohija and the central government in the Republic of Serbia. An acceptable legal framework should be found that would enable the world, European and national heritage in Kosovo and Metohija to be preserved. The principle of territorial cooperation and regional policy programs of the European Union support cooperation between regions, adapting to the specificities of space. Cultural heritage as a sectoral area represents the potential for regional cooperation between Kosovo and Metohija and other regions in Serbia. Spatial plans are instruments that open the possibility for cooperation, because the protection of cultural monuments is a matter of joint responsibility of local, regional authorities, the state and the international community, when it comes to the area of Kosovo and Metohija (Trkulja, Šaula, 2013).

## 6. Contribution to the program of architectural-urban protection and restoration of monumental historical cultural monuments of the Kosovo-Metohija school

Concept of restoration in architecture includes approaches that aim to completely or partially restore the purpose of an object or complex, including restoration and a number of other methods. Restoration is a unique procedure in which the restored object is returned to its original state, i.e. authentic state. A necessary condition for the restoration process are valid historical sources and unquestionably confirmed facts about the spatial, design and engineering features of the system being restored. All other procedures, when historical sources and facts are missing, or are incomplete, represent architectural design in the narrower sense, the basic principles of which relate to all other design topics (Petrović, Rašković, 2011).

Since 2005, there have been two types of renovations in Kosovo and Metohija, the first modest one, which was carried out by the Eparchy of Raško-Prizren with the help of the Serbian state (partial renovation of the Holy Archangels Monastery near Prizren, the Devič Monastery near Srbica, the Zočište Monastery near Orahovac, the church in Osojan ) and the second type of reconstruction is the one imposed by foreigners and the Council of Europe and carried out by Albanian companies. This second type of renovation, in addition to its debatable quality, only helps further usurpation by illegal institutions. None of the sanctuaries restored in this way were restored in the true sense of the word, but the work on the restoration had only a political connotation.

When approaching the program of architectural-urban protection and restoration of monumental historical cultural monuments in Kosovo and Metohija, it seems that two institutions are present, each in a different role and from its own angle. First is the state with its concept and second is the Serbian Orthodox Church (SOC). Both of these institutions must be the bearers of reconstruction and their work on reconstruction must be synchronized. The state has the role of the investor (founder) and the SOC has the indisputable, centuries-old role of the holder (beneficiary). For the state, these buildings are a valuable architectural work and cultural monuments that should be protected from devastation of any kind, provided for scientific study, and presented to the public. For the SPC, these are holy places and spiritual centers intended for worship.

The program for the restoration of the construction heritage in Kosovo and Metohija by the mentioned institutions should be as follows: in the case of the state and its

institutions, access to the processing of heritage artifacts and the restoration itself is required; in the case of SPC, it is the revival of the true, original purpose for which they were once established. Different aspects of the approach to the renovation program by the state or the SPC will not contribute to quality results, because there is a tendency to take a monopoly position in the conception and management of architectural renovation, which can be manifested in two forms: favoring one concept of the renovation method; and the imposition of concrete solutions by those in charge of reconstruction. Neither of these two forms is desirable, so a unified action and cooperation of the state and the Serbian Orthodox Church is needed in programs of protection, and especially in programs of restoration of holy places.

The protection of architectural heritage is a very delicate mission that should be supported by a large pool of knowledge and experience (Cvetanović, Momčilović - Petronijević, 2021).

## 7. Contribution to the concept of the future strategy in preserving the cultural heritage and heritage of Kosovo and Metohija

In modern conditions, institutional dealing with the overall Serbian cultural heritage in Kosovo and Metohija is somewhere between the department of the Ministry of Culture, the Office for Kosovo and Metohija and the department of the Ministry of Foreign Affairs. This kind of disorganization is a characteristic of not being able to find a way around a situation that is still going on and of constantly waiting for things to resolve themselves. Insufficient involvement becomes incomprehensible, since these are monuments of the greatest possible importance for the individual and collective memory of the Serbian people, which are exposed to obvious and brutal destruction. In fact, the current state of functioning of the institutional protection of cultural heritage and heritage in Kosovo and Metohija is such that the only objective comment would be that there is a devastating absence of a clear reaction from the state of Serbia regarding the protection of two spiritual and cultural heritages. And just as it is not known which ministry is responsible for the issue of heritage in Kosovo and Metohija, or everyone touches it a little bit, so it is not known what is being done to solve it, or at least the public is not sufficiently familiar with the basic details of the discussions that have been now run with international institutions that are engaged in the protection of our heritage.

Unfavorable political solutions greatly complicate the protection and preservation of Serbian cultural heritage in Kosovo and Metohija. That is why there are constant and unpunished attacks by Albanians on churches and monasteries, and what they cannot destroy they try to appropriate. The main reason for this state of affairs is the fact that Serbia lacks a realistic and sustainable strategy in the field of cultural heritage protection in Kosovo and Metohija. On the other hand, the so-called The Republic of Kosovo has adopted a national strategy for cultural heritage where there is no mention of any destroyed and devastated building or plan for the protection of buildings owned by the Serbian Orthodox Church. https://www.mkrs-ks.org/repository/docs/srb_strategija_za_naslede.pdf on the other hand, the Office for Kosovo and Metohija states that even all the crimes are not enough, so outrageous attempts are being made to replace and rename the Serbian cultural identity in Kosovo and Metochius. So far, no perpetrators have been found for all the crimes. There is a danger that, at the beginning of the 21st century, a unique multicultural and multiethnic region will disappear from the soil of Europe (https://www.kim.gov.rs/kulturno-nasledje.php)

Based on the analysis of the current situation, as well as the principles of cultural development, the future strategy on the preservation of cultural heritage and heritage in Kosovo and Metohija should advocate for a more significant role of protection and restoration, relying on relevant research and a planned and systematic approach to the

development of the cultural system as a dynamic and the driving segment of social and institutional. This would not be achievable without understanding and emphasizing cultural heritage as a guardian and creator of value, the importance of culture for each individual and the entire society, as well as the representation of our country and people in an international context. Therefore, the Strategy would be determined for the vision of the desired state which reads: Dedicated to preserving and nurturing the cultural and historical heritage of Kosovo and Metohija and the distinctive and unique culture of the Republic of Serbia, which contributes to the harmonious development of the human personality, society and international relations, satisfying the cultural needs of all citizens of the Republic of Serbia and members of all nationalities.

The strategy can define one general and five specific goals. The general goal of the Strategy for the Preservation of Cultural Heritage in Kosovo and Metohija is: Protection, improvement and restoration of cultural and historical heritage. The indicator at the level of the general goal is determined by the participation of citizens of the Republic of Serbia in protection and preservation programs, and is measurable according to the number of visits to architectural monuments of culture. The specific objectives of the Strategy are:

- Improvement of the regulatory framework, institutional capacities and financing system;
- Development of the investment system in the restoration and protection of cultural heritage;
- Encouraging initiative and equal participation of citizens in initiatives for the restoration and protection of architectural heritage;
- Improvement of international cooperation and the process of European integration in the field of protection and restoration of cultural heritage;
- Digitization and promotion.

The strategy of the Republic of Serbia in this area should include three main problems:

1. Physical protection of cultural heritage;
2. Professional conservation and restoration;
3. Cultural policy of local Serbian communities in Kosovo and Metohija.

The strategy should achieve the following main goals:

- Defining and determining the scope of Serbian cultural heritage in Kosovo and Metohija;
- Short-term and long-term program solutions for its protection;
- Position and role of Serbian institutions in Kosovo and Metohija;
- Principles and models of cooperation with international and local subjects.

Positive solutions for which the Republic of Serbia should advocate in the strategy for the preservation of cultural heritage and heritage, and thus specifically the schools of Kosovo and Metohija, and how they exist. The main priorities include several elements:

1. Inventory and insight into the state of the overall heritage in Kosovo and Metohija. Only on the basis of such an inventory, with an on-the-ground inspection and a request for data and reports made by temporary institutions, it would be possible to approach the institutionalization and concretization of protection and restoration;
2. Insisting on the sharing of responsibilities in the process of cultural heritage protection and its restoration. The current situation completely excludes the participation of not only Serbian institutions, but also experts. It is absurd that all protection and restoration projects are carried out by Albanian institutions and companies. The lead roof covering that was stolen in 2013 in the very center of the city from the Church of Our Lady of Ljeviška in Prizren, and then inadequately replaced, shows that this state of affairs is

unsustainable. Monuments that do not have the support of the local population, such as the Dečani monastery, are in much greater danger of destruction and inadequate restoration;

3. Preparation of expert studies on the assessment of the safety of cultural heritage and heritage in a situation such as this, when there is no possibility of direct involvement;
4. Restitution of ownership - the current situation shows that the Serbian Orthodox Church is forced to face legal and administrative tasks on its own, such as defining the boundaries of cultural monuments, exercising rights over their full disposal, wild and illegal construction in the vicinity of monuments, independent performance of restoration works and conservation works;
5. Standardization of geographical names, toponyms and places in Kosovo and Metohija and protection from violent changes;
6. Continuous, systematic work of the professional and scientific public to spread the truth about the Serbian cultural heritage in Kosovo and Metohija;
7. Digitization and promotion of Serbian cultural heritage in Kosovo and Metohija;

In the strategy of protection, restoration and preservation of cultural heritage in the territory of the AP Kosovo and Metohija, the basic principles must be respected:

- The permanent character of cultural monuments and the continuity of their values requires the continuity of the work of the services and excludes actions that would call that character and continuity into question;
- No demolished cultural monument must be left to oblivion;
- Registered monuments, according to European standards, must not be worked on without documentation and personnel with recognized references in the protection of cultural assets;
- Restoration of demolished or damaged cultural monuments must be carried out according to the original condition, based on documentation.

## CONCLUSION

This paper points to the problem of architectural-urban protection and restoration of the preservation of the heritage of the Kosovo-Metohija school. The characteristics of the selected monumental monuments of the culture of Serbian medieval architectural creativity, which in the context of time span the period from the second half of the 13th to the end of the 14th century, are indicated, and represent an integral part of the cultural heritage of Europe and the world, because its architectural features are a significant construction work, which surpasses national borders.

The most valuable are the medieval monasteries of the Serbian Orthodox Church, unique in that they bear witness to the meeting of Byzantine and Romanesque architecture. The special importance of the cultural heritage on the territory of the AP Kosovo and Metohija is reflected in its testimony to the origin of the Serbian state, church and culture, and therefore it represents a key element of the cultural identity of the Serbian people and is an integral part of the European cultural heritage. Since June 1999, 174 religious buildings have been demolished, damaged and desecrated in Kosovo and Metohija. Only on March 17, 2004, 36 Serbian Orthodox religious places and buildings were demolished, damaged and desecrated. The most important medieval heritage suffered serious damage, especially the Church of Our Lady of Ljeviška in the center of Prizren, after which UNESCO placed Serbian medieval monuments in Kosovo and Metohija (Visoki Dečani, Peć Patriarchate, Bogorodica Ljeviška, Gračanica) on the List of World Heritage in Danger. In addition to all that, after March 2004, instead of institutional solutions for the

protection of cultural heritage on the territory of Kosovo and Metohija, the process of forming ad hoc instruments began. With the signing of the Memorandum on General Principles for the Restoration of Serbian Orthodox Religious Monuments between the Serbian Orthodox Church (SPC), the temporary institutions of self-government in Pristina (Ministry of Culture, Youth and Sports) and the Council of Europe, with UNMIK as the guarantor of the agreement, the restoration included only individual objects that are under the auspices of the SPC. There is a lack of strategic vision, planned action and coordination in the implementation of the policy of cultural property protection, and there are no conditions for the implementation of unified management, provision of projects, their financing and implementation control. Projects are often financed by international institutions and other donors, but without clear and expertly verified priorities and plans. The contractors do not even have the professional references to perform that responsibility (as stated in the analysis of all the missions of UNESCO and the Council of Europe) and have not shown concern to effectively take care of the cultural heritage. In parts of the territory of Kosovo and Metohija inhabited predominantly or exclusively by the Albanian population, the rich Serbian cultural heritage is still exposed to a high risk of deliberate destruction.

Due to non-compliance with UN Resolution 1244 by temporary institutions (first UNMIK and now EULEX), the Republic of Serbia has no opportunity to take care of its cultural heritage in Kosovo and Metohija, which according to all European and world charters and standards is its inalienable right and obligation. The main objections to the current policy towards Kosovo and Metohija, and also to the field of historical heritage protection, could be summarized as follows: there are no precisely defined goals, there is no clear and sustainable strategy, there is a lack of models and strategic directions of action and the public in the work. The preparation of strategic and planning documents is a particularly demanding undertaking in areas where there are conflicting parties, and in which objects of cultural importance are the most frequent and biggest victims. Even today, in the parts of the territory of Kosovo and Metohija inhabited by the Albanian population, the rich Serbian cultural heritage is exposed to deliberate destruction. Protection and restoration must be based on principles that open up space for certain improvements that will contribute to the quality of the end result, which is certainly the revival of monastery complexes and their contribution to the preservation of national memory.

From an architectural point of view, Serbian medieval monuments also explain the ways in which Serbian national independence and spirituality were created. They followed the historical movements, the ups and downs of the state, but were built continuously regardless of the state of the state, from the founder's personal affinities and the ruler's desire to continue the tradition in cultural material goods started by Stefan Nemanja. Although most, in fact all of the mentioned churches and monasteries no longer exist in their original form, because they were demolished, destroyed, burned, looted, they were never destroyed. It seems that the secret of the survival of the Serbian people itself lies in their construction and renovations.

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# A 13TH CENTURY MEDIEVAL BULGARIAN INN FROM THE CITY OF SOFIA, IN THE CONTEXT OF THE ARCHITECTONICS OF SIMILAR LATE BYZANTINE XENODOCHIAS AND EARLY OTTOMAN CARAVANSERAIS FROM THE SOUTH-EASTERN PARTS OF THE BALKAN PENINSULA AND ASIA MINOR

**Nikolay Tuleshkov***

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**Abstract**: The article examines three specific medieval inns from the territory of the Macedonia region as it existed during the 13th to early 15th centuries, specifically from the cities of Sofia and Plovdiv (Puldin, Philippopolis, now in Bulgaria) and Thessaloniki (Salonika), now in Northern Greece. Two of the three inns—located in Sofia and Thessaloniki—are Bulgarian and Byzantine, respectively, while the third, in Plovdiv, dating from the early 15th century, was built by the Ottoman governor of Rumelia, which also encompassed the first two cities. Typologically, the two pre-Ottoman buildings are of a type that has a unique Byzantine counterpart in Constantinople (Istanbul), known as the Balkapan Han. This structure was originally built as a revenue-generating property of the Hagia Sophia cathedral and, after the city's conquest and its conversion into a mosque, was endowed by the sultan as waqf (a charitable endowment) for the cathedral's benefit. Today, we do not know when Balkapan Han was built. However, the article provides evidence that the inn in Sofia dates back to the mid-13th century, while the one in Thessaloniki dates to the 14th century, possibly from the time of Venetian rule over the city (1423–1430). This period began when the city's governor, Andronikos, realizing he could not ensure its defense, surrendered it for 50,000 ducats. Beliye dates it to the 13th–14th centuries, though its architectural style suggests the latter of the two centuries. For the third site—the caravanserai "Kurshum Han" ("The Lead Inn") in Plovdiv—it has been proven that it was built between 1430/31 and 1432/33 as a structure with a stone ground floor and a wooden upper floor, which was later, likely in the 16th or early 17th century, also replaced with a solid structure.

*The conclusion is that the typology of these three inns is local to the eastern Balkans—Byzantine-Bulgarian—integrated into Ottoman architecture through local Bulgarian builders.*

***Key words**: Balkan peninsula, Bulgaria, History of the Medieval Balkan architecture, Medieval inns, Ottoman caravanserai, Second Bulgarian Empire, Medieval Sofia, Medieval Thessaloniki, Medieval Plovdiv.*

The oldest caravanserai along the route of Via Militaris was located in Sofia, and it is actually pre-Ottoman, dating generally from the end of the 12th to the middle of the 13th century. It is known in the literature as the "Chokhajiiski

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Han" and was the property of one of the medieval Sofia churches - "St. Nicholas Golemi" (in the Middle Ages - "St. Nicholas the Great"). Anastas Ishirkov points out that in its "*dependent*" small church "St. Nikola Mali" (opposite the main entrance of the "Chokhadzhii Han", demolished in 1891) "*the merchants who came to the caravanserai located next to it, used to go to church there*" [1]. He obtained this data from a text in a notebook published from Popkonstantinov: *"In the year of Christ 1448, it is known when there were Father Hráno and Father Mladénů, ôrtátsy (allies) from the smaller temple, with Nikolaѧ, then it was the caravanserai, the caravan inn, it was a small (property) in the grounds of the church* (i.e. in the ground floors of two of the buildings open to the main road)*, and the caravansary, where the merchants came to the inn, there they went to the church, the epitropus - an innkeeper (hanji) Nésho"* [2].

But Ishirkov, interpreting the note, incorrectly came to the conclusion that the property of the inn belonged to the subordinate church. Most likely, however, it was built around the end of the 13th century, perhaps initially as a larger prayer chapel of "St. Nikola Stari", designed to serve the religious needs of travelers and merchants staying in the inn. That is why it is positioned in front of its main entrance. Later, during the Ottoman rule, when many of the city's churches were destroyed or converted into mosques, it was consecrated and began to serve as one of the city's churches.



The church "St. Nikola Mali" in Sofia. Archival photo of its demolition in 1891

1. Ishirkov, A. The city of Sofia in the 17th century. – In: Materials for the history of Sofia, vol. III, Sofia, 1912, p. 26
2. Popkonstantinov, Hr. Memoirs of Sredets. – Periodical magazine, year 3, No. 10, Sredets, 1884, p. 94

For the creator of the main church "St. Nikola Stari" Sebastocrator Alexander Assen is assumed, who from around 1219 ruled the Sofia region as his appanage. The basis for this is the building inscription from 1241 from the neighbouring church "St. Petka Stara", indicating him as its founder. Therefore, it is considered, and with reason, that the second temple, located almost next to it, was restored at roughly the same time. And this is confirmed by the architectural marks of the preserved wall from "St. Nikola Stari", where there is mixed masonry with acoustic pots built into the brick belt, or perhaps Mysian Panic ornaments, characteristic of the 10-14th century period (and for Pomoravia, in modern-day Serbia, until the first decades of the 15th century, as works of Bulgarian architects).



The preserved wall from the church "St. Nikola Stari",
after the bombings of January 10, 1944

Let's also point out that the only established so far church in Sofia with Panic decoration is the two-story ossuary church "Sts. Nicholas and Panteleimon" of the medieval monastery near the Boyana Castle "Batil", built before 1259 by Sebastocrator Kaloyan, in front of the western facade of an older cross-domed cathedral from the 10th - 11th centuries (dedicated to St. Pantaleimon). A monastery residential wing located nearby and parallel to the church was found archaeologically on its southern side.

Undoubtedly, similar to the access to the two-story church of the Bachkovo monastery, here too from the second floor of the monastery building, the entrance from the upper level of the church was reached via a bridge. The lower one served as a burial place, and the old temple was turned into a mortuary chapel [3].

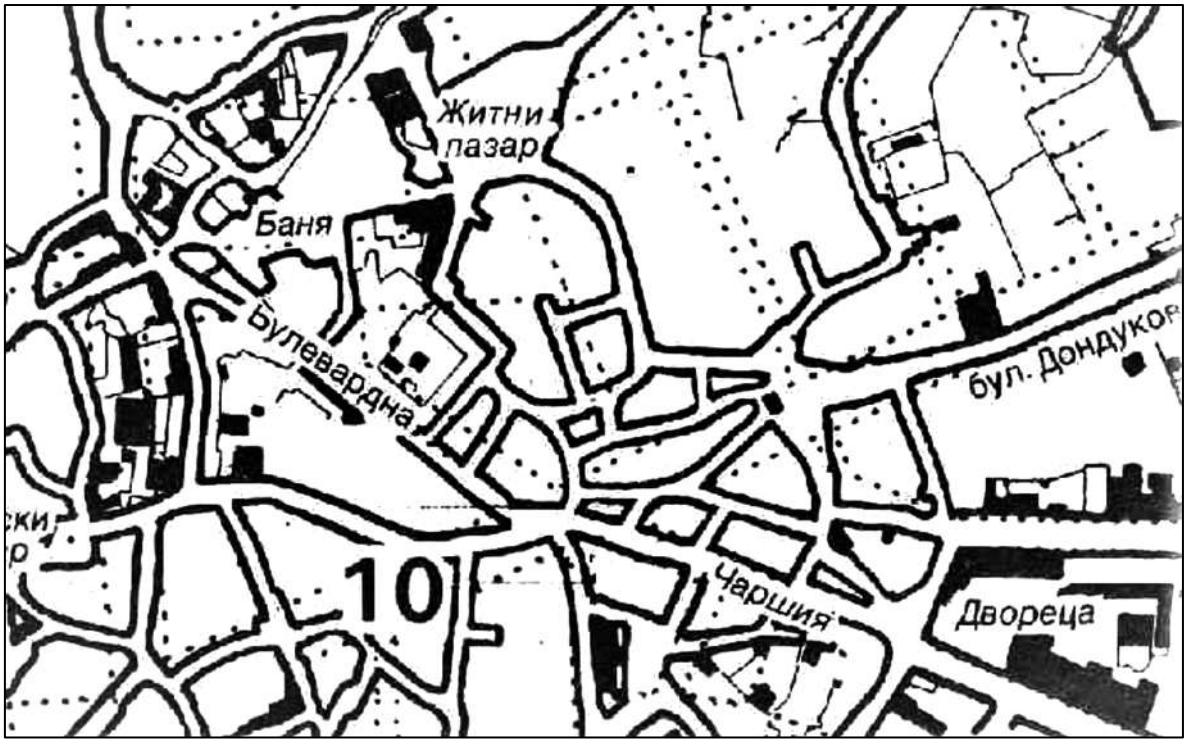
Clarifying the question of the property interdependence of the three subjects - the main church, the chapel (later consecrated as a temple) and the inn, by analyzing the specified documents, we can deduce the hypothesis that the "Chokhadzhii Khan" was erected by Sebastokrator Alexander Assen in the period circa 1220 - 1241, as a profitable building of the temple "St. Nikola Stari", created at the same time. And if it is also taken into account that the expansion of the Boyana church was the work of Sebastocrator Kaloyan, the conclusion emerges that St. Nicholas Mirlikliyski was the patron of the high-ranking rulers of Sofia in the 13th century.

The memory of all this was alive among Sofians even after the 15th century, because the Russian professor Viktor Grigorovich will note in his book about his journey through the Bulgarian lands, how *"in Sofia there are several ancient monuments related to famous legends. They include the Hagia Sophia mosque* (4th and 5th century St. Sophia church, renovated in 6th and 9th centuries, on St. Alexander Nevsky Square), *the "Gül Mosque"* ( the Rotunda "St. George" from 4th-6th century, converted into a mosque by Sultan Selim I) *and the Chohaji Khan"* (from choha - cloth)*..."The Chohaji Khan", a building with vaults, as they say was built by the Bulgarian kings for warehouses..."* [4].

It can also be seen that towards the middle of the 15th century the inn began to be called the "Carvansara". If one interprets Evliya Celebi's story from around the middle of the 17th century about the inns of Sofia, he clearly perceives that two separate large-scale inns stood next to each other - the "Chokhajilarsky" and the "Buyukka inn" [5]. But due to the church ownership of the first of them, although as he claims it was one of the largest in the city, he does not mention who its creator was. Which is not characteristic of him, since in his travelogues, whenever the benefactor is a Muslim, he indicates it.

3. Tuleshkov, N. Architecture of Bulgarian monasteries. Sofia, 1988
4. Viktor Grigorovich. Essay on travels in European Turkey. Second edition, Moscow, 1877 (First edition, Kazan, 1848), p. 137
5. Evlia Celebi. Evliya Celebi's journey through the Bulgarian lands, in the middle of the 17th century. – PSP, vol.70, St. 9/10, 1909, p. 69

So is his text about the Safavid "Inns and Caravanserai". In this case, however, he only briefly notes "the big "Buyuk Han", which is opposite the arcade", but this, according to the location determined, is precisely Chokhadzhiyski Han. Ishirkov picks up this phrase of Celebi and writes in his text about both as separate subjects, but describing them with completely matching parameters. From here, in the historical literature, it is usually considered that it is a question of two different caravanserai located next to each other in a common group with an arcade. The confusion is finally consolidated with the explanatory additions applied to a revised map of the city from 1879, made for an "Anniversary collection" from 1940, dedicated to old Sofia. In this area, as can be seen from it, the most large-scale building is the Chokhadzhii Han, and opposite it, the "geometer" who made the map - Toma Pishtachev, depicts a triangle from the Kyurkchii hamlet, in the middle of which is the church "St. Nikola Mali", and on its two sides, according to him, were the "Buyukka Han" from the northwest and the "Karvasarata (carvansarai)" from the southeast. The "Chokhadzhii Han" is also marked as a separate huge object opposite them.

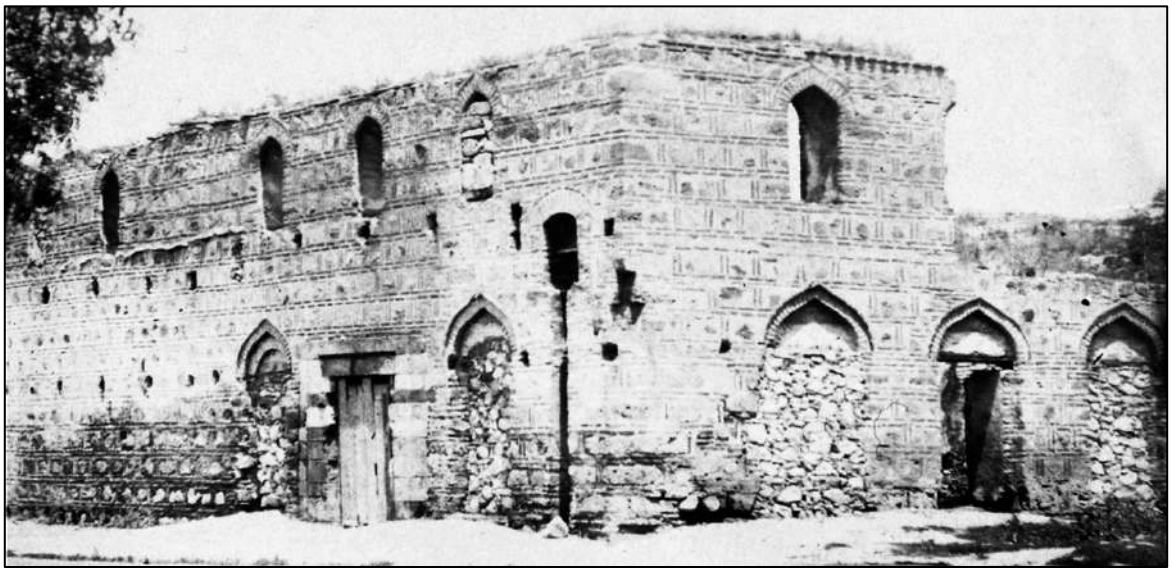



Fragment of the plan of old Sofia from 1879 with applied regulation, according to the project from 1881 (geometer T. Pishtachev), with the Chokhadzhii Han, behind the inscription on "Bulevardna" street

But the analysis of the area clearly shows that there is simply not enough space for the placement of these three listed large-scale objects. Moreover, at least "St. Nikola Mali" and one of the Sofia synagogues are located there as well. And "*Karvasara*" itself, i.e. *"Chokhadzhi Han"*, is actually correctly drawn right opposite the church - on the other side of "Bulevardna" street,

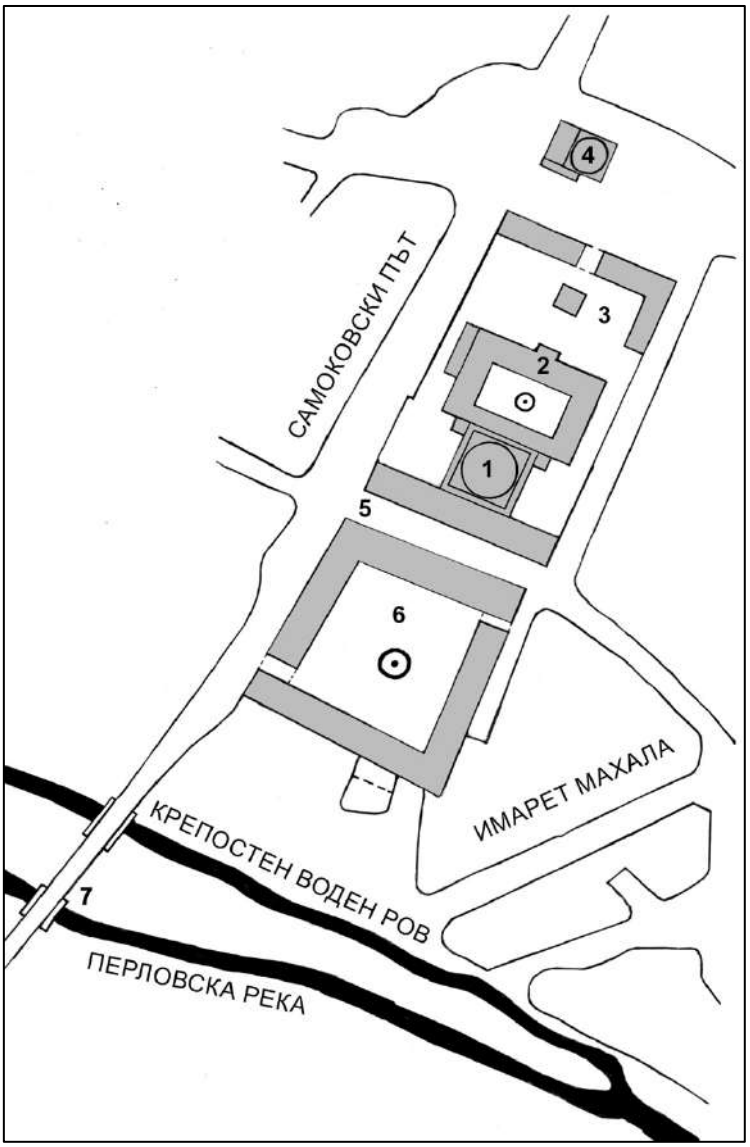
drawn by the geometer exactly in front of its facade. This same triangular neighbourhood is hemmed in on the other side by an arcade, and on the third by three of the city's four Jewish "havri" (synagogues). In general, it can be said that even if there were some earlier inns here, they were undoubtedly small private buildings, and not large-scale waqf caravansarai.

This whole mess started by Evliya Celebi was continued by Sprostranov, who, placing the three objects in this part of the city at the same time, mistakenly began to claim that the name *"Karavansara"* refers to the *"Big* (Turkish: "Buyuk") *inn"* mentioned by Evliya Celebi to be *''opposite the arcade''*. While in the inscription published by him from 1448, the inn from the 13th century is very clearly called that. This is how the three large-scale inns were placed here, instead of one called by different names over time. Even the description given to this non-existent separate caravanserai - *"Buyuk Han"* - is actually entirely covered by that of the *"Chokhadzhii Han" - large, with "two doors" and "shops around"*. He also indicates that it existed until the Liberation, as a disorganized place inhabited by *"poor Jewish families"* [6]. After that, when writing about the *"Chokhadzhii Han"*, besides repeating the same main characteristics, as inherent to it, he will also quote Drish (1719) who reported *"point-arched galleries"*, while in old photographs and drawings all its vaults are of course semi-cylindrical, and so it is clear that he most likely described the caravanserai from the quliet (religious-benevolent architectural ensemble) of the "Black Mosque", which according to a photograph from the early 1880s, has a pointed arch form.



View from the caravanserai of the "Black Mosque" (with the bricked-up shops), from the corner between present-day "General Parensov" and "Tsar Shishman" streets. Photograph by Ermen Kaye from 1884

6. Ishirkov, A. The city of Sofia in the 17th century. – In: Materials for the history of Sofia, vol. III, S., 1912, p. 29. This is also mechanically repeated by Hristo Zlatarev in his "Memories of pre-liberation Sofia" from the Jubilee Collection of the "Ivan Denkoglu" Society from 1940



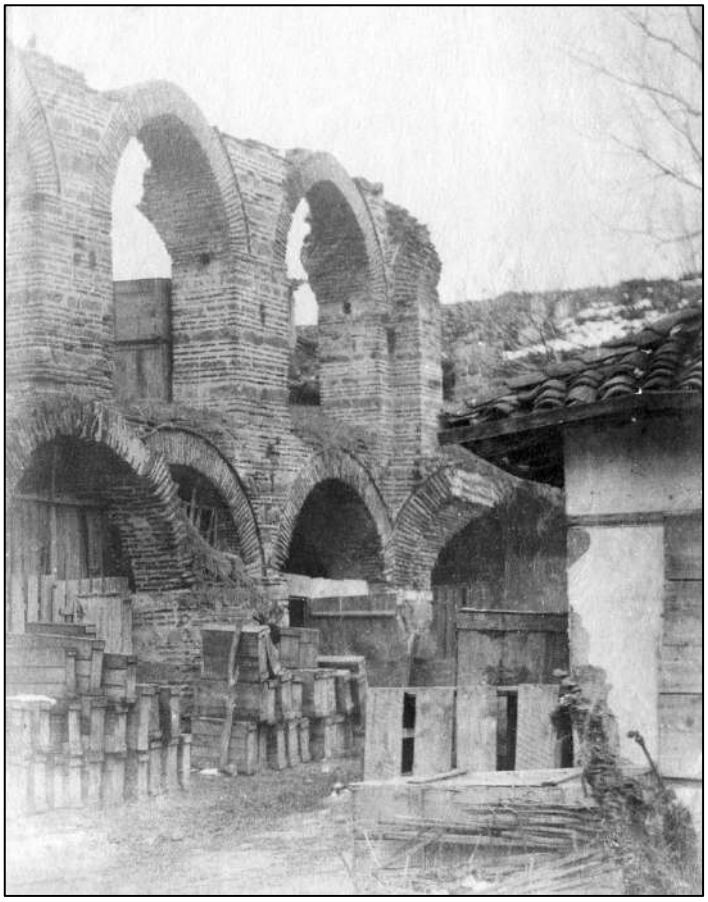

Schematic reconstruction of the kyule of the "Black Mosque", according to Tuleshkov. 1. Mosque, 2. Inner courtyard in front of the iwan of the mosque with a teke, 3. Madrasa, 4. Bath, 5. Street with shops, 6. Caravanserai, 7. "Kaden bridge" over the Pearl River

In 1850, Edmund Spencer found the Chokhadzhii Inn already damaged and wrote: *"The caravanserai or inn is partly in ruins and is the most majestic building ever erected in these provinces for the accommodation of travellers and their goods. It is built entirely of dressed stone* (in fact, the masonry is mixed—opus mixtum) *and is fireproof throughout, with arcades. Walking through the vast stables, warehouses, galleries, and countless individual rooms, we find abundant evidence of Sofia's significant medieval trade, as only this inn managed to survive and accommodate a large number of travellers..."* [7].

7. Spenser, Edmund. Travels in European Turkey in 1850 through Bosna, Servia, Bulgariaq Macedonia, Thrace, Albania and Epirus, with a visit to Greece and the Ionian islands. London, 1851, vol. II, p. 376 (translation from English N.T.)



Views from the "Chokhadzhii Han" in Sofia based on French photographs from circa 1879 - 1882. "Old Sofia" Collection



Same as above



Same as above



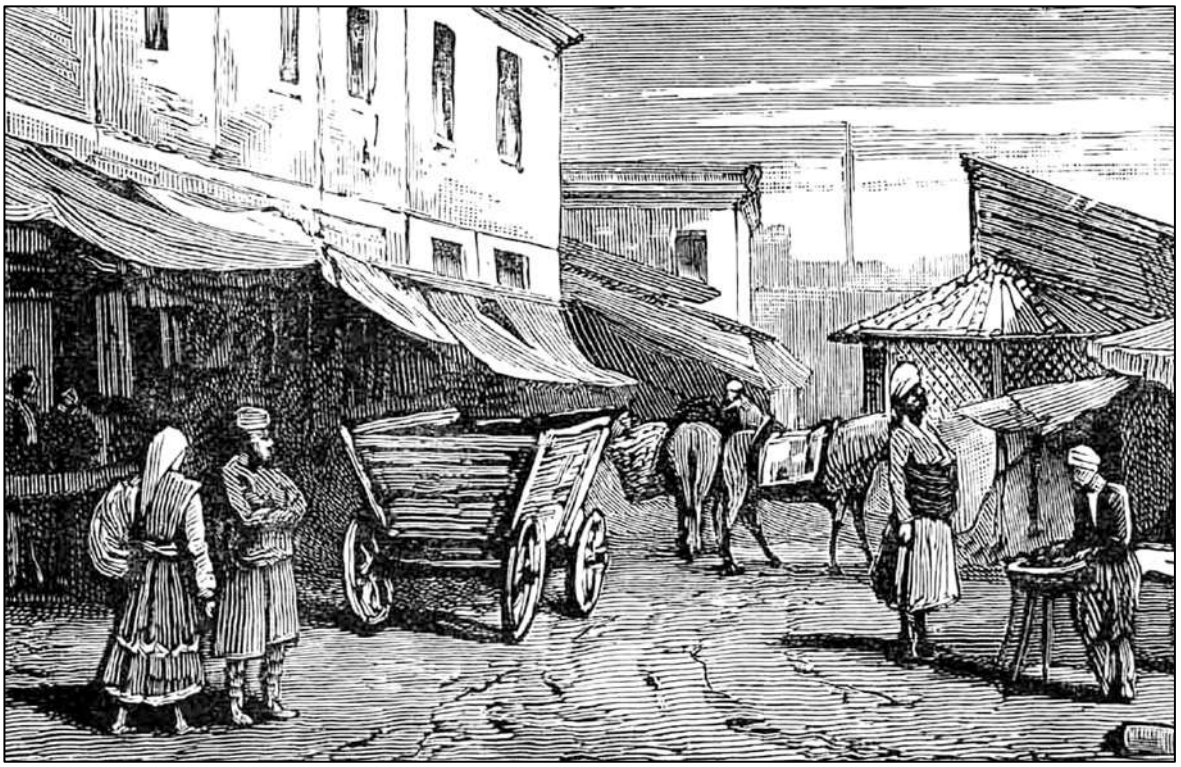
The ruins of the "Chokhadzhii Han" in Sofia from the back gate
by Oberbauer's watercolor

Despite the ongoing decay, after the Russian troops entered Sofia on December 23, 1877 (January 4, 1878), the French volunteer from the 26th Don Cossack Regiment, Dick de Lonlay (pseudonym of Georges Ardouin, historian, journalist, and painter), described it as still fairly preserved: *"The street of goldsmiths and currency exchange consisted mostly of a large rectangular building—the former caravanserai, equipped with arcades and galleries, painted with frescoes in all colours, contrasting only with the fresh reddish and dark tones of the brick walls, onto which large iron hooks are attached, meant to support awnings in the summer that protect the shop facades and sometimes the heads of the 'giaours…"* [8]. This is the only testimony that the upper gallery of the inn was decorated with frescoes during the Ottoman period, likely between the 16th and early 19th centuries. This also explains the iron hooks embedded in the wall above the outer shops on the ground floor of the inn, the purpose of which puzzled other authors. Apparently, during the rainy and cold months, the awnings mentioned by de Lonlay, hung in the summer from these hooks, were taken down and stored along with their wooden or metal supporting structures [9].

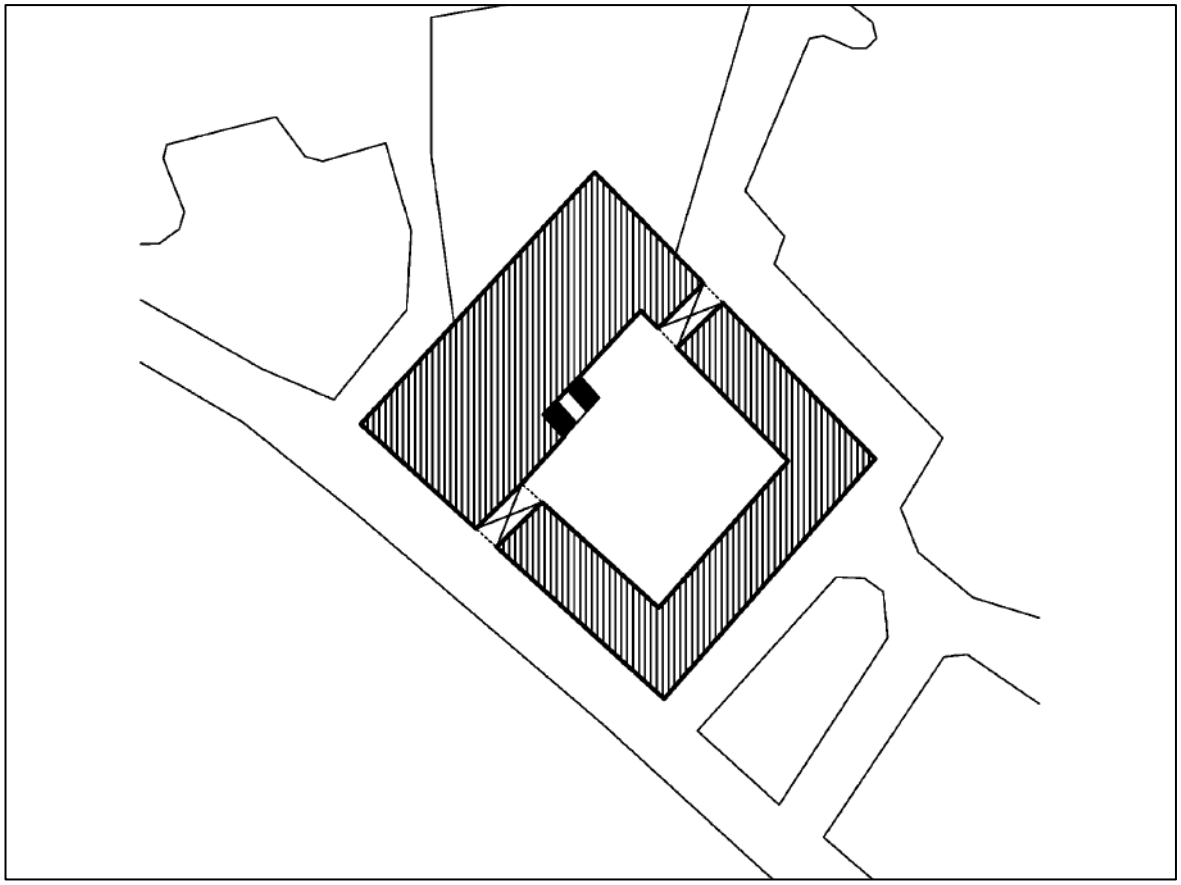
We can see what these awnings looked like from an engraving in "The Graphic" from 1885, depicting the shops between the Kurshum Khan caravanserai and Muradiye Mosque in Plovdiv.

The plan of the Chohadji Inn, which belongs to the second functional type, outlines the building's contour (at least 70 x 60 meters, or over 4200 square meters of built-up area) in a way that shows the functional courtyard is surrounded by wings, one of which, occupying the northwest side, is twice as wide—this is likely the large stable mentioned by Spencer. According to two preserved photos of this medieval Bulgarian inn, it was a long, two-aisled hall, covered longitudinally with brick cylindrical vaults similar to those I have seen documented by Charles Texier in a pre-Ottoman xenodochium (inn) from the 14th century in Thessaloniki. The other three sides of the courtyard were enclosed by three two-story wings, all featuring arcaded galleries on both levels in front of a series of connected rooms. Two of the wings were wider due to the rows of vaulted shops opening onto the two streets surrounding the inn—Kapan Street (later Boulevard Street, and from 1883, Knyaz Alexander Dondukov Street)

8. When the Ottoman Serdar (military leader) Lala Shahin Pasha besieged Sofia in 1380, in one of his reports he wrote: *"... Trade in the city is quite developed, because on every step they look like leeches on the well-worn roads on which travelers travel and travelling-merchants, merchants of safe goods and products, who work in Sofia and are sent to Rumelia (a region covering all the conquered territories in Europe, with headquarters in Odrin) and further on. The roads and bridges are very big..."* (according to Stancheva, M. Sofia - from antiquity to modern times. Sofia, 2010, 142 - 143.)
9. Lonlay, Dick de. L'armee russe en campagne souvenirs de guerre et de voyage par un volontaire du 26-me regiment de cosagues du don. Djouranli-Eski-Zara-Schipka-Pélichat-Lovtcha-Plevna-Gorny-Doubnick. Paris, 1888

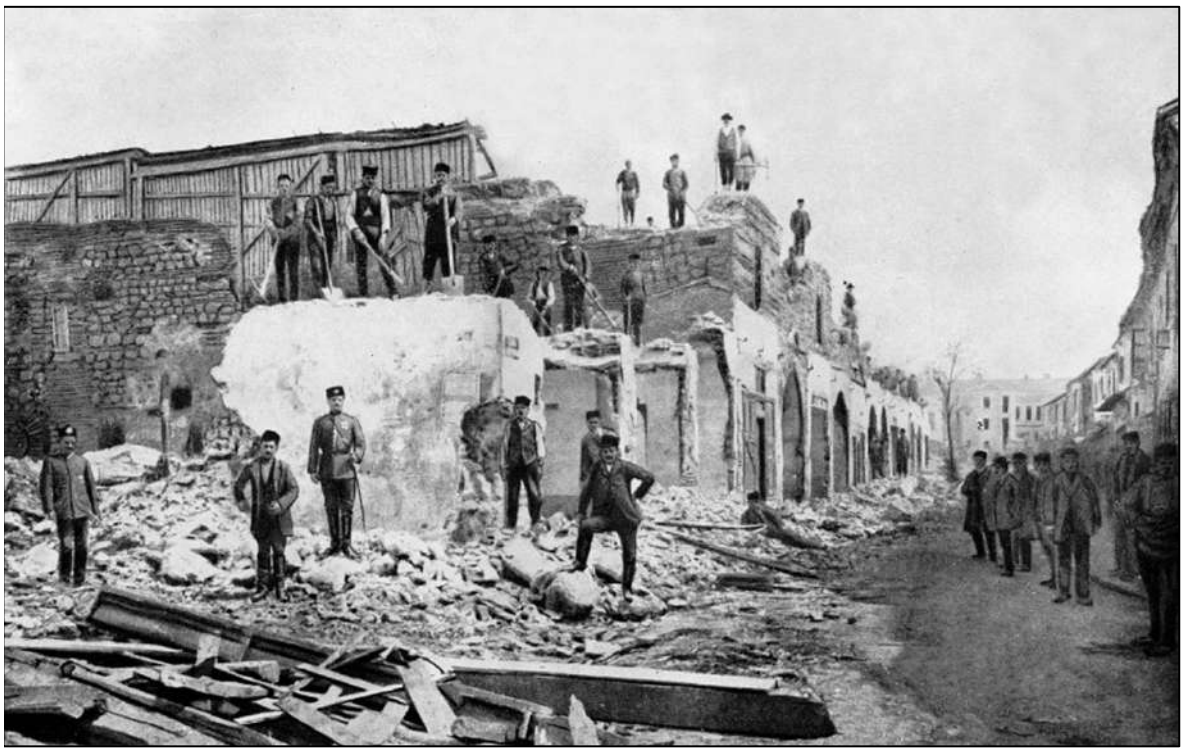


Fabric awnings of shops in front of the "Mouradie Mosque" in Plovdiv according to a fragment of an engraving of "The Graphic", London, 1885

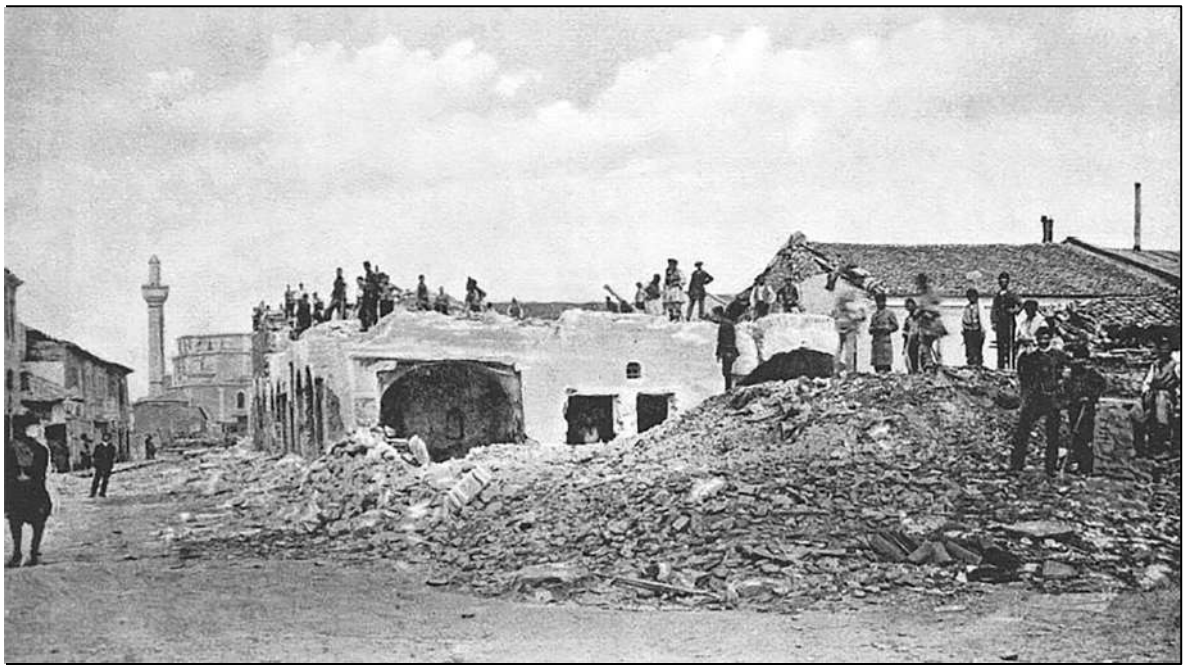


Schematic plan of the "Chokhadzhii Han" in Sofia, based on the plan from 1879, according to Tuleshkov

to the southwest, and a lane leading to the nearby Devil's Market (Shaitan Charshiya) to the southeast, which continued past the northeastern wall to a second gate leading to the Grain Market. This layout is clearly visible in photos from 1888, taken during the demolition of the inn.



Archive photo from the demolition of the "Chokhadzhii Khan" in Sofia in 1888. View from Bulevardna Street with the yachar building in the foreground



Archive photo from the demolition of the "Chokhadzhii Han" in Sofia in 1888. View from the other corner of the buildings along Bulevardna Street and the street to "Shaytan Bazaar"

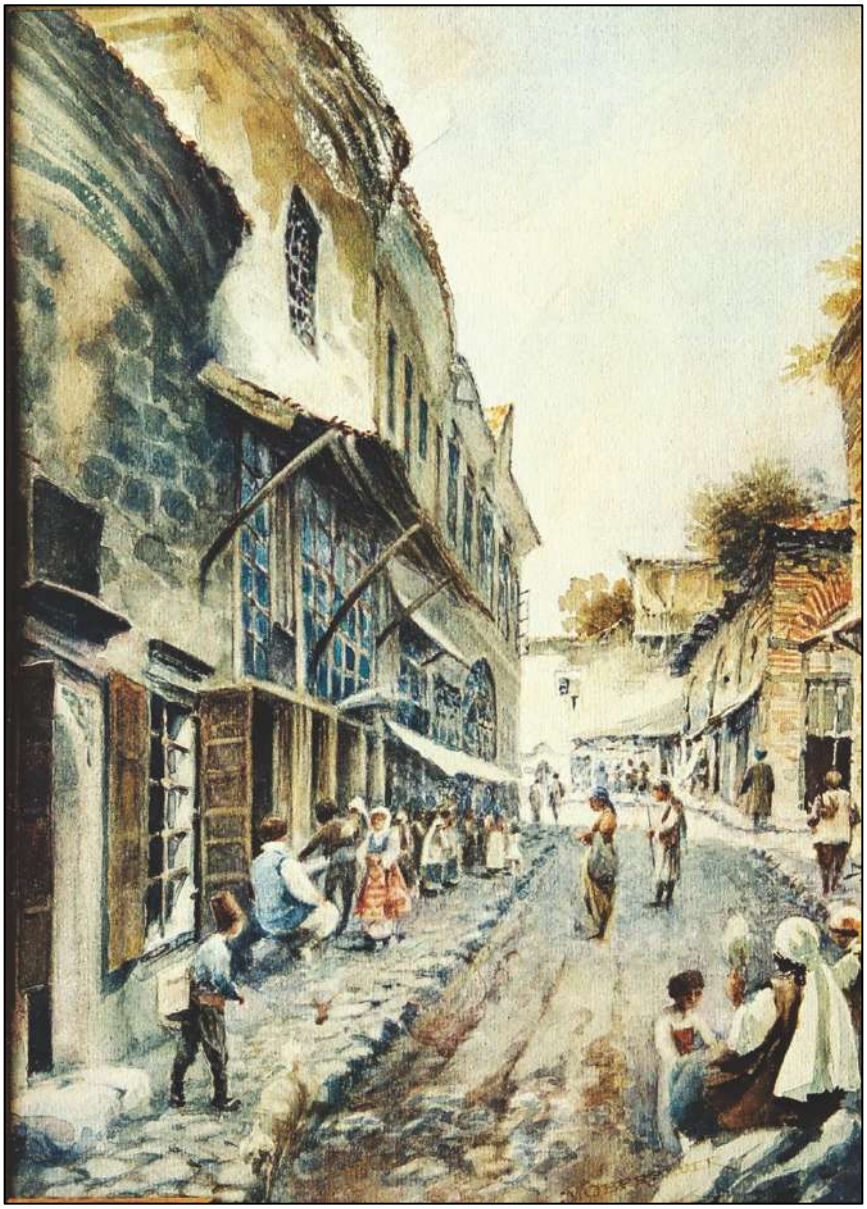
It is slightly possible that the ground floor of the third, rear wing also housed shops. For example, in the Byzantine xenodochium in Thessaloniki, the three inhabited wings had single-story shops in front of the ground-floor facade. In an aquarelle by Oberbauer, the tall vault in the foreground, behind which the main entrance pavilion covered with a dome is visible, is most likely the second entrance. The springing of perpendicular arches on both sides suggests that it too had a domed cover.

To the southwest, near the stable of the Chohadji Inn, is one of the entrances mentioned in old descriptions. It led into the courtyard from the main street, recorded as "Boulevard Street" in the 1879 city plan. To the left, between it and the stable's wing, a wide staircase is outlined, leading to the upper floor, but it was probably a later addition. According to photos from around 1880, the original stairs were about 1-meter-wide, resting in their lower part on a small half-vault, while in the second part, they extended outward, supported by an arch from the ground floor, creating a landing in front of the rooms at the gallery entrance.

Hristo Zlatev points out that there was a second *"opposite"* entrance leading to the narrow market street beyond the bend, as indicated in the 1879 city plan. On the plan, it is positioned directly across from the main entrance. In photographs from the early 1880s, a second, narrower stone staircase, attached parallel to the arcades, can be seen at the opposite corner of the building. At its highest point, where it ends in a landing in front of the gallery, the staircase is supported below by an arch, while the lower sloped part of the steps rests on a half-arch. Its masonry is identical to the rest of the building. Zlatev continues his description, explaining that the *"backside"* of the interior rooms, facing the street, housed *"vaulted shops with 5 metres of frontage and 6-7 metrers in depth"*[10]. This means that, together with the rooms facing the courtyard, which were about 4 metres deep, the colonnaded gallery in front of them (around 2 metres), and the total width of the walls and columns, the width of these wings was about 14 metres. The south-eastern corner of these shops, preserved after the building's demolition in 1888 and later divided lengthwise into two, formed the structure of the so-called *"Goldsmiths' Market."* It can be seen on the left in the background of one of Sofia's watercolours—*"The Goldsmiths' Market"* (1890s) by Oberbauer.

The chain-linked rooms in the inn's courtyard were accessible through surrounding open arcaded galleries, *"vaulted corridors,"* as Ireček writes, adding that on the upper floor behind these galleries were *"rooms for foreign merchants, and above each small room rose a dome*

10. Zlatev, Hr. Memories of pre-liberation Sofia – In: Jubilee Collection of the "Ivan Denkoglu" Charitable Society. Sofia, 1940. The sizing of the inn was carried out based on the dimensions of the shops indicated in this work - 13 in number for the main facade and one axis with the entrance portal, or a total of 14x5m=70m. However, we do not know the thickness of the walls, the sum of which must be added, as well as whether the 5 meters in question, measured by Zlatev, are not axial.

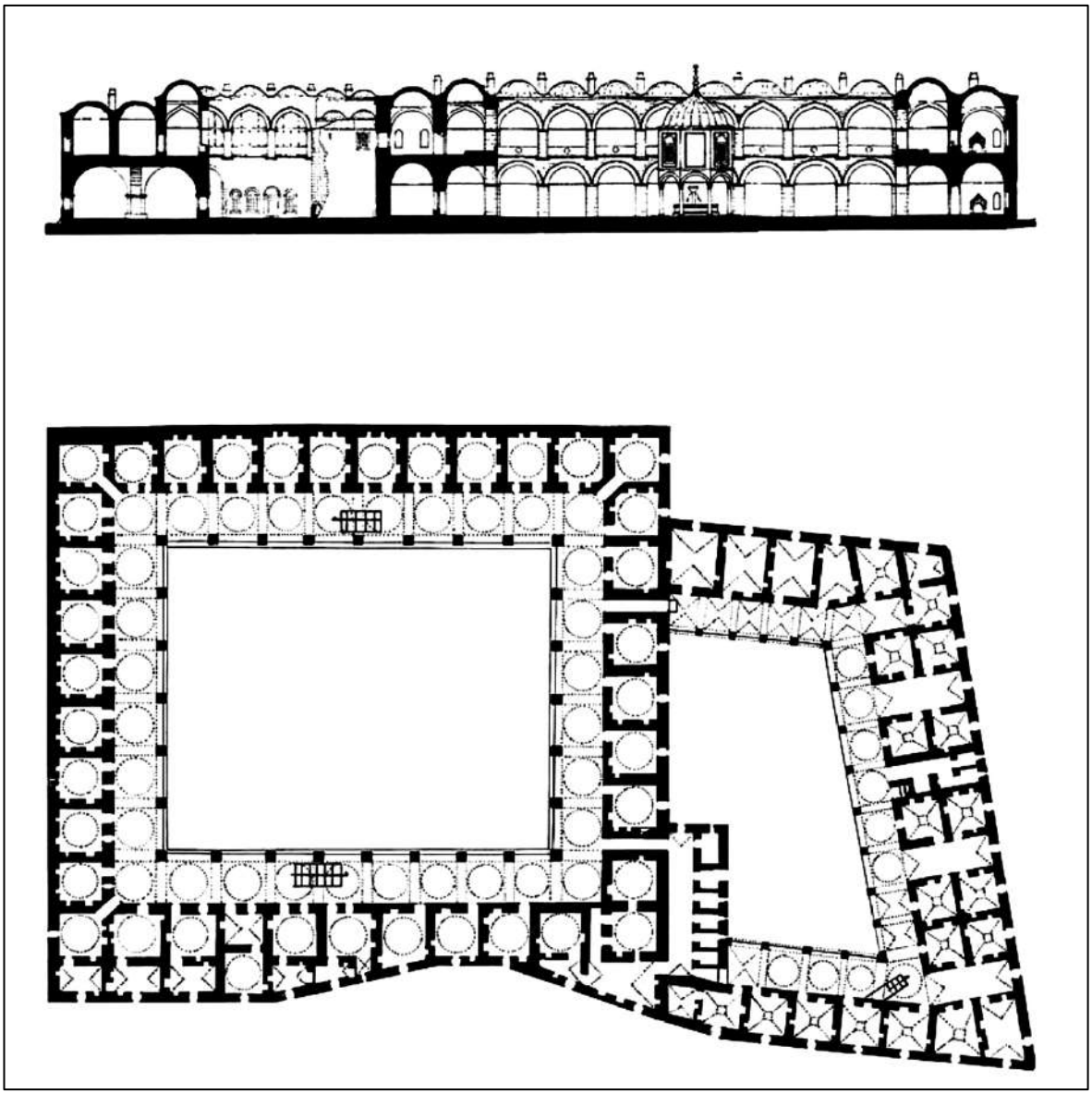


The goldsmith's bazaar in Sofia. At the bottom right are the remains of a preserved group of shops from the buildings at the corner of Bulevardna Street and the street to "Shaytan Bazaar"

(i.e., a calotte), *covered with lead"*[11]. It appears that the rooms in the two wider wings, which housed shops, consisted of two enfilade-connected spaces. This is likely what is referred to in a travelogue by Antonio Benetti from 1680: *"I am staying in a wonderfully built inn, divided into two apartments, entirely covered with lead, with a large courtyard and a beautiful fountain in the middle."* Such a combination of double rooms could only have existed if the inhabited wing was wider, as was the case in Sofia, due to the shops in front of the ground-floor rooms or over wide stables. In both cases mentioned,

11. Irechek, K. Travels in Bulgaria. Sofia, 1974, 76 – 77; Tuleshkov, N. Architecture of medieval innkeepers from South-Eastern Europe – In: GNAM, 13, In Honorem Professoris Violetae Volkova – Neseva, Sofia, 2016, 233 – 237

it seems that only the Chohadzhiiski Han had this configuration. Similar two-room inhabited cells can be found in the widest part of the wing with shops and on the floor above the stables in the second courtyard of the caravanserai of Rustem Pasha in Edirne (1554, by Mimar Sinan).



Plan and section from 1948 of "Rüstempaşa Han" in Edirne (Bulgarian Odrin), by Ali Saim Yülgen

From old photographs, it can be seen that large domes, covered with lead sheeting, were present over the two tower-like entrance portals. However, since the roof of the second floor is already destroyed, there are no traces of the smaller domes that would have been over each of the inhabited rooms there. Judging by the width of the surrounding wings visible in the 1879 plan, it is clear that there were single sleeping rooms on the lower level as well, similar to those in the early Ottoman caravanserai in Plovdiv. A characteristic feature of the "Čohadžiyski Han," however, was that the stables had a second floor,

likely consisting of large storage rooms with solid walls facing the courtyard, where tall doors allowed the lifting and storing of goods.

The inn was built using mixed masonry (Opus mixtum) with alternating belts of three rows of bricks and one row of stone blocks of varying lengths, though in some areas it transitioned to cellular masonry. The vaults and domes were entirely made of brick. In a photo from 1888, taken during the demolition, a brick six-pointed rosette (the so-called "Ж" (Zh) ornament) can be seen above one of the columns on the ground floor to the left of the main gate. This ornament, originating from pagan antiquity, became a stylization of Christ's monogram—the chi-rho, which, apart from being part of Christian culture since late antiquity, is one of the oldest ornaments in medieval Bulgarian architectural painting [12]. There are also brick arcades with thin brick archivolts, as well as instances of the mentioned cellular masonry. All these features are characteristic of medieval Bulgarian architecture from the Second Bulgarian Empire in the 12th–14th centuries, though some elements, such as the "Ж"-ornament and cellular masonry, date back to the 9th century.



Archive photo from the demolition of the "Chokhadzhii Khan" in Sofia in 1888. To the left is the stable. Above the column between the two first arches on the left, there is a bricked "Ж" (Zh)-ornament (Christ's monogram), indicating that the property is a church

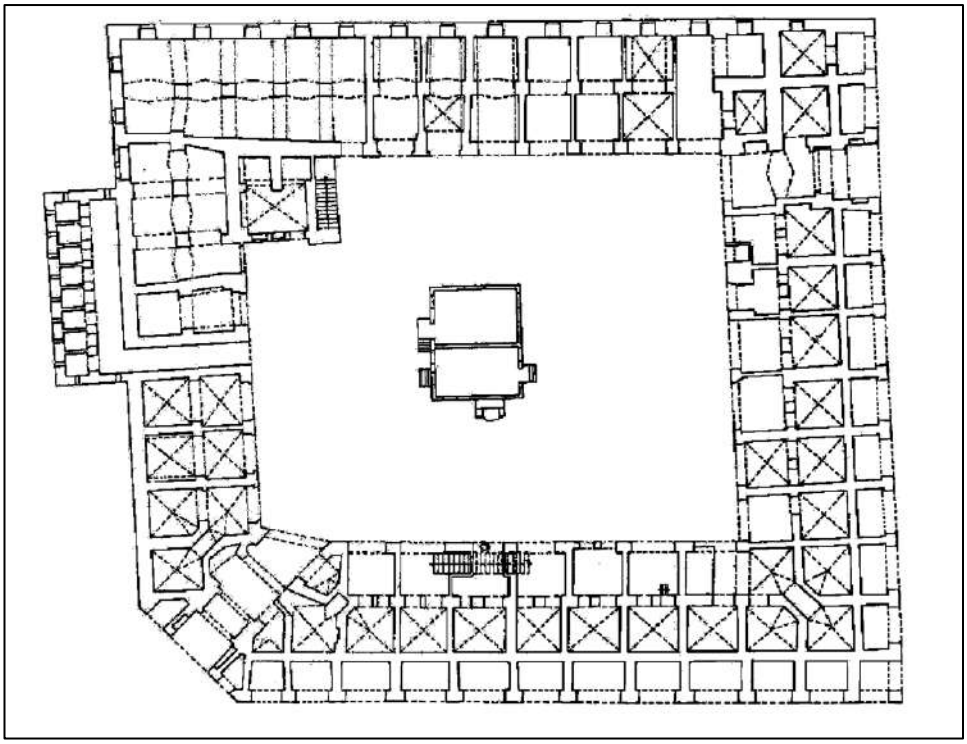
12. Tuleshkov, N. The architectural art of the old Bulgarians. Volume 1, Middle Ages, Sofia, 2001 (discussed in detail in the chapter "The Painting Style - Flaming Gothic of Byzantium")

Based on the architectural analysis of the site and comparable features with other pre-Ottoman Bulgarian structures, it can generally be suggested that the inn dates from the late 12th to 13th century and was the work of southern Bulgarian craftsmen, as most of the construction features possess the stylistics characteristic of their work.

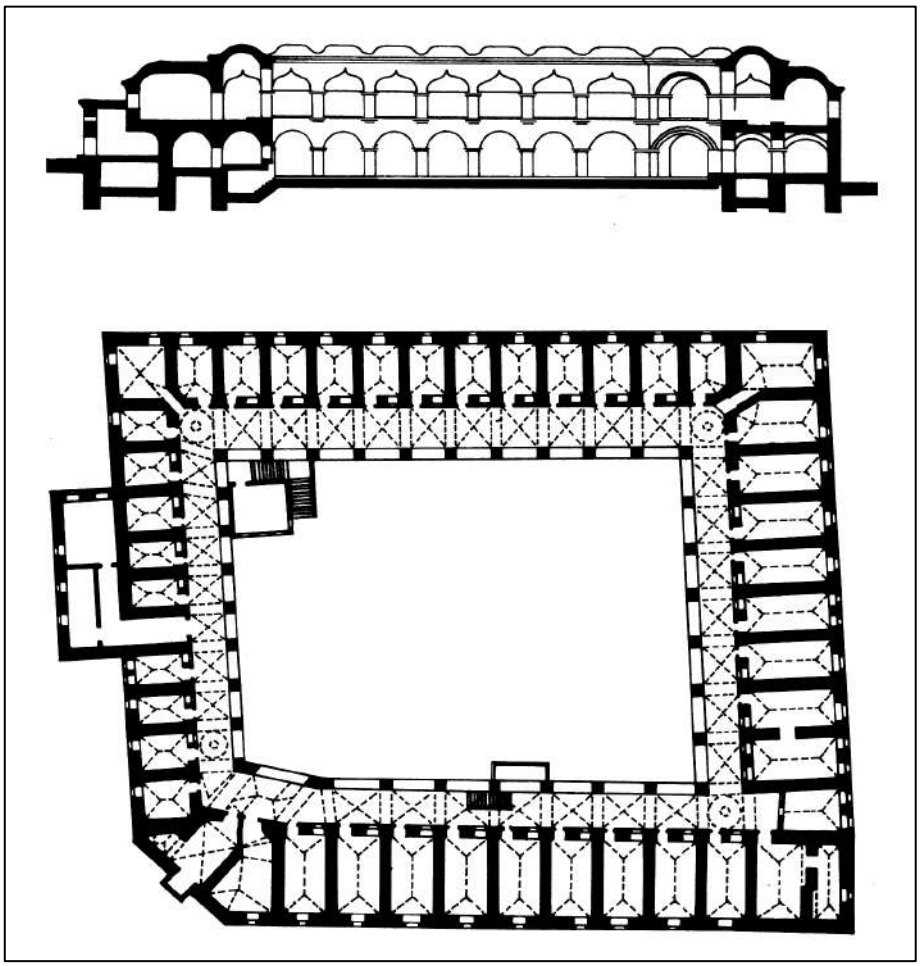
In terms of its functional typology, the *"Chokhadzhiiski Inn"* resembles the *"Kurshum Inn"* in Plovdiv (also known as the *"Lead Inn"* due to its lead-covered roof), which was an early Ottoman building. It was demolished by the Plovdiv authorities between 1928 (after being damaged by the Chirpan earthquake) and 1933. Contrary to some authors' belief, it had a spatial and functional connection not with Shahbedin Pasha's mosque, but with the Muradiye (Jumaya) Mosque, built by Sultan Murad I Hüdavendigâr (1362–1389) as an imaret and later rebuilt as a large Friday mosque, accompanied by a caravanserai, an imaret, and the Tahta Hamam ("Flea Bath") by Murad II (1421–1444) between 1430/31 and 1432/33. Clearly, we are dealing here with a külliye (a complex consisting of a mosque, a caravanserai, and a bathhouse), with the bath located next to one of the caravanserai's entrances. The two main structures—the mosque and the inn—were positioned in the characteristic manner, opposite each other, and it is likely that there was a market street or a small square between them. Later, an arcade (a covered market) was erected on the other side of the bathhouse.




A panoramic view of the central parts of Filibe around 1880 based on a fragment of a photograph by Dimitar Kavra. 1. Muradiye Mosque, 2. The Bazaar, 3. Kurshum Han, 4. Tahtakale Hammam



Plan of the ground level of "Kurshum Han" in Plovdiv according to Zlatev-Tuleshkov



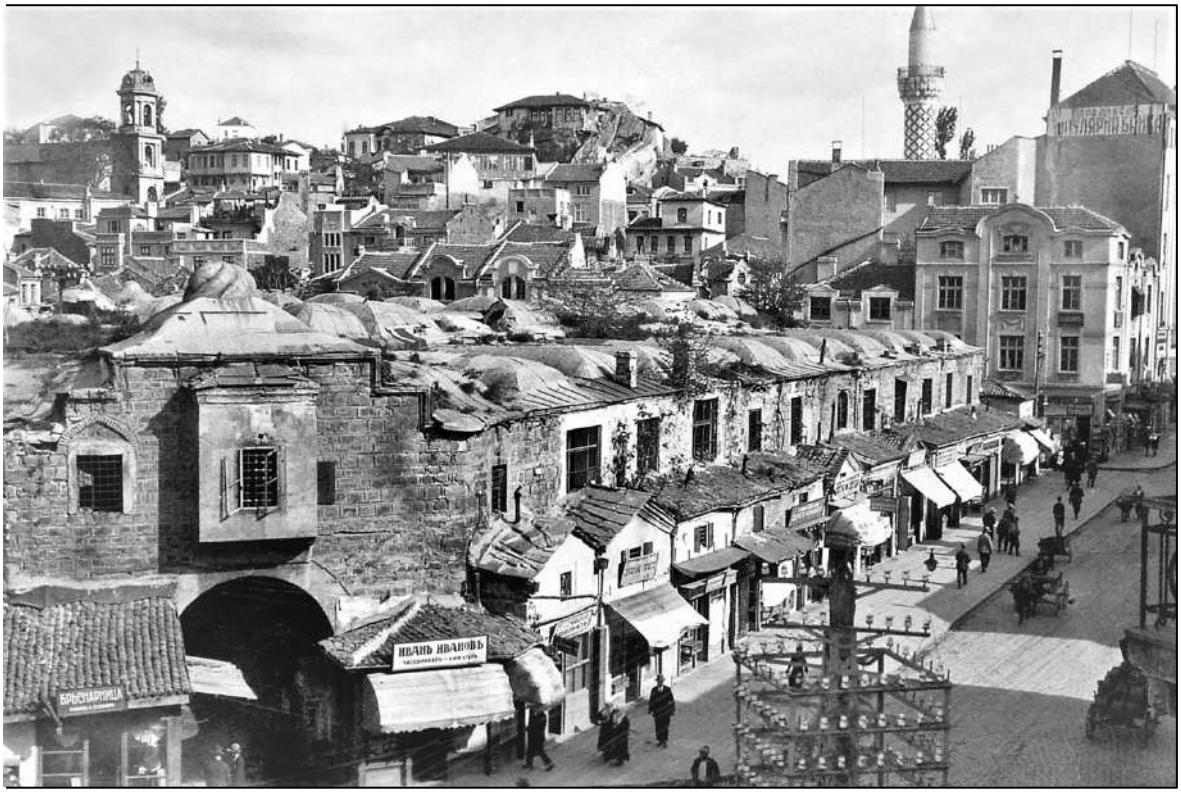
Section and plan of the second level of "Kurshum Han" in Plovdiv

Similar to the functional layout in Sofia, in addition to the two buildings with shops, the third, which has a double-aisle design, was used as a stable. It was probably renovated in the 19th century, with half of the structure near the second courtyard gate being partitioned into several deep rooms, undoubtedly intended for shops and workshops. Only about one-third of the original large space continued to be used as a stable. At the same time, a row of windows was opened in the outer wall. By partitioning the ground-floor galleries, the original sleeping quarters in the remaining wings were transformed into separate shops.



View from the back of "Kurshum Han" in Plovdiv, before its demolition

The caravanserai was built with simplified cell masonry, while its vaults were entirely made of bricks. Notably, there is a significant difference between the architecture of the ground level and the upper level, with the entrance portal featuring a stone vault, separated on the facade from the cell masonry by a single-row brick archivolt. Additionally, the first floor facing the courtyard was also constructed using simplified cell masonry, where the horizontal rows and the vertical divisions between the stone blocks were made of single bricks, and the vaults had semi-cylindrical brick constructions. In contrast, on the upper floor, the horizontal rows consisted of three bricks, and the vaults were pointed, with a keşkemer (sharp) design. Unlike the lower arcades, the upper ones had imposts and iron tie rods. Meanwhile, the external masonry up to the roof cornice was of the simplified type throughout.



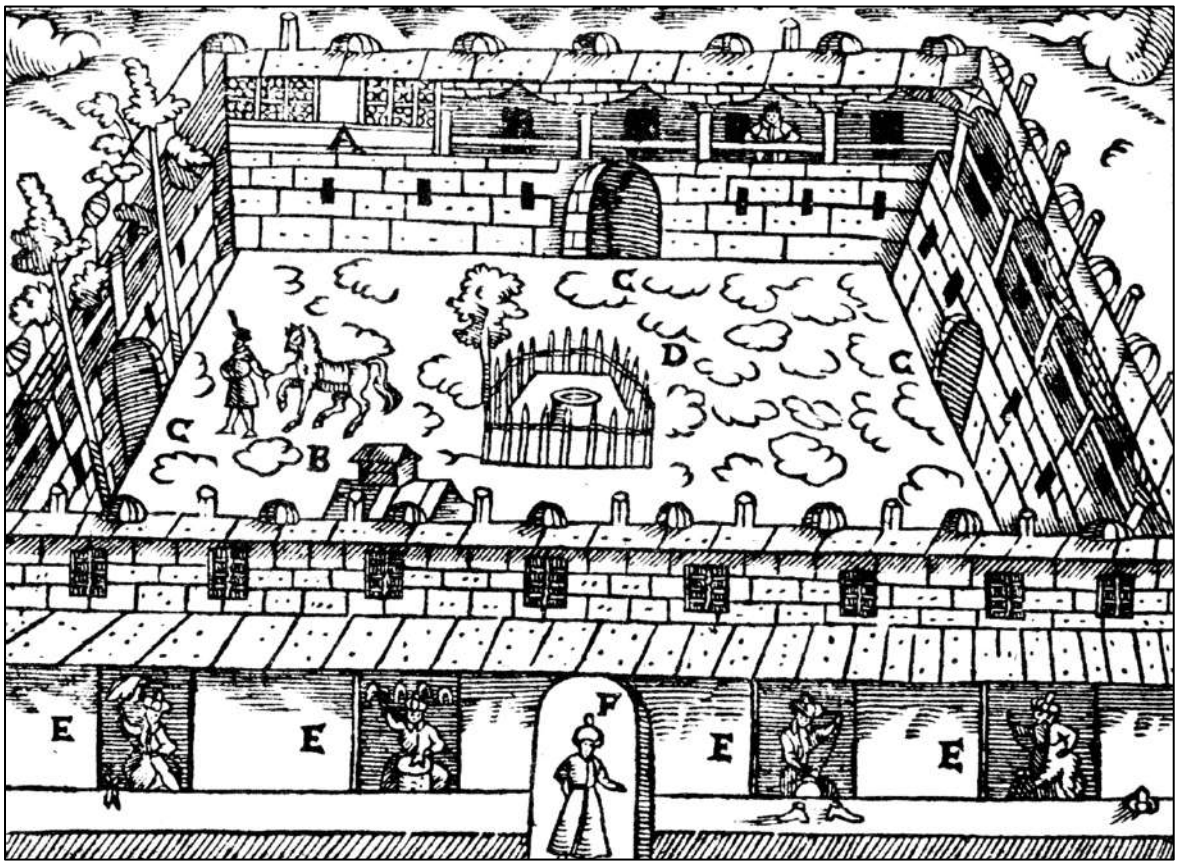

View from "Kurshum Khan" in Plovdiv, with the 18th-19th century expansion of the shops forward to the street. Based on a photo from circa 1930



View from the courtyard of "Kurshum Han" in Plovdiv in 1929. Collection DA-Plovdiv

All of this clearly indicates that the entire upper floor was massively rebuilt, most likely between the end of the 15th and the beginning of the 17th century, and this may have been done on the site of the original half-timbered wooden structures.

There is evidence of caravanserais with such later rebuilt wooden upper floors, for example, "Koza Han" (Turkish for "The Silk Caravanserai", 1491, architect Abdul bin Bulat Shah, an Islamized Georgian) in Bursa, and based on 19th-century engravings, the caravanserai in Mezidler, Balıkhisar, had wooden galleries on the second floor. According to an engraving by Solomon Schweiger, a similar caravanserai in Istanbul with wooden columns and plastered false pointed arches (keshkemi) above them housed the delegation he accompanied in 1578. It also featured chain-built shops and workshops attached in a low, perhaps auxiliary structure in front of one of the gates.

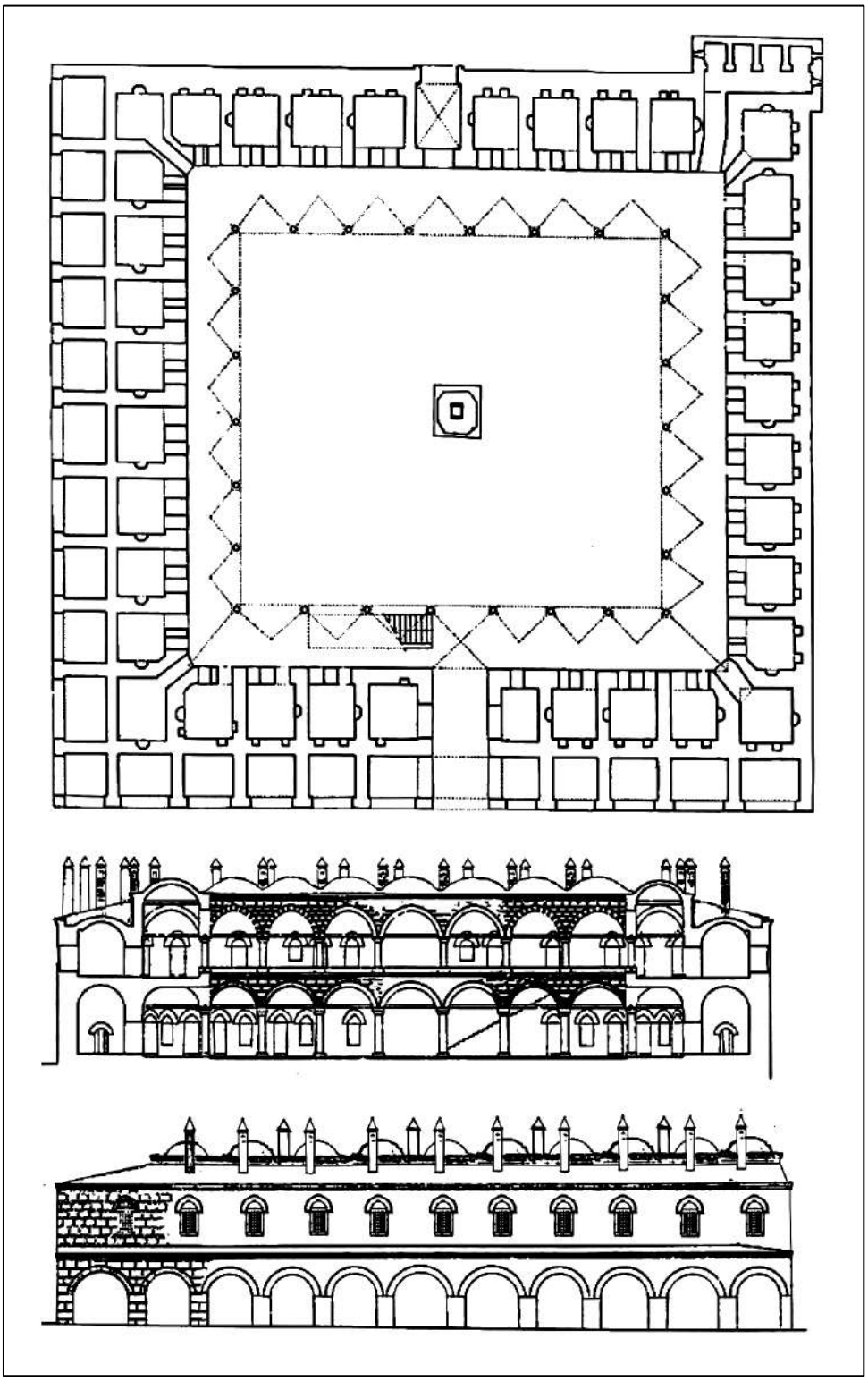



Istanbul caravanserai of the type with separate rooms for travelers from the engraving of 1577, published in 1608 by Solomon Schweiger

A typology similar to the Sofia inn and the early Plovdiv caravanserai can also be found in one of the earlier Ottoman caravanserais – "Kurşunlu Hanı" (1497/8) from the Anatolian city of Manisa. Endowed as part of the Hatuniye Mosque complex by Hüsnüşah Hatun, one of the wives of Sultan Bayezid, it was severely damaged in the earthquake of 1611. It was restored in 1643 and repaired again in 1677. The waqf document mentions that it had 21 shops, 36 wooden, and 38 solid guest rooms. This means that initially, the upper floor was built as a timber frame and was later rebuilt in stone in 1643. This building also had a complex layout, with chain-arranged shops along two of its external sides, nine of which were demolished when a street was built. Evliya Çelebi referred to it as "Hatuniye Han" and described it as a *"well-built*

*Ottoman inn," "similar to a fortress with forty domes* (calottes)*."* The courtyard space measured 28.20 by 24.60 metres, with an octagonal fountain at its centre

From the period until the 15th century, specifically the latter half, I am not aware of other such designs in Ottoman practice. Moreover, such solutions are rare even afterward, appearing in only a few instances, as this was the time when the construction of individual commercial buildings, like arcades, intensified.



Plan of "Kurshunlu Han" (1497/8) in Manisa, Asia Minor Turkey, according to Juksel

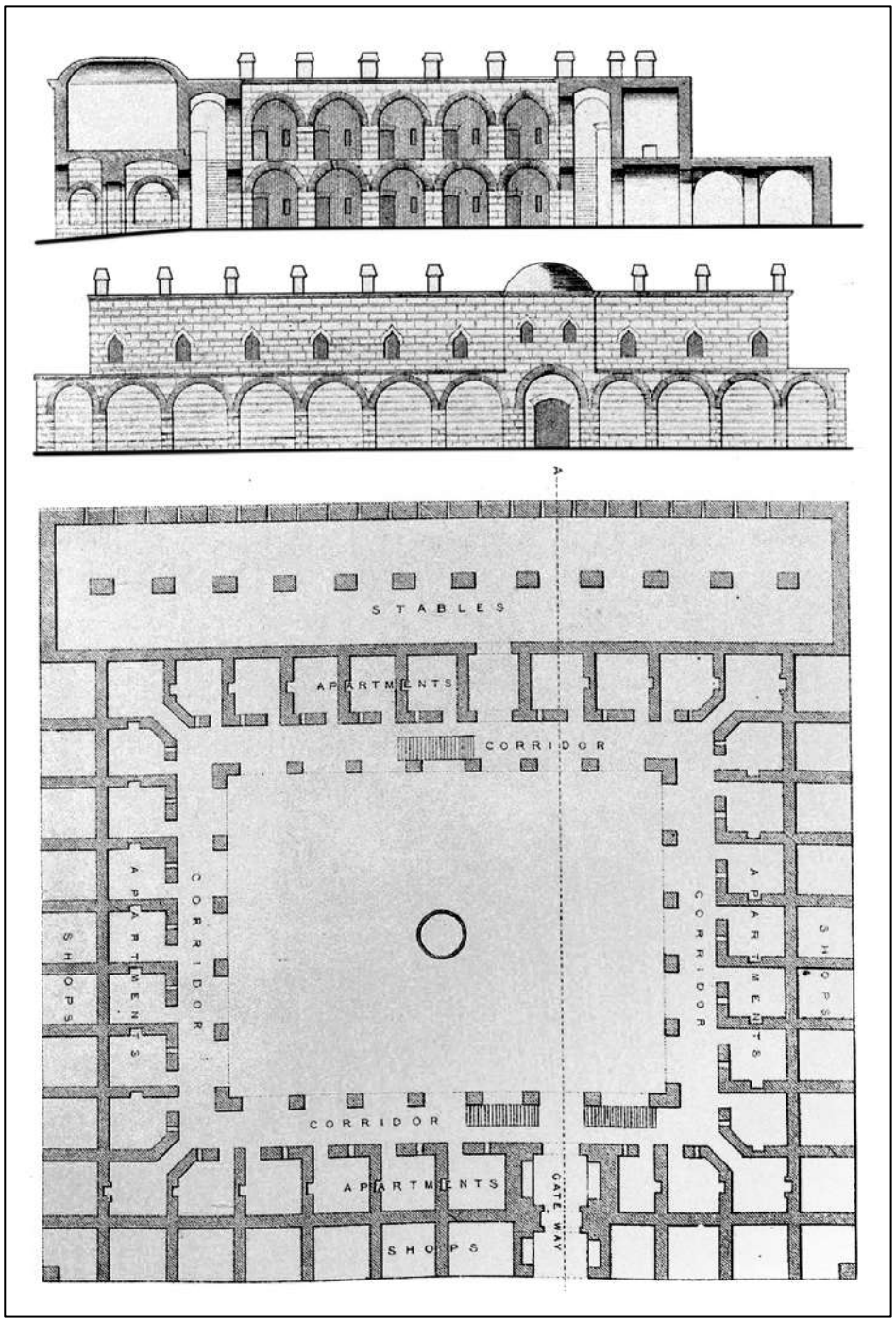


View from "Kurshunlu Han" in Manisa, after restoration works

The similarity is even greater with the "Büyük Han" in Thessaloniki. It was described at the end of the 19th century by Bélière as a pre-Ottoman Byzantine structure dating from the 13th–14th centuries [13]. In his work, he includes a plan of this now non-existent building. However, this architectural documentation was created by architect Charles Tahiér, published in 1864. The accompanying text in the book notes that the caravanserai was built using mixed masonry [14].

In a brief study, the Greek historian Androudis, based on an Ottoman document from 1430, concludes that it was built precisely then, after the conquest of the city [15]. However, the city was handed over by its Venetian rulers to Sultan Murad II on March 29, 1430. Evliya Çelebi also notes that the first new public and military buildings in the city date from after 1431, when the old Byzantine citadel "Yedi Kule" ("The Seven Towers") was renovated with the addition of a new main tower-gate (1431). However, the major Ottoman public buildings appeared here much later, during the time of Sultan Suleiman the Magnificent, with construction primarily carried out by Mimar Sinan between 1535/36 and 1545/46, according to Çelebi [16].

13. Beylie, M. E. L'habitation Byzantine. Grenoble – Paris, 1902
14. Texier, Charles; Pullan, Richard P. Byzantine architecture; illustrated by examples of edifices erected in the East during the earliest ages of christianity. With Historical & Archaelogical descriptions. London, 1864
15. Ανδρούδης, Π. Μεγάλο Καραβάν–σεράι (Büyük Kevansarayi) της Θεσσαλονίκης. Ιστορικεσ και Αρχαιολογικεσ μαρτυριεσ. – In: Balkan Studies, 11, Thessaloniki, 1970, 63 – 97
16. Evlia Celebi. Travelogue. Sofia, 1972, p. 181




Plan of the Byzantine xenodochia ("Buyuk Han") from the 13th - 14th centuries, according to arch. Charles Texier (1864)

On the other hand, it is quite clear that the construction of such a significant building as the "Büyük Han" could not have been organized and completed in the few remaining months of the 1430 construction season, immediately after the city's conquest. Moreover, it is unlikely that there was a need for it, as this large commercial and port city undoubtedly had sufficient inns (xenodocheia), baths, and churches, many of which were immediately converted into mosques by the conquerors. Similarly, to the procedure for the seizure of Constantinople's "Balkapan Han" (which belonged to the Hagia

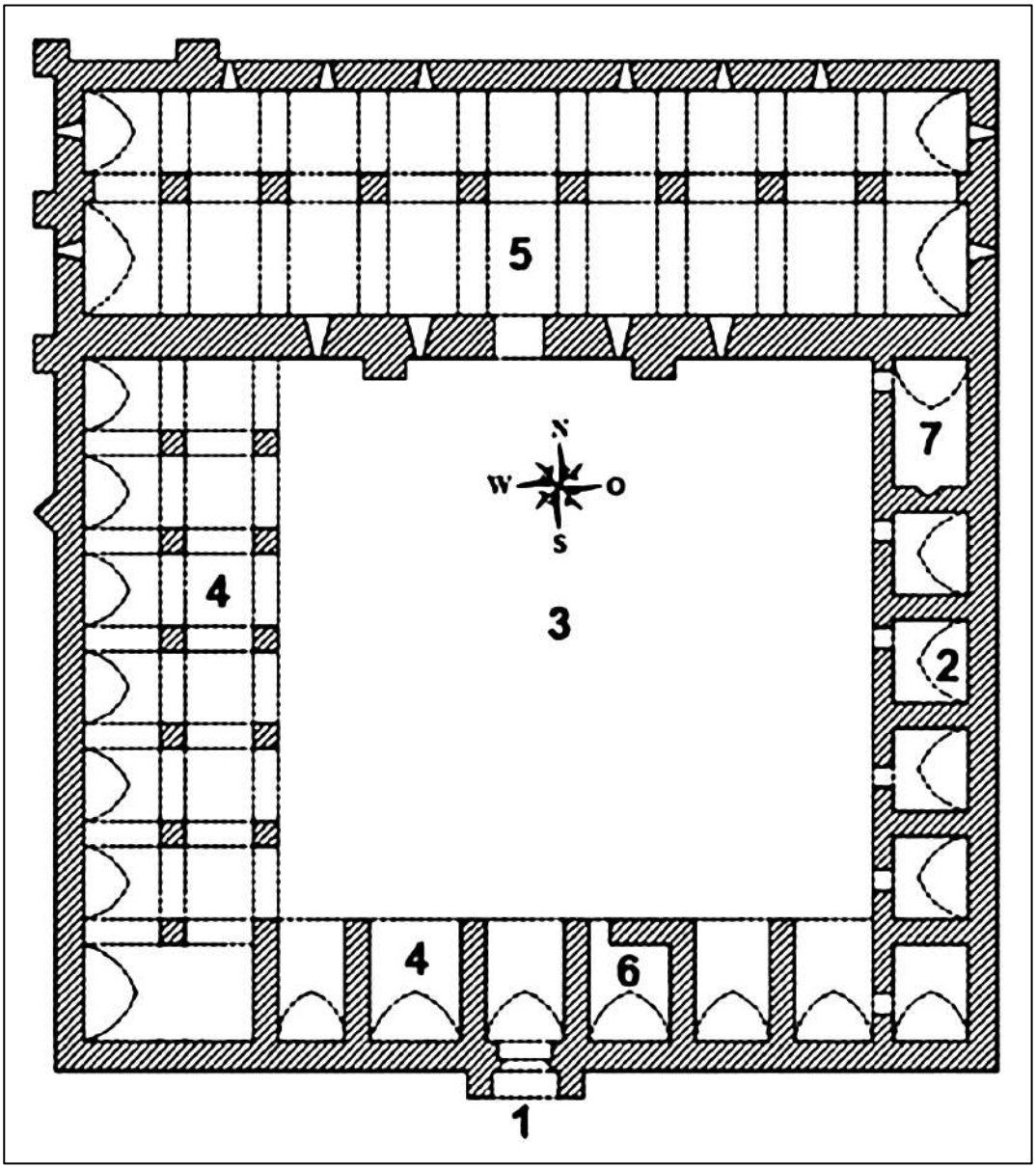
Sophia and was of the same typology), this case likely involves a document confirming old property rights of one of Thessaloniki's major churches, which was converted into a mosque in the same manner.

Therefore, the opinion of Beilier, based on his personal research over 115 years ago, remains well-founded. Even if Androudis's thesis is accepted, it is clear that the local craftsmen who built the structure, based on the architectural features, were working entirely within the spirit of their pre-Ottoman architectural traditions. Interestingly, a register from the early 17th century shows that Thessaloniki's "mermetchi" guild (builders responsible for constructing and repairing public buildings), based on the names listed, was mainly composed of Bulgarian masters [17].

Androudis rightfully makes some comparisons between the layout of the Byzantine inn in Thessaloniki and two similar Ottoman caravanserais—one in Plovdiv (early 15th century) and one in Manisa (1497)[18]. However, both represent an extremely rare typology for their time, whose typological roots are clearly directly connected to pre-Ottoman examples, no later than the late 14th century. In this case, we are dealing with two-story inns of the same type as the Byzantine "Balkapan Han" in Constantinople, a type applied by Islamized Anatolian architects in the construction of early Ottoman caravanserais in Bursa during the 14th–15th centuries. The difference between them and the inns in Sofia, Thessaloniki, and Plovdiv lies in the presence of hall-like stables on one side of the courtyard structure and the presence of chain-arranged shops on the ground floors of two of the other wings, open to the streets. This scheme was also applied in some of the later Ottoman urban commercial buildings (arcades) dating from the 15th–17th centuries.

The pre-Ottoman, in this case, Byzantine origin of the scheme seems to be present at Kargi Han on the road from Antalya to Konya, which is considered by a number of authors to be a Byzantine, or even late antique (Roman) building, which, despite the lack of a book and the specifics of the construction, is pointed out and as a Seljuk from the period 1236/7 – 1246, i.e. the time of the Konian sultan Ghiyas ad-Din Kay-Khosrow II. However, restoration works seem to be taking place then. However, in this case, unlike the late medieval sites considered here, the great hall (5) is not a saloon, but a general sleeping quarters for passengers, while the place for riding and pack animals is under the shed (4) to the left of the entrance (1) to the courtyard.

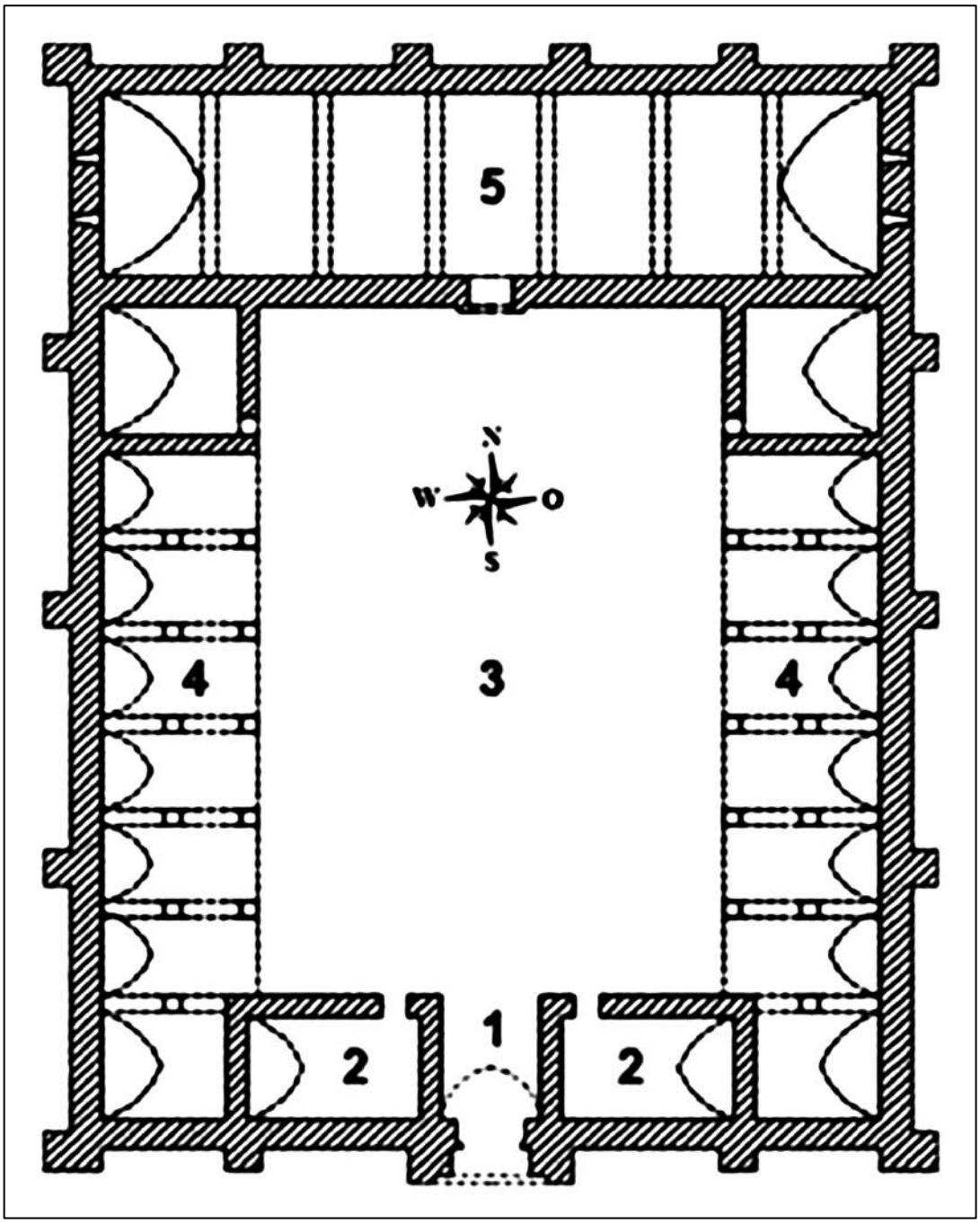
17. TIBI, 1972, p. 407
18. Ανδρούδης, Π. Μεγάλο Καραβάν–σεράι (Büyük Kevansarayi) της Θεσσαλονίκης. Ιστορικεσ και Αρχαιολογικεσ μαρτυριεσ. – In: Balkan Studies, 11, Thessaloniki, 1970




Byzantine xenodochia near Ataleia (Lat. Attalus, Tur. Antalya), restored by the Konian Sultanate in the period 1236/7 – 1246 as Kargi Han. Plan by Erdman

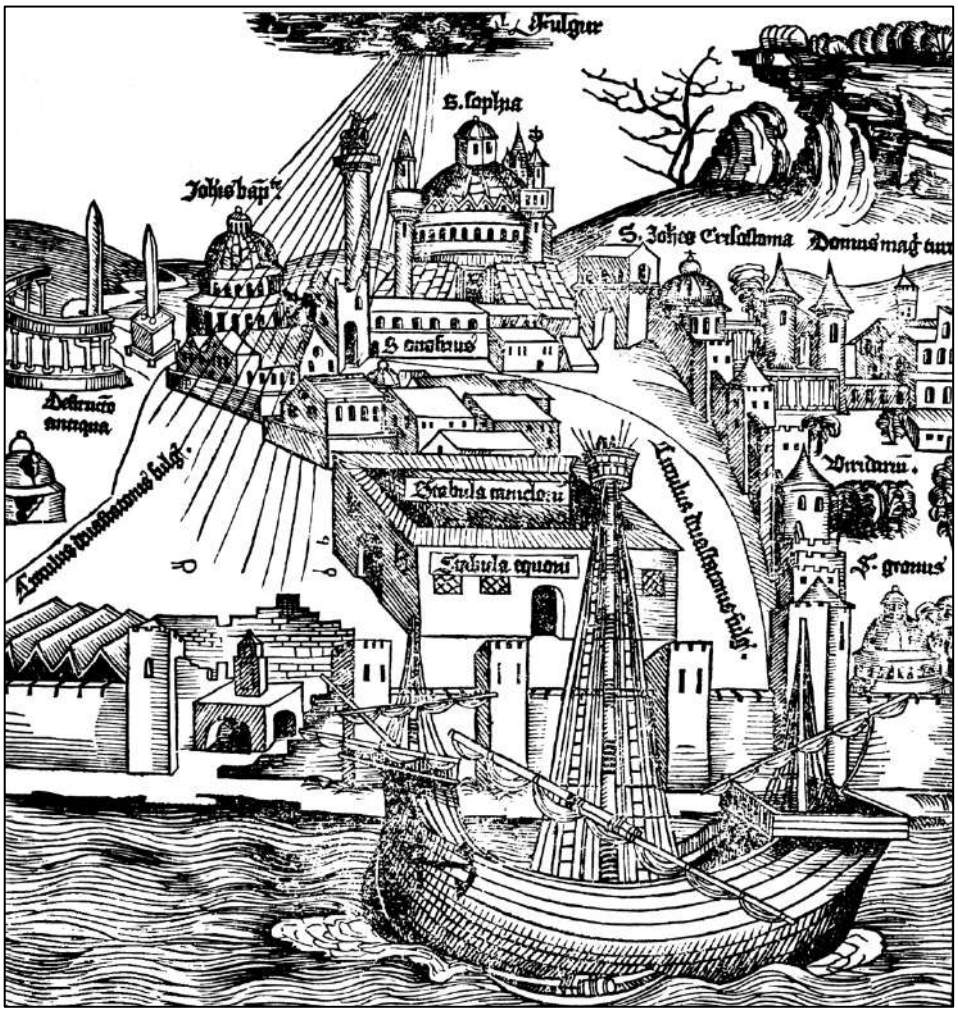
It seems that the small premises opposite this shed, including the mosque (7), are the result of a reconstruction carried out on the site of an original mirror-planned second shed. This is also confirmed by the inadmissible for the era violation of planning symmetry. This symmetry can be seen in the structure of another of the several Seljuk caravanserais on the roads after Antalya - Kirkgöz Han (1236/7 - 1246), where there are two opposite sheds. Undoubtedly, this construction was inspired by Kargi Khan.

But the earliest of all the inns known to us so far, built according to the original pre-Ottoman functional reading of this scheme, remains the "Chokhadzhii Han".

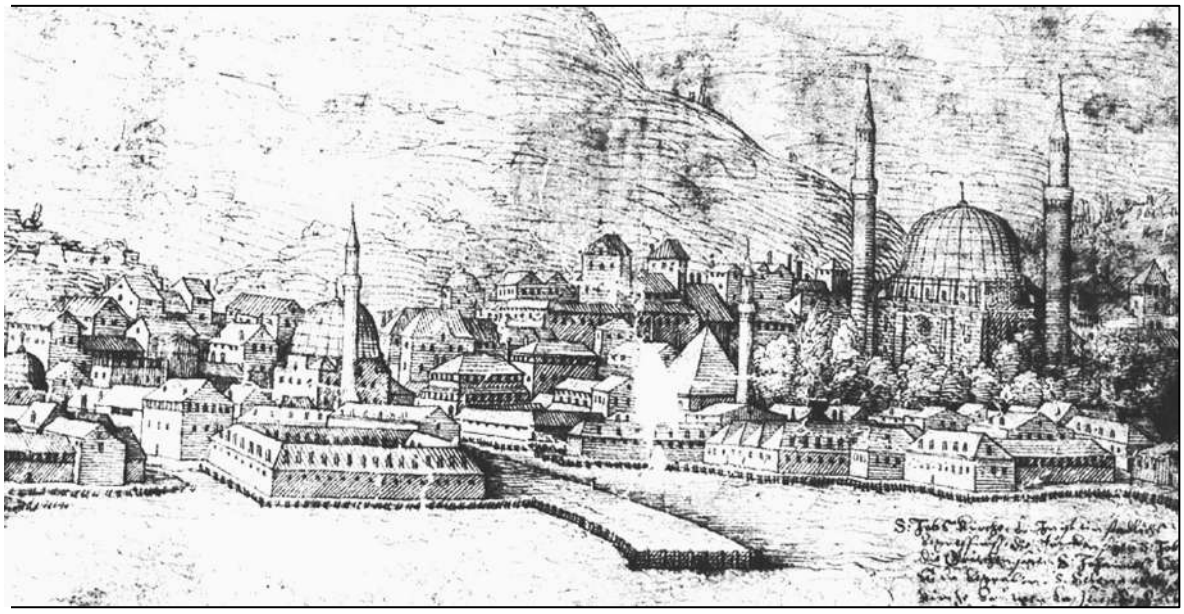



"Kirkgöz Han" near Antalya, built by Konya Sultanate in the period 1236/7 - 1246

It is characteristic that, as is the case with the "Chokhadzhii Khan", as well as with the "Balkapan Han", the remains of its earliest Byzantine construction have survived as a partial part of a basement and in separate corpus fragments (among the accumulated chaotic numerous reconstructions and primitive repairs), are mixed masonry (Opus Mixtum) of alternating stone-square belts with levelling strips of three rows of bricks. However, the original view from this building is known to us from engravings dating from the 15th - 16th centuries, as well as from European maps of Constantinople from before 1453, when the city was captured.




View from the Istanbul Byzantine Xenodochia ("Balkapan Han") according to Schedel's "Weltchronik", 1493 edition



View from the Istanbul Byzantine Xenodochia ("Balkapan Han") in 1559 by Melchior Lorichs



View from the Istanbul Byzantine Xenodochia ("Balkapan Han") from the end of the 19th century

For the ownership of this inn by the church "St. Sofia" is learned from an edict of Sultan Mehmed III (1595 - 1603), which notes how it is "known as Balkapan, which Sultan Mehmed Fatih (1444 - 1446 and 1451 - 1481-b.C.T.) dedicated of the mosque "St. Sofia-i Sherif". It becomes clear that the temple converted into a mosque after the capture of the city in 1453, having this xenodochia as its property, kept it as part of the properties of the waqf newly created by this sultan. Evliya Celebi defines it as "an inn as big as a castle" in which many Egyptian merchants also "gaily" resided at that time. Semavi Eitse established that the original yard had dimensions of about 42 x 31 m [19].

Therefore, if we exclude the much later implementation of "Kurshumlu Han" in Manisa, as the earliest (from the period of the 13th - 15th century) with these typological characteristics and scale, we can point out the "Chokhadzhii Han" in Sofia, "Buyuk Han" in Thessaloniki and "Kurshum Inn" in Plovdiv. That is, three territorially close buildings, separated from each other by about 150-250 km and connected to each other by ancient main roads.

19. Eyice, Semavi. Balkapanı Hanı, İstanbul Eminönü’nde şehrin en eski ticaret hanlarından biri. – In: İslam Ansiklopedisi, Vol. 5, Türkiye Diyanet Vakfı Yay., İstanbul, 1992, pp. 33-34

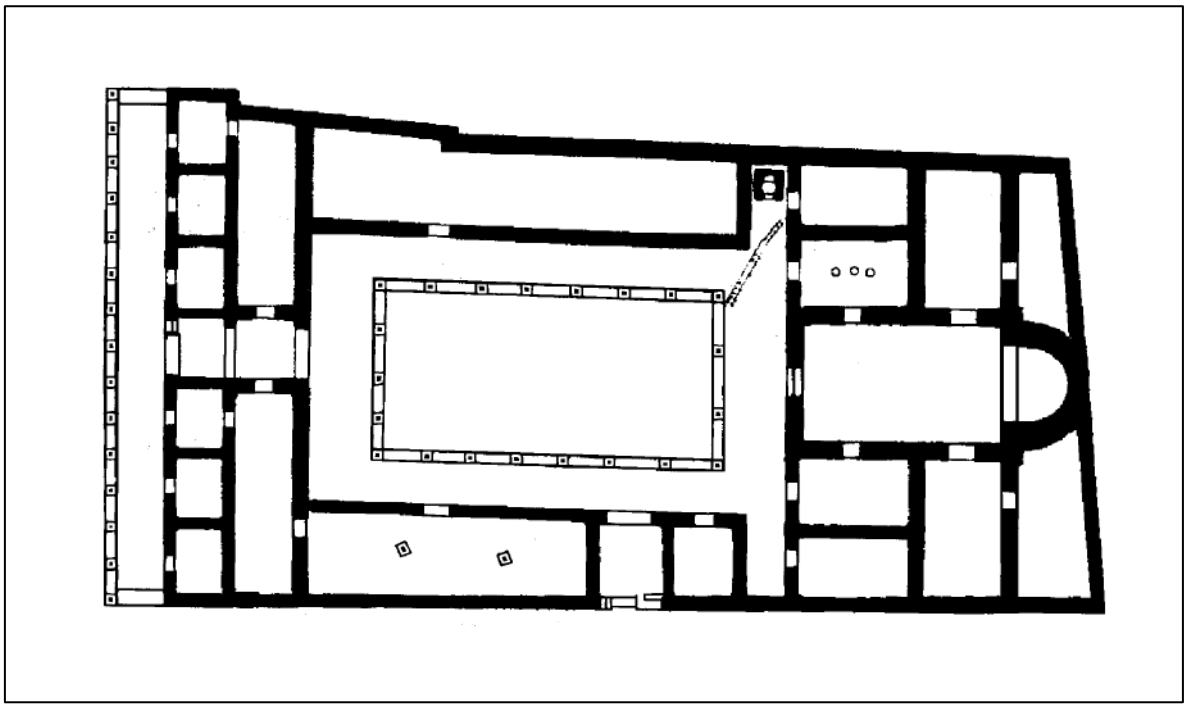
For now, a hypothesis about the local origin of their functional scheme in approximately this small Balkan territory, or more precisely in the ideological boundaries of the medieval region of Macedonia (then called "Lower Land" or "Lower Bulgaria"), then occupying approximately the territory between Edirne, Stara Planina, Sofia and Belomorie region. A scheme that definitely has its genesis in the late Roman and Byzantine innkeepers, but expanded with store parts [20].

In the same way as applied to these three innkeepers (Greek - xenodochia), much earlier the six shops in front of the so-called atrium-peristyle "House (Domus) Pansa" in Roman Pompeii, which is actually a mansion, were incorporated into the buildings much earlier. There are also shops in front of other Pompeian buildings, including baths and inns. The image in the Poitinger map of the "Aqua Kalide" road station from today's Burgas Mineral Baths shows a building with an inner courtyard and a series of shops on the ground floor of one of the buildings, accessible from the surrounding space. Of course, in this case it is a pictogram, but one that represents one of the Roman typologies, which is the principle on which this map was developed. Archaeologically, however, Roman road stations similar in plan have been uncovered. Thus, in the ancient city of Abritus (civitas Abrittus, Abritum) near present-day Razgrad, a rather large urban mansion of this type was excavated with six shops (probably macelliums) positioned in front of the main entrance behind a serving portico.




Image of the Roman mansion "Aqua Kalide" (today near Burgas) according to the Poitinger map

20. Tuleshkov, N. Architecture of medieval inns from Southeast Europe. - In: GNAM, 13, In Honorem Professoris Violetae Volkova - Neseva, Sofia, 2016, pp. 233 – 237



Plan of a mansion in the Roman city of Abritus (today on the eastern edge of Razgrad) from the 5th - 6th centuries, according to Ivanov-Stoyanov

Behind them is the entrance block with the central entrance and jachers on either side of it. Next is a courtyard surrounded on all four sides by a colonnaded gallery, behind which on the two long sides there are large common sleeping quarters. At the bottom, the entire remaining area is occupied by a food block, with dining rooms, kitchens and storage rooms. A bathroom has also been excavated right next to the mansion.

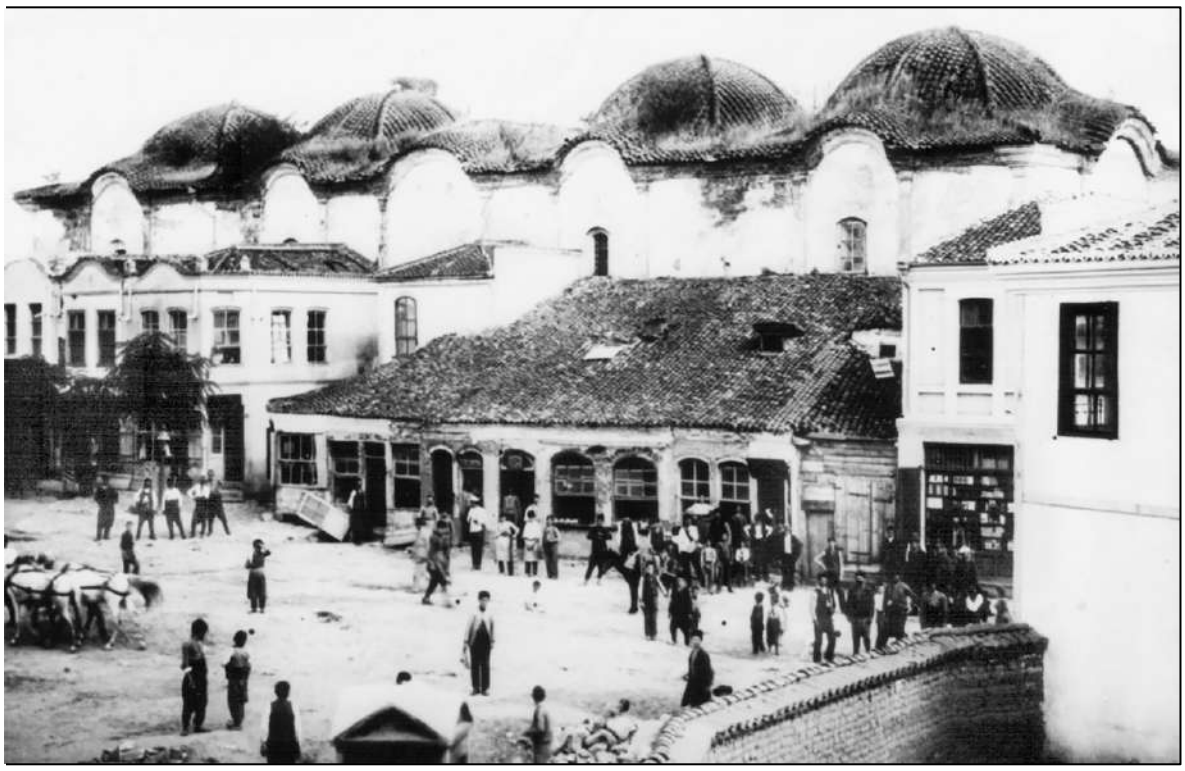
Undoubtedly, the typology continued to be applied in the East during the Middle Ages. In the case of the Ottoman caravanserai, this functionality was apparently transferred directly from the Byzantine practice after the annexation of Byzantium and Bulgaria, together with the architects and builders themselves. But subsequently, towards the 16th - 17th centuries, it will be present quite rarely in the construction programs during the implementation of these buildings.

If we look at the "Chokhadzhii Han" in the light of all this and the sealed images from the archive photos, we will also establish the fact that there were shops not only in the building facing the main street ("Boulevardna"), but also on the southeast side facing a small apparently also a shopping street. However, it led from the main one, past the inn, directly to the "Shaytan Bazaar" and through the Gulchesme neighborhood to the "Grain Market".

It is therefore possible that there were also shops on the ground floor of the building on the north-west side, with the rear of the two entrance portals contacting the same street turning at this point. Or it is more likely that the scheme with regard to the sides built with shops completely repeated that of the

Thessaloniki "Buyuk Han", but with the difference that, according to archival photos, in Sofia there are also shops in front of the narrow front of the yakhra from the main street. The nave itself, however, seems also like that of the Thessalonica xenodochia to have been one-storey high, divided by massive naves[21]. Today it is no longer possible to ascertain when the partial warehouse superstructure appeared on it, visible in the first photograph from the early 1880s- those years, but on the basis of its architectonics it can be argued that it did not happen later than the first half of the 14th century. There is a possibility that other parts of the second floor were also repaired then.

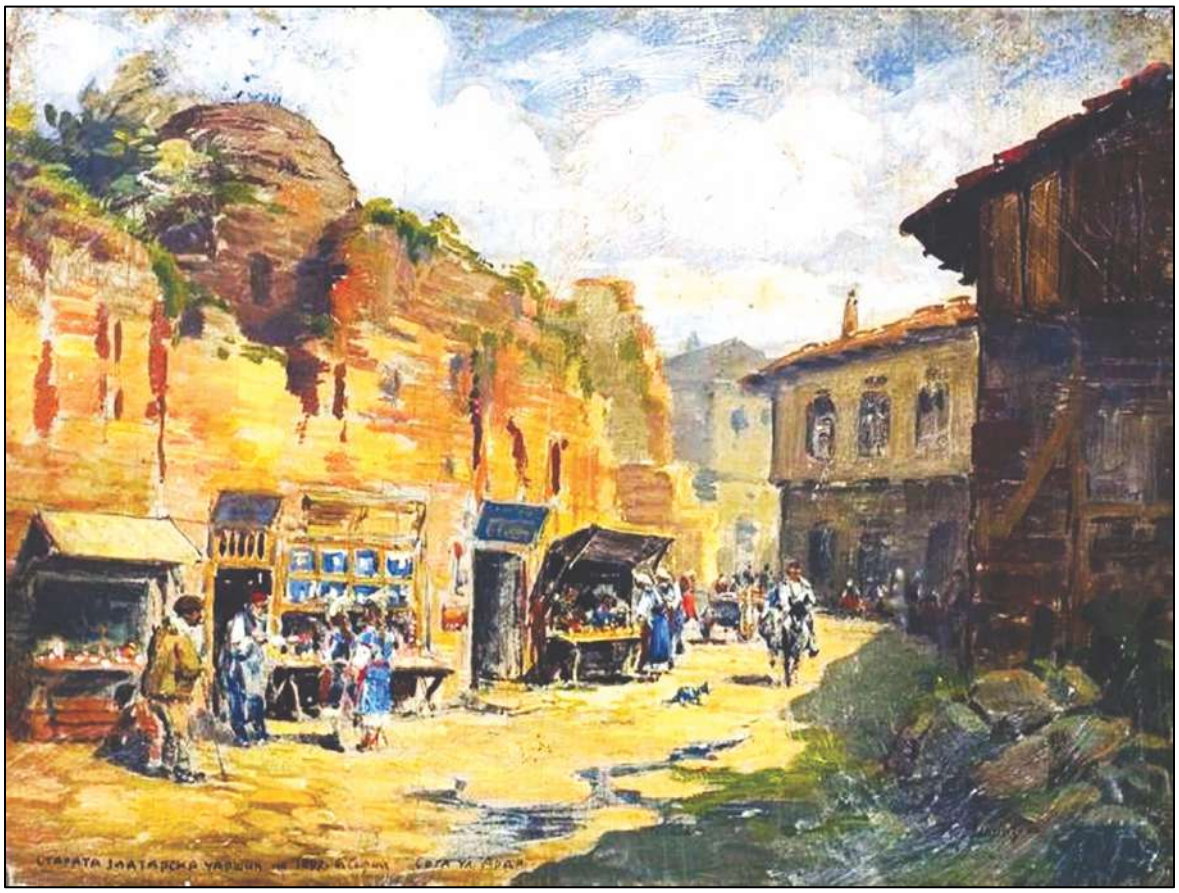
The Plovdiv caravanserai also had shops, only on its two sides [22], which in the 18th–19th centuries were extended outwards towards the streets with additional volumes upgraded with second levels. And such expansions carried out in the 19th century are also found at other Ottoman caravanserai and commercial buildings, for example in front of the caravanserai in Pazardzhik and the arcade in Yambol.



The expansion of the shops of the Yambol Arcade in the 19th century (photo Nikifor Minkov, 1880)

21. The same as above
22. Zlatev, T. The Bulgarian city during the Renaissance. Sofia, 1955, pp. 75-78, plan

The final destruction of the crumbling "Chokhadzhii Han" took place towards the end of the 19th century. According to Konstantin Irechek, in the decades before 1880, when he mentions it (published in Volume I of his diary), the skylights above his second-floor rooms were still covered with lead sheets, which, however, *"were stolen at night by an overseer and sold to the Rila Monastery, which is covered from here."* And since the only building of the monastery with such a coating is the cathedral church, this apparently happened during the period of its completion between 1837 and 1838.

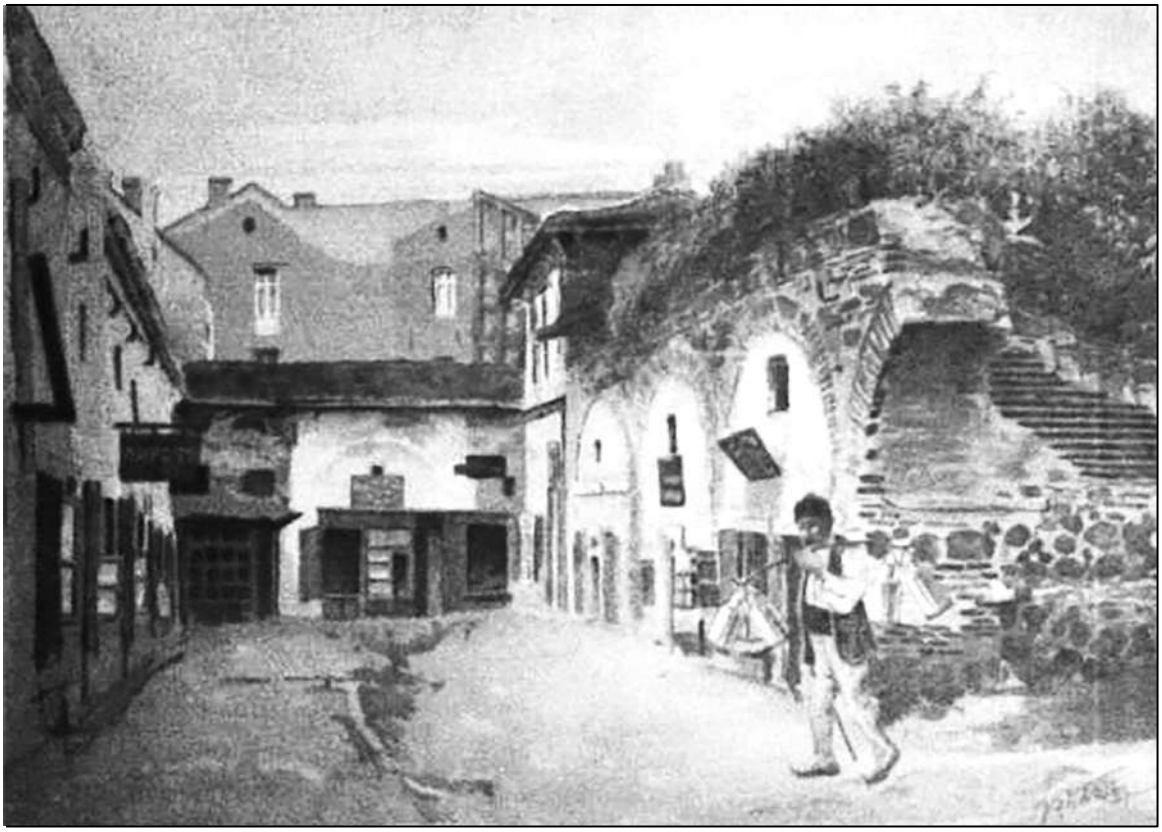


View from the building with the rear entrance of the ruined "Chokhadzhii Han". Aquatint by Petar Morozov from 1897, undoubtedly drawn from a photograph from before 1888

In 1888, however, in accordance with the town planning plan, the mayor of Sofia, Dimitar Petkov, demolished its buildings, leaving only a very small part of the lower shop floor in its southeast corner, which was covered with a wooden roof. In 1915, in the "Deutsche Balkanzeitung" magazine, Dimitar Shishmanov described these remains: *"These little shops are nestled in the niches of the thick half-ruined wall of a medieval fortress. In many places along the wall facade, the plaster has fallen off, and from the exposed construction it is clear that a gallery with arcades once stood here. These arcades were made of thin, light red bricks joined together with stone-hard mortar. Now they are walled off in front and small vaulted shelters* (i.e.

shops) *have been formed inside the wall. Above the doors gape square windows, barred by strong but already rusted bars“*. This part of the *„Goldsmith's Street“* development has been painted by many artists - professionals and amateurs, the earliest being Oberbauer's watercolor. *„The Goldsmith's Bazaar"*, where its remains are shown at the bottom left, in their already reconstructed form. However, in the remaining paintings, which are already from the beginning of the 20th century, the gradual destruction of this small remnant of four vaults is already clearly visible.

**This is the final end of the most unique medieval Bulgarian inn, one of the largest on the Balkan Peninsula. And it could have been preserved and restored if, in the fateful year 1888, it was protected by the then Bulgarian Historical College. But unfortunately, the word "if" is not in the vocabulary of history.**



The goldsmith's bazaar in Sofia, with the remains of the commersial part of the "Chokhadzhii Han". Watercolor by Joseph Peter from 1916

# ABOUT THE EXPERIENCE IN STRENGTHENING AND RESTORATION OF HISTORICAL BUILDINGS IN BULGARIA

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*University of Structural Engineering and Architecture, VSU ".L.Karavelov"*

***Abstract***: *The report attempts to give a brief overview of the Bulgarian experience on strengthening and restoration of old buildings, some of which have been declared cultural monuments in Bulgaria, and onto which modern construction technologies have been applied to increase their life-cycle including installing and tensioning of anchor cables, applying shotcrete, and other modern approaches.*

***Key words***: *reinforcement, restoration, brickwork, anchors, shotcrete,reconstruction, reinforced anti-seismic brick zone, anchored retaining wall, strengthening by CFRP; strengthening by ties and by Jet Grouting*

## 1. Rescuing of St. Cyril and Methodius Cathedral in Burgas – from Strategy to Reality[1]

### 1.1. Introduction –

The construction of St. Cyril and Methodius Cathedral in Burgas started on 15.08.1895. The architectural design was provided by the Italian architect Ricardo Toscana[1]. The building was completed as we know it in the 1940s when the two towers were topped. The church is a three nave basilica approximately 32 meters long, 21 meters wide and has an area of 516 $m^2$. The height of the main dome above ground is around 25 meters. The structure comprises of load bearing brick and stone masonry walls and stone columns, supporting brick masonry arches, barrel vaults and domes. The main dome with 8.4 m diameter is a timber structure developed over an immense brick masonry tambour. The whole structure is supported by single and strip stone foundations. Since 1979 the church is announced as a national heritage architectural monument. In 2011 construction of a new underground parking started immediately next to the church, with only 6 m. between the anchored secant pile retaining wall and the north bell tower. Due to the large horizontal displacements of the wall the soil under the church experienced considerable deformations, thus subjecting the structure of the church to significant uneven settlements. By the time the final excavation elevation of 15 m was reached, the church has suffered severe damage. At this stage measures for emergency support of the structure were implemented and full

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geodetic, geologic and structural survey were carried out. A view of the church and the unfinished parking is shown in Fig. 1.



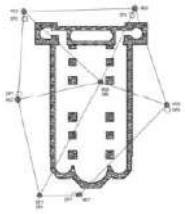


**Fig. 1.1.** A view of the church and the adjacent excavation with the secant pile anchored retaining wall
**Fig. 1.2.** Geotechnical survey boreholes and dynamic penetrations

## 2. Survey results

The scope of the survey followed the guidelines given in Eurocode 8, part 3.

### 2.1. Geotechnical investigation

Seven boreholes with depth of 20 m were studied. Dynamic penetration tests were performed in all of them. Plan of the boreholes and DPTs is shown in Fig. 2. One of the main conclusions was the considerable change of the underground water level because of the dewatering activities during the construction of the parking. That led to change of the soil deformation and strength parameters. Additionally, it was found, that a slip surface had occurred in the borehole closest to the excavation.

### 2.2. Structural survey

The main task of the in situ measurements was to identify the structural system and its load bearing members. The crack distribution was thoroughly studied in order to produce a detailed picture of the damaged building and a summary is presented in Fig. 3. Photos of some of the biggest cracks are shown in Fig. 4. The strength parameters of the masonry materials were obtained by laboratory and in situ tests.

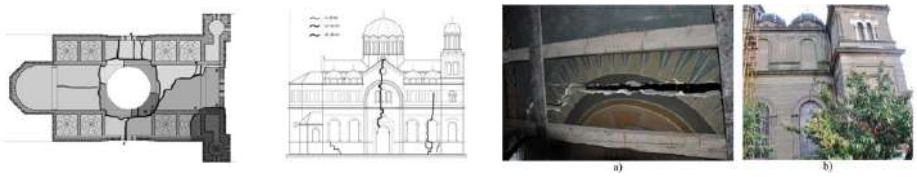


**Fig.1.3.** Crack distribution in plan and on the north façade
**Fig. 1.4.** Cracks wide up to 80 mm in the: a) western barrel vault; b) north façade wall

### 2.3. Geodetic measurements

The results of the measurements that took place monthly for over a year showed that the cap of the secant pile wall moved about 200 mm. This led to major settlements and horizontal displacements of up to 16 mm of the north bell tower, inducing critical damage in the load bearing structure.

## 3. Strengthening strategy

### 3.1. General description

The presented bellow strengthening approach is proposed in the design project for repairing and strengthening of the church. The main activities of this approach are summarized as follows: - Strengthening of the soil and foundation; - Repairing of the cracks; - Strengthening of the brick masonry barrel vaults and domes by CFRP; - Strengthening of all arches by ties; - Pre-stressing of masonry walls on several levels; Finally, a system for monitoring the strengthened structure was developed and executed. Each of the listed above measures is briefly described.

### 3.2. Strengthening of the soil and foundation

The underlying soil base was strengthened by execution of soil-cement "jet-grouting" columns, as shown on Fig. 5. This technique was selected because of the severely damaged soil beneath the church and also because it posed no threat for the anchors of the excavation, as well as the micropiles, previously executed as an emergency strengthening measure. During the execution, due to the damaged soil base the grouting parameters, such as pressure, speed and water-cement ratio had to be adjusted several times in order to achieve proper diameter and strength of the soil-cement columns. A specialized small portable rig was used for execution of the inner rows.

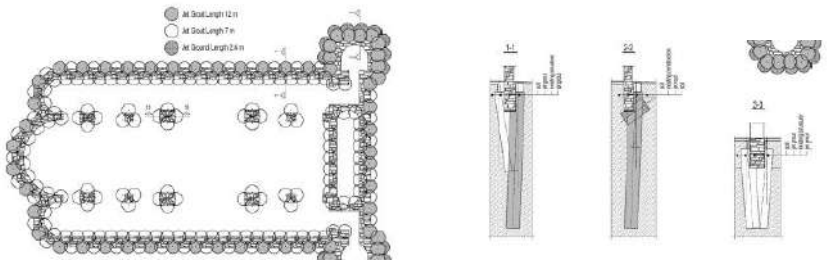


**Fig. 1.5.** Strengthening of the soil base by Jet Grouting

The connection between the existing foundation and the jet-grouting elements is accomplished by execution of new RC foundation beams (in Fig. 6), which are continuously anchored to the stone strip foundations by means of steel rods. Additionally, steel I profiles are embedded for better connection between the RC beams and jet-grouting columns.



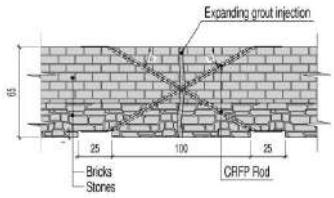



**Fig. 1.6.** New foundation beams with prestressing
**Fig. 1.7.** Repair and strengthening of cracked façade wall

### 3.3. Repair of the cracks

The cracks in the structural members were repaired by injection of different types of expanding grout, depending on their width. Additionally, as shown in Fig. 7, the cracks in the walls were "sewn" with CFRP rods, bonded to the structure with epoxy resin. Those measures are aimed to reestablish the integrity of the structural elements and the connection between them.

### 3.4. Strengthening of the brick masonry barrel vaults, domes and arches by CFRP

Externally bonded CFRP is used for strengthening of all damaged brick masonry barrel vaults, domes and arches (Fig. 8 and Fig. 9). All calculation are with accordance with Eurocode 8 part 3. The extrados concept is selected for CFRP strengthening of barrel vaults because of art painting on the intrados side. The same concept is used for the brick domes. This method was chosen due to the following benefits: − No weight is added to the structure; − It allows for the iconography on the inner side to be kept; − The CFRP acts as a tension reinforcement and prevents collapse mechanisms, in case of future support movement;

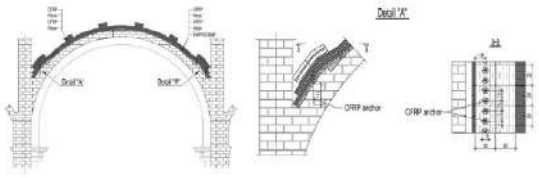





**Fig. 1.8.** Strengthening of brick masonry barrel vault
**Fig. 1.9.** Strengthened barrel with CFRP-design vault

### 3.5. Strengthening of all arches with ties

New tie elements are introduced at the base of the masonry arches at two levels and in two orthogonal directions (Fig. 1. 10). The main purpose is to ensure the global stability of the structural system both for vertical and seismic loads. They are connected to the existing masonry structure in a way that reduces the stress concentration and prevents local disintegration of the masonry due to cyclic dynamic reverse excitations occurring during an earthquake. The tie elements prevent the formation of collapse mechanism in the arches, in case of horizontal displacements in the column tops or foundation settlements. View with the executed tie elements is shown in Fig. 1.11.

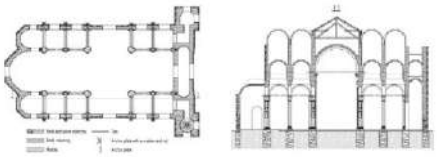




**Fig. 1.10.** Plan and section with the tie elements
**Fig. 1.11.** Inside view with tie elements

### 3.6. Prestressing on several levels

Three closed contours of prestressed elements were introduced at different levels(Fig.1.12), binding together the separate parts of the structure and ensuring its uniform behaviour under seismic loading. Due to the geometric imperfections of the existing structure the paths of the tendons had to be further modified during execution. Initially chosen bars had to be substituted with high carbon steel strands which allow for a more flexible positioning and simpler anchoring devices (Fig. 1.13).

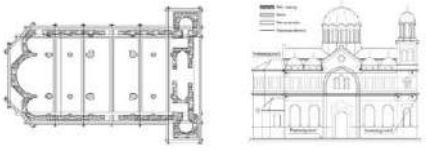




**Fig. 1.12**. Plan and elevation of the prestressing levels
**Fig. 1.13.** Prestressing at Level 2

**4. System for geotechnical monitoring**

The monitoring system is implemented so that the behaviour of the strengthened structure and its foundation can be evaluated and analyzed. For acquiring sufficient volume and types of relevant data the following instruments were installed: − Digital tilt meters were placed on the structure for monitoring horizontal displacements resulting from possible uneven settlements (Fig. 1.14 a) ); −Digital biaxial inclinometers were used for following the in-depth horizontal displacements of the soil underneath the church (Fig. 1.14 b) ); − Digital piezometers were installed in boreholes for monitoring the ground water table and the pore pressure (Fig. 1.14 c) ); The instruments are wired in such a way, that allows them to be connected to a single multichannel data logger (in Fig. 1.15). It can be accessed remotely via Internet and data can be read in real time.





**Fig. 1.14.** Installation of instruments for geotechnical
**Fig. 1.15.** Installed and connected multichannel data, Monitoring: a) tilt meter; b) inclinometer; c) piezometer logger

**5. Conclusion**

Based on the practical study presented herein the following main conclusions could be drawn: − The church St. St. Cyril and Methodius in Burgas which is a part of Bulgarian national heritage was severely damaged during the construction of the new underground parking nearby and needed urgent retrofit: − The strengthening strategy was developed and executed on the basis of performed survey; −This strengthening approach aimed to solve all structural problems of the temple for both vertical loading and seismic excitation; −Some of the technical solutions had to be adapted to better fit the actual execution; − Constant interaction between the designers and the contractors was required in order to adjust design and technical solutions

**6. Acknowledgement**

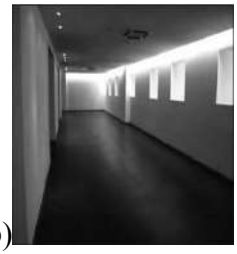
Our team of "Yoda" Ltd. would like to express deep gratitude to our "sensei" – Prof. Jordan Milev who is the main reason for the success of the presented complicated project. We lost Jordan too soon – sooner than we all wanted to. We believe that the rescue of this temple would guide the soul of this magnificent person to heaven. Sensei, you will always be missed!

**2.Cross Shaped Barracks in Vidin[2]**

**2.1. Brief Description of Cross shaped barracks in Vidin**

The Cross-Shaped Barracks building is a cultural monument and one of the 100 National tourist attractions in Bulgaria. It is situated in Vidin, which is a Bulgarian city on the Danube River. The building was constructed in 1801 by local ruler Osman Pazvantoglu for the deployment of the Ottoman troops (Fig. 2.1.). After the liberation of Bulgaria from

the Ottoman Empire, the building was used as a court and barracks of Bulgarian troops[2]. The building is famous for its specific cross shape in plan (Fig. 2.2.).

a)  b) 

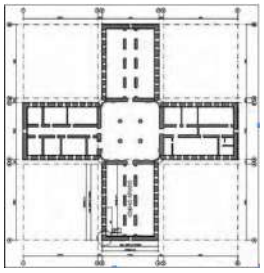


**Fig. 2. 1.** Final view: (a) exterior and (b) interior

**Fig. 2.2.** Structural design project drawings

The building structure is of brick and stone masonry (*Fig. 2.3*). The foundations are constructed as dry stone masonry. The roof and the floors are timber structures.

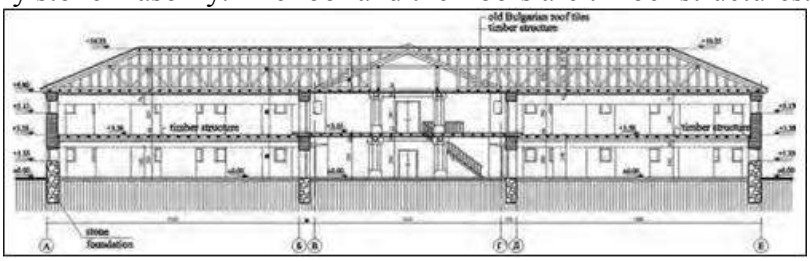



**Fig. 2.3.** Typical cross-section of the structure (design project)

The building had not been maintained properly, and a settlement of the south section corner had occurred due to moistness of the soil and caused substantial cracking of the walls. Moisture was observed in all the walls up to 1 m above the ground, which had caused damage to the external plaster as well as several cracks in the internal walls. The building is situated in a region of grade 7 seismic activity according to the Bulgarian seismic code. The project aimed to rehabilitate the existing structure and adapt the building to an ethnographic museum for the region.

**2.2 Maintenance and rehabilitation of the Cross –Shaped Barracks Building**

Before the rehabilitation of the walls, the masonry was processed using polymer materials to act against the moisture and in order to fill in the cracks. The strengthening itself was designed to be carried out by means of steel elements to be anchored to the walls and sequentially sprayed with concrete (*Fig. 2.4. and Fig.2.5.*). The chosen design solution provided for the best possible preservation of the architectural authenticity, as well as for the strengthening of the building for vertical and horizontal loads.

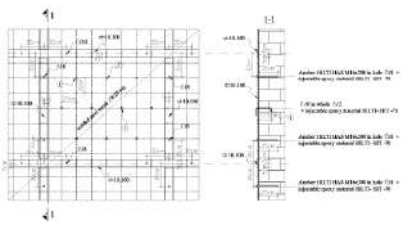




**Fig. 2.4.** Cross shaped barracks - detail of the with sprayed concrete
**Fig. 2.5.** Strengthening of the brick with sprayed concrete

## 3. Rehabilitation of the complex reinforced concrete Shell Roof structure of an industrial Building[3]

### 3.1.Brief Description of the Presented Case Including Project Aims and Challenges

This case study presents the investigation and design of the rehabilitation of a storage structure for the cement industry and in particular of its roof. The storage was designed and constructed within a two-year period between 1956 and 1958 as part of a cement plant in the northern part of Bulgaria[3]. The storage is approximately 500 m long and is divided into seven separate structures(indicated as blocks in the following text) by expansion joints (Fig. 3.1. and Fig. 3 2.).



**Fig. 3.1.** General view of the building

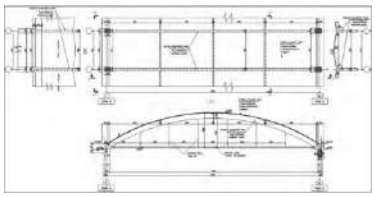


**Fig. 3.2**. Sections of the roof

The main structure is a single-span frame in transverse direction and multiple-span frames in longitudinal direction. The structural span width in transverse direction is 33 m, and the span width in longitudinal direction is generally 6 m. The roof structures of three of the storage blocks are steel trusses with a cover made of trapezoidal steel sheets. The roof of the other blocks is a reinforced concrete (RC) shell structure. The RC shells span 33 m in transverse workshop direction and 6 m in the longitudinal direction. The shell structure is thin, elegant and unique for Bulgaria. It represents efficient implementation of the theoretical advantages of shell structures. The shell is divided by means of RC arch ribs supported by steel elements (two channels of 180 mm) for resisting the tension in transverse direction at each column position. The shell is additionally divided by secondary beams/ribs in the longitudinal direction in order to increase the stiffness and to minimize the shell thickness. These beams are considered as the final transverse rib of the shell. The storage has been operational for decades without need for additional maintenance during the long period of use. Material corrosion and structural damages caused mainly by crane operation have deteriorated its condition and have raised a reasonable question about the structural safety and reliable behavior of the structure. A team led by the author(Assoc. Prof. Al.Traykov) of the present study carried out an extensive investigation of the storage structure. It included visual observation, laboratory testing of the materials both on site and on samples, and computer modeling of the entire structure and its parts.

Calculations and design checks were carried out according to the present-day codes that are valid in Bulgaria. Even so, the roof structure theoretically displayed perfect behavior. That behavior contrasts sharply to the real condition of the roof. The designers team considered two options—to replace the RC shell roof by means of steel trusses or to preserve the original roof structure. The owner chose to preserve the original structure. An investigation that involved collecting specific details for rehabilitation of the main elements—shell, joints and beams—was carried out. The design was adequate and followed the main principles of sustainable engineering and construction, preserving a structure of historical value, obtaining economic advantages and protecting the environment.

### 3.2. Influence of Construction History Analysis Results on the Project during the Assessment Phase and in the Design of the Intervention

Regarding the importance of construction history (CH) must be considered in the decision of intervention procedures, the period of construction of the particular structure as well as the main ideas behind the use of the structure's type was taken into account. Different aspects of the construction history of roof shell structures are studied. A comprehensive review of the theory, modeling, construction and use of various types of shell structures was studied.

### 3.3. Project-specific Experiences and Lessons Learned

As discussed in 3.2., the construction of thin shell concrete structures ended abruptly at the end of the 1970s. One reason was the higher cost in comparison with other structural systems. The other reason was the theoretical uncertainties about the structural behavior of the shells. However, computational methods and the efficient development of software allow engineers to model the structural behavior of shell structures in a very realistic way, including the material and geometrical nonlinearities. Those developments, as well as the developments in concrete technology and innovations in relation to its materials, have given new life to the idea of constructing new shell structures and rehabilitating existing concrete shell structures. The most important lesson learned is that it is possible to extend significantly the life of concrete shell roofs taking advantage of their perfect static behavior. That could be achieved by means of using materials and construction methods that comply with the original idea of their design.

### 3.4. Choice of Strengthening Method

Significant efforts were devoted to study the construction period of the roof, its structural type and construction material (*Fig. 3.3*). Plenty of information was collected in order to choose the most appropriate techniques for strengthening. Different options were considered, including the replacement of the original RC shell structure by means of steel frames roof. Innovative methods, were studied as well. In those works, the application of innovative strengthening method using textile RC is described. The method consists of applying three layers of fine grained concrete and textile carbon fabric, adhering to a rough, sandblasted concrete surface. However, strengthening by using any kind of fiber-reinforced plastic (FRP)fabric was not approved because of the large area that is necessary to be rehabilitated and the greater requirements during the construction. Considerations about the maintenance included the risk of any damages to the structure as well, for instance the provision of waterproofing on top of the structure.



**Figure 3.3.** The roof from inside the building

Computer modelling of the entire storage building and a separate model for the roof alone were created by means of SAP2000 software. The results reveal the amazing behavior of the roof. The bending moments in the shell structure are practically zero for vertical loading due to self-weight, dust and snow. The above considerations led to the choice of a most "classic" method for reinforcement, which appeared most suitable for the project. A layer of small-size aggregate concrete with a single rebar mesh on a cleaned and rough surface was applied. Anchoring of there in for cement mesh to the shell ribs was used for better connection. As a result of the structural investigation and design, a unique structure has been preserved. It combines theoretical achievements realized in a clear and simple structural form. Post the rehabilitation, the storage will be in use for a long period.

**4."DSK" Bank Building, Burgas[4]**

The building was built in the city of Burgas in the 1930s for a bank office (Fig. 4.1 and Fig. 4.2).It is still used as a bank. The construction is a monolithic reinforced concrete construction from beam slabs and columns. Over the years, many changes have been made, most often without a special design solution. A serious part of the supporting structure is affected and damaged by these interventions[4].



**Fig. 4.1.** DSK Bank, Burgas - facade

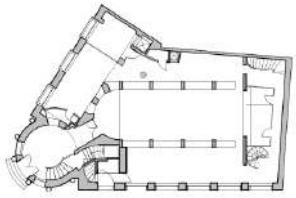


**Fig. 4.2.** DSK Bank, Burgas - plan

Due to the year of design and execution, the building is not specifically secured for seismic impacts. The modernization of the bank requires some changes to the interior, but mostly restoration of the existing structure. Since there is no change in the functional purpose, as well as due to the low level of seismic activity of the region, it is not necessary to provide an additional structure to absorb the seismic impacts according to modern norms. The rehabilitation program includes: * Restoration of all damaged structural elements; * New premises for the bank archive; * New bank vault.

A solution with sprayed concrete (shotcrete) was chosen, given the large areas and a large number of affected structural elements: slabs, columns, beams that need to be restored(Fig.4.3a,b,c,d), where: A) STAGE1: removal of the concrete coating;
B) STAGE2: Connecting new steel elements to the existing plate; C) STAGE3: Adding new reinforcement welded to the steel profiles from stage 2; D) STAGE 4: Shotcrete

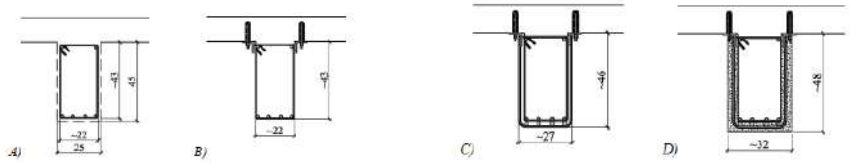


**Fig. 4.3a,b,c,d.** Stages of restoration of existing reinforced concrete beams:

**5. Building of the former "Globus" Cinema, "Slaveykov" Square, Sofia5[5]**

The building was built in the 1930s.The building consists of a basement, one floor and an atrium-type roof structure to illuminate the space at an elevation of ±0.00 (Fig. 5.1.).A 6-story residential building was built without a joint to this building. The construction of the cinema is a monolithic reinforced concrete structure, which consists of girder slabs (Fig. 5.2.), columns and foundations[5].

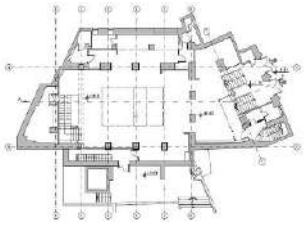


**Fig. 5.1.** Architectural elevation distribution ±0.00

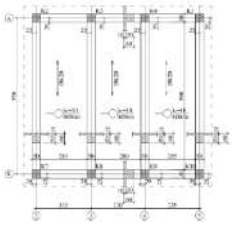


**Fig.5.2.** Formwork plan and existing reinforcement available plate at elevation ±0.00

The roof structure is entirely from steel. The building was designed in accordance with the norms in force in the 1930s.The grades of the materials used (concrete and steel) are relatively low (in accordance with modern requirements), but as can be seen from the inspection and the conducted survey, the structure has proven good behavior without serious damage. Over the past 75-80 years, the building has been used for various functions.Initially, and for a very long period, the building was a two-level cinema hall. It later housed a hardware store. At the moment, it is necessary to establish the possibility of locating a store from a supermarket chain. The new technological loads, however, are significantly greater than the original ones and the existing structure cannot take them.

After a serious survey and a significant number of computational checks of the slab, beams and columns, it was found: • The existing structural elements cannot take the increased load. Reinforcement of the structure is technically impossible due to the fact that different floors are owned by different owners, and the reduction of new loads is against the interests of the client; • The lack of a joint between the residential building and the cinema building is a serious problem for the seismic safety of the structure; • The status of the cinema building as a monument of our cultural heritage further complicates the adequate design of the interventions. This case shows that the change in the function of historic buildings is often in conflict with some new requirements and in these cases it is essential to find an adequate solution, taking into account the specific requirements for historic buildings commented above.

**6. Episcopal Basilica in the Town of Sandanski with a Baptistery[6]**

The episcopal basilica (Fig. 6.1., Fig. 6.2.) and the baptistery to it are located in the center of the town of Sandanski and are part of an early Christian complex. The floor mosaics are of great artistic value. Part of the colonnade and the outer walls have also been preserved[6].



**Fig. 6.1**. Basilica of St. St.Ioan – Plan

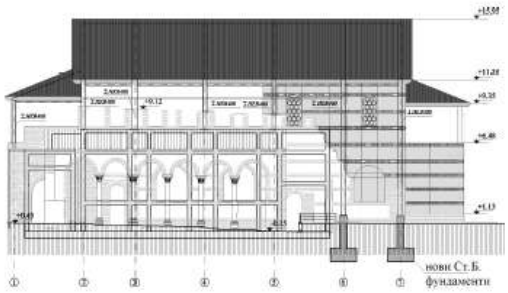


**Fig. 6.2.** Basilica of St.Ioan- Cross section

The roof structure is completely missing. *The baptistery has partially preserved walls,* but the roof structure is also completely destroyed. The idea of the project is to reconstruct the basilica and baptistery, giving the opportunity to expose the mosaics and by being protected from atmospheric influences. Naturally, the goal is to the original silhouette of the basilica and baptistery was also restored. *The project for the basilica includes a coated steel structure from steel sheets* (analogue and vision of the original coating). The steel structure is without intermediate support, because of the floors mosaics. Seismic forces are absorbed by frames in the transverse direction and vertical connections in the other direction. The new vertical elements are anchored in new reinforced concrete foundations. *The walls are restored with stone and bricks, according to the original walls (white cement, limestone, crushed stone and brick fragments) (Fig.6.3, Fig.6.4.).* In a similar way, the baptistery to the basilica is being restored with a steel structure



**Fig. 6.3**. Inside **View**



**Fig. 6.4**. Outside view

7. **Sugar Factor, Sofia [7]**

The original project was Belgian and was completed in the period 1897-1898 (Fig. 7.1a,b). Sugar factory consists of two buildings: *Large factory* building with an area of 7162 $m^2$ and *Small factory* building with an area of 1200 $m^2$ . The two buildings are a typical representative of industrial construction from the end of the 19th century.






**Fig. 7.1a.** Sugar Factory,(Sofia original view-1900)
**Fig. 7.1b.** Sugar Factory (Sofia -2002)

*The large building* consists of several buildings with 2/3 levels (total height approx.: 11.50 m) and a distance between the axes of 7.00 m. *The small building* is a hall with a distance between the structural axes of 14.15 m and plan dimensions of 66.00 m/9.80 m.

The structure is brick and stone masonry with a thickness of 60 cm, filled with mortar(Fig.7.1a,b). The floor structures are the typical "Prussian vault" type: I steel

secondary beams at a distance of 90-110 cm and brick vaults between them (Fig.7.2.). The main beams for floor structures have steel I sections.



**Fig. 7.2.** Floor structures are sections Prussian Vault



**Fig. 7.3a.** The columns are round tubular

The roof is executed with steel trusses (distance between the steel trusses 4,20 m) with span 7,0 m (Fig.7.3a), secondary steel beams between the trusses and roof-tiles. The foundations for the columns are pad-footings from stone or rubble concrete and strip foundations for the masonry walls. The columns are from round tubular sections of cast iron with a diameter of D=200mm(Fig.7.3a and 7.3.b).), or from two parts steel I sections, connected with diagonals(Fig.7.4). All connections are riveted.





**Fig. 7.3b.** The columns are round tubular parts - sections D=200mm
**Fig. 7.4.** The columns from two vertical steel I sections, connected with diagonals.

The two buildings functioned according to their purpose until 1926, after which they were used for warehouses and some types of small production. In the long history of the factory, numerous interventions were carried out in the load-bearing elements, which led to serious damage to the original structure and its authentic appearance.. The lack of maintenance in recent years has led to an emergency and pre-emergency condition of a large part of the supporting structure. The situation is near collapse(Fig.7.7 and Fig.7.8.)





**Fig. 7.7.** Replacement of the roof structure
**Fig. 7.8.** Actual view of "Small Factory Building"

This area has the potential to be transformed as a phoenix of revival of urban activities in Sofia by adapting a mixture of cultural, commercial and residential functions within the existing large scale factory buildings. A future revitalization project should take into account the aesthetic and engineering qualities of the authentic structure whose

masonry brick walls, "Prussian vault" floor structure and steel trusses for roof structure with the sophisticate details should be the framework of the new architectural design (Fig. 7.9. and Fig.7.10). The idea is to achieve an effect as close to the original as possible[7]. After restoration, the space can be used for various purposes: shops, restaurants, cinema, etc. In this specific case, it is possible to seek embedding of new structural elements to absorb future seismic impacts. A possible revitalization project of the area is developed as a diploma project [8].





**Fig. 7.9**. Potential adaptive project proposal [8]
**Fig. 7.10.** Potential adaptive project proposal [8]

The fact that parts of the authentic structure has disappeared enables the insertion of new elements within the 19th century shell. A special interest and attention should be given to the authentic cast iron columns with a base and a capital bolted to the fundaments and the upper beams. A possible revitalization project of the area is developed as a diploma project [8].

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# KNEZ SELO: TYPOLOGY OF RESIDENTIAL BUILDINGS AND CHALLENGES IN PRESERVING TRADITIONAL ARCHITECTURE

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***Abstract**: This paper analyzes and proposes conservation strategies for the architectural heritage of the rural settlement of Knez Selo in Serbia, which is notable for the preservation of traditional Serbian rural architecture. The research focuses on identifying the main characteristics of traditional houses through a typological analysis, with particular attention to their stylistic, functional and structural elements. By assessing the current state of conservation and the specific characteristics of each house type, the study aims to provide a basis for more effective strategies for the protection and revitalization of rural houses in Knez Selo. The purpose of the study is to identify the main characteristics of traditional architecture and the challenges of preserving these structures in a modern context. A secondary goal is to contribute to the preservation of the cultural heritage through concrete proposals for the protection of architectural objects that are an integral part of the local identity and cultural landscape.*

***Key words**: Knez Selo, residential architecture, typology, heritage protection, traditional houses, rural areas*

## 1. Introduction

National architecture represents the sum of spiritual values and material achievements of a nation (or group of nations) in the context of the construction of habitats and other spaces throughout history. [1] In Serbia, until the middle of the 20th century, traditional construction was a common approach for building houses and other buildings in rural households.

This method is carried out by local artisans who apply the knowledge acquired over generations, using natural materials that are mostly available locally. [2] Architectural heritage is an important part of the cultural identity of any community, and the preservation of rural architecture plays a key role in maintaining the continuity of tradition and cultural landscape. Knez Selo, as an example of a rural environment rich in traditional architectural objects, offers a valuable insight into the past, but at the same time it faces the challenges of modernization and demographic changes that lead to the abandonment and decay of old houses. Traditional houses in Knez Selo are characterized by specific structural and stylistic elements that reflect local resources, climatic conditions and cultural

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habits. These houses, built mainly in the period between the 19th and the beginning of the 20th century, have a significant value as part of the cultural heritage, but also as a potential for the development of modern strategies for the sustainable development of rural areas. However, in addition to these traditional houses, in the part of the settlement known as the Weekend Settlement (Vikend Naselje), there are also more modern houses built in the last decades of the twentieth century and the beginning of the twenty-first century. Although, these buildings are an important part of the modern image of the village, the focus of this work is on the protection and revitalization of the older, traditional buildings, while the modern buildings will not be the subject of detailed research, but for the purpose of creating a complete picture of the totality of residential construction in the village and highlighting important architectural and environmental elements.

The aim of this paper is to identify, through a typological analysis of the houses in Knez Selo, the main characteristics of traditional architecture, as well as the challenges of preserving these buildings in a modern context. The paper also considers modern methods of protection and revitalization of rural architecture, focusing on the possibility of adapting traditional houses to new needs while preserving their authenticity. In this context, it is necessary to consider the role of the local community, institutions and experts in the process of heritage conservation, as well as the legal and economic aspects of protection.

Scientific methods used in this thesis include multiple steps. The first method was literature analysis, which allowed to understand the theoretical framework and previous researches in the field of rural architectural heritage protection. The methodology of the work includes a field visit to Knez Selo, where an analysis of the state of preservation of the houses, their constructive and stylistic-aesthetic characteristics is carried out, with the aim of assessing the current state of preservation of the buildings and their functionality in the present time. During this research, standardized forms were used to collect data on building materials, constructive solutions and aesthetic features of the houses. Typological analysis was used to identify common features among the buildings and to classify the houses based on their form, functional organization, and period of construction. This combination of methods allowed a comprehensive assessment of the condition of the buildings and provided a basis for proposing active protection and revitalization measures in accordance with modern principles of heritage conservation.

## 2. Analysis of the location - Knez Selo

Knez Selo is situated on the edge of the Nišava valley, in the area of the town of Niš in the Nišava district, Serbia. The village is situated to the northeast of Niš, about 12 km from the city center. The village boundary of Knez Selo, with an area of 10.45 km², has an irregular elliptical elongated shape, with an aspect ratio of 1:3 and a $k_{kfa}$ coefficient of 6.63 (the ideal coefficient is 4), which reflects the unfavorable physical characteristics of the rural area. [3] (Fig 1). Based on the geographical representation of the village boundary, the boundary can be divided into three parts: the mountainous part, the central settlement where the largest number of houses-village is concentrated, as well as the part with arable land. The most important part for the further research of the residential architectural heritage is the central part, which represents the settlement of Knez Selo, i.e. the village. To the north of the village there are the branches of the Calafat Massif with forests, meadows and pastures, while to the south, east and west, below the village, there are arable lands that dominate the soil structure according to the type of use. [4] The terrain is sloping, with a southwest exposure, making it a very pleasant and sunny place for settlement and agriculture.



**Fig. 1.** Village Boundary of Knez Selo (https://www.google.com/maps/place/ 03. 09.2024.)
**Fig. 2.** Orthophoto view of Knez Selo (https://a3.geosrbija.rs/, 29.09.2024.)

Based on the urbo-morphological structure, Knez Selo mainly belongs to the compact settlement type, and according to its basic function, to the primary rural settlements. (Fig 2) [5] The network of local rural roads in Knez Selo is developed, branched in irregular forms, conditioned by the configuration of the terrain, through which very important communication with economic resources and neighbors is achieved. Also, Knez Selo developed under the influence of the relief and the main road - Matejevac road, expanding in a linear direction to the south and southeast along the main road directions, so in the structure of the settlement we recognize some elements of a linear settlement. [6]

Most people live in the area along and around the main road. The plots with houses are very close to each other, while the houses are mostly located in the depth of the plot. The irregular shapes of the plots are the result of the inherited situation due to the unplanned development of the village throughout history, as well as the slope of the terrain. In addition to the residential function, various agricultural activities are developed in the courtyards of the houses.

The demographic structure of the population of Knez Selo is very diverse. The largest concentration of people in Knez Selo was in the sixties of the last century, with 1,520 inhabitants, since then this number has been gradually decreasing until today. According to the latest census from 2022, Knez Selo has 680 inhabitants, which is a significant difference. [7]

### 2.1. Settlement structure and characteristics

Knez Selo is a settlement with a long history, whose roots go back to the Roman period. The village was under Ottoman rule until the liberation of Niš in 1878, after which it expanded with the construction of residential houses and developed as an agricultural settlement. In the period between the two world wars, important public buildings were built, including a school, the renovation of the church, a cooperative, and the construction of a tuberculosis sanatorium. After the Second World War, Knez Selo went through a process of family stratification and migration, but in the 1970s, due to the improvement of infrastructure and living conditions, it developed into a suburban settlement with the return of the population and the settlement of new families in the weekend settlement around the sanatorium. [4]

The structure of Knez Selo is multi-layered and characteristic both in terms of the time of its origin and construction styles, as well as the purpose of the buildings. In addition to the residential area and traditional houses of the village, there are also buildings of social and strategic importance, so the recognizable standard structure of the settlement

is marked by the construction of the sanatorium hospital complex in 1945, but also by the construction of a modern Weekend Settlement. The construction of several buildings of public character and special purpose, such as the Co-operative Home, the School, the Church, the Slaughterhouse and the Bus Station, are also important for the final appearance of the settlement. [4] As the research work deals with the topic of typology of houses, in the continuation of the work the focus is on the analysis of the residential area in Knez Selo. The architecture and rich structure of the residential area can be divided into buildings of traditional rural settlement, buildings around the sanatorium and houses in the Weekend Settlement. Today there are 253 households in Knez Selo, and the total number of housing units is 482, with an area of about 29,500 $m^2$. There are 293 inhabited buildings, 48 temporarily uninhabited, 9 abandoned, while a significant number of buildings are those used for rest, recreation and during seasonal work, as many as 132. [7]

## 3. Typology of houses

Knez Selo, as a clustered settlement, developed its architecture mostly without any particular order and plans. The architecture of the buildings was strongly influenced by the relief, climate, protection strategy, economic needs, culture and customs. All buildings were built naturally, without special professional help, according to the needs of the households, and the appearance and design of the houses were based on acquired experience and material possibilities. The styles of the houses changed over time, so that we can observe the entire residential architecture through several phases:

- 1st phase: In the 19th and early 20th century: Morava style houses (in Serbian: *"Moravska kuća"*)
- 2nd phase: Interwar period
- 3rd phase: After the Second World War until today: a) the beginning of construction with hard materials; b) modern houses built in the 1960s and 1970s c) construction of Weekend Settlements g) settlements around sanatorium.

### 3.1. First phase: During the XIX and the beginning of the XX century

In the 19th and early 20th centuries, the organization of the household was such that the house was usually built deep in the yard, surrounded by high walls-fences or by buildings of an economic nature with a high gate at the entrance. The garbage dump was located near the barn. In densely populated villages, due to the small size of the plots, the cattle sheds were often located on projecting plots and not within the yard. This type of organization and arrangement of buildings in the village yards remained in Knez Selo for a long time, almost after the Second World War.

The dwellings were constructed in a straightforward, utilitarian, and environmentally conscious manner, exemplifying a distinctive Morava architectural style. Despite the continued existence of older houses constructed in the Morava style, these structures are largely neglected and in a state of disrepair. Only one of the structures is currently protected by the state. The fundamental structure of the house was square or rectangular shape. The house was constructed on two levels, comprising a basement and a ground floor (Fig. 3 and 4). The basement was constructed of stone and served as a storage space for food, tools, and other items. In contrast, the ground floor was built using mud and wood and served as the primary living area for the local population. The ground floor was accessible via stone and wooden stairs. The houses were either one-part or two-part structures, comprising one or two smaller rooms and a centrally placed fireplace. The furnishings and equipment within the houses were simple and modest. [4]



**Fig. 3.** One of the oldest houses in Knez Selo, left (Nikolić B. I Nikolić S. [4])
**Fig. 4.** The house and its outbuilding, middle, right (author)

The Bundwerk construction (in Serbian: *"bondruk konstrukcija"*) of the house is characteristic of Morava houses. The basic wall of the skeleton is made of horizontal and diagonally placed thick beams (in Serbian: *"direk" and "mertek"*). On the interior and exterior of the walls, laths or half-forms (in Serbian: *"kovanice"*) are nailed. The wall structure is then filled with a mixture of well-packed mud and straw. (Fig. 5 a) and b)) [4]The walls were coated with a layer of finer mud and straw, followed by a final layer of pure mud, sand, and lime. Once the walls had dried, they were whitewashed with slaked lime as required. The floor is constructed of beams that are connected with boards and covered with a layer of mud and straw, which is approximately 7-10 cm thick. The roofs of these dwellings were pitched, covered with tiles, and, in some instances, with straw. The roof was embellished with a prominent chimney, and the ceilings were nearly absent. The dwellings were equipped with diminutive windows devoid of double-paned glass and were protected by wooden or iron grilles.



a) b) c)

**Fig. 5**. Applied wall constructions in the first and second phase of house typology-characteristic Bundwerk construction, examples a), b), c) (author)

### 3.2. Second phase: Interwar period

In the aftermath of the Great War, the advent of a novel architectural style in Knez Selo was a notable phenomenon. Houses from the 1930s continue to exert a dominant presence in these areas, impressing with their monumental scale, architectural beauty, and intricate structure. The configuration of the terrain and the layout of the houses in the settlement contribute to their striking appearance, characterized by their considerable size, white walls, elaborate balconies, arcades, and windows.

The dwellings were considerably more expansive than the typical Morava abode. The houses are rectangular shaped. The second floor was constructed above the obligatory

cellar (ground floor), which served as a storage room for foodstuffs. This floor was reached by wooden stairs. The second floor of the house featured a spacious guest room, accessible from which was a kitchen and a bedroom. In the center of the house, a substantial terrace/porch (in Serbian: *"trem"*) was constructed, encompassing a considerable length and featuring ornate wooden pillars and arches. This terrace provided direct access to the aforementioned guest room and an additional, diminutive space that was primarily utilized by the newlyweds. (Fig. 6a, b, c, d,e,f and g.) The windows were of considerable size, comprising two smaller sashes, one positioned at the top and another at the bottom. The roof of the house was pitched and covered with tiles, with two to three long brick chimneys. The construction of the walls was similar to that of the "Morava" style houses, with the exception of the use of small pieces of broken roof tiles that were "stuck" into the roughly plastered walls with mud, and then plastered with sand, lime, and a small quantity of cement. (Fig 5 b) The ceiling is constructed from slats and reeds and plastered with a mortar comprising lime, sand, and fine sand. The dwellings were coated with a whitewash composed of slaked lime.

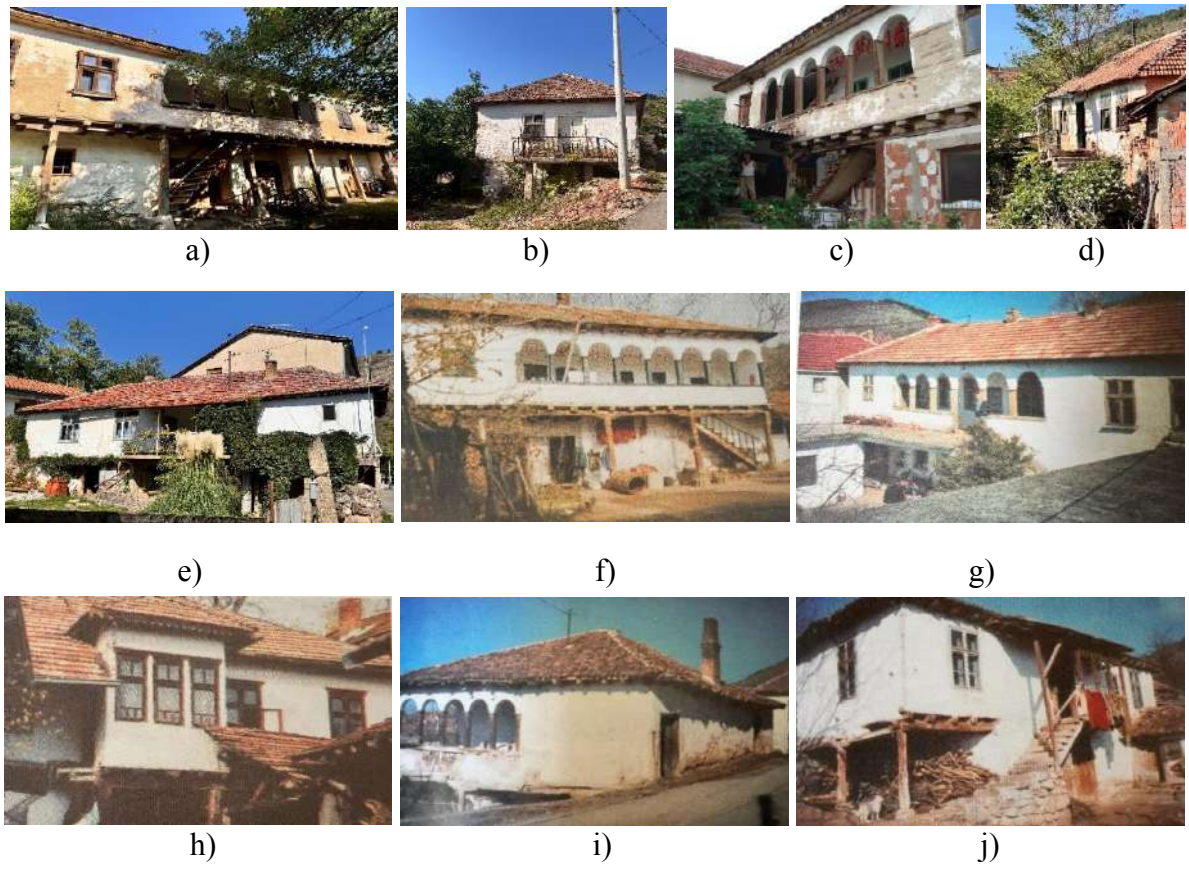



**Fig. 6.** Characteristic Houses from the Interwar Period (Fig. a, b, d, e: author, fig. c: Turnšek AJ. B. et al. [3], and fig. F, G, H, I, J: Nikolić B. and Nikolić S., [4] )

Despite the demolition of a number of older houses, the majority of these structures remain in relatively good condition and continue to be utilized for residential purposes. This is due to the fact that they have been adapted to accommodate modern living standards. In the present day, the houses constructed during this period serve as a form of "decoration" for the village, contributing to its distinctive beauty and visual appeal within the context of the surrounding natural environment, which encompasses forests and fields. In terms of aesthetic appeal, functionality, visual character, and ecological impact, the houses from this period are the most notable among all other houses in Knez Selo. These

houses bridge the gap between the traditional and the modern, infusing the streets and alleys with a vibrant and striking visual character. Individually and collectively, they exude a remarkable sense of harmony. (Fig. 6.)

**3.3. Third phase: After the Second World War to the present day**

Following the liberation from Ottoman rule, the entire socio-political and cultural landscape was transformed, ushering in a new era. The needs of the populace and their way of life are undergoing a transformation. Larger and more spacious houses are being constructed with modern hard materials, thereby giving rise to new styles of building in architecture over time. In the context of contemporary modern construction, it is possible to distinguish a number of distinct phases. These include: (a) the initial stages of construction utilizing hard materials; (b) the construction of modern houses in the 1960s and 1970s; (c) the development of weekend settlements; (d) the construction of settlements in proximity to sanatoriums. The aforementioned phases will be elucidated in brief for the sake of providing a general impression of the typology of houses in Knez Selo. However, as they are not yet part of the architectural heritage, they will not be included in the subsequent analysis of architectural heritage protection.

In addition to the appearance of new styles, the design of the household has also changed. In small courtyards, 200 to 500 m² in size, the house is located in depth, while around it are all the accompanying buildings built mainly from concrete blocks. There are almost no barns or haystacks anymore. Yards are mostly concreted so that very little land is left for green areas, gardens and orchards. Prestigious houses and yards have spaces for householders to rest. The fences around the house are still Ottoman in the beginning, high made of concrete blocks with obligatory high gates, while later lower fences and gates of different materials are built.

**a) Utilization of durable materials**. In the post-World War II era, residential structures were constructed using durable materials and a rectangular shape with a sloping hipped roof. The typical configuration of the house comprised a ground floor and a basement. The projecting terrace was situated above the basement and accessed via concrete stairs. It was frequently glazed. The spatial organization of the rooms remained largely consistent with that of the preceding architectural style. These houses are plastered with traditional plaster, though they are often whitewashed with a lime and yellow mixture or another pastel light color. The wooden windows have been modified to include triple-hung glazing, while the stair railings have been constructed from wrought iron.

**b) Contemporary residential structures erected during the 1960s and 1970s.** The construction of modern houses commenced in the mid-20th century. The houses were rectangular in shape, with a stone or concrete basement and a floor constructed from baked bricks. The ground floor comprises a living room, a kitchen, and a small basement storage area. The bedrooms are located on the second floor. In some instances, bathrooms are constructed on the ground floor of these houses. The defining features of the hipped roofs, clad in tiles and featuring wooden double-glazed windows, remain consistent with those observed in the preceding period. Additionally, numerous older residences have undergone renovations, with the basements converted into living rooms and kitchens, while bedrooms are situated on the first floor. The introduction of new standards in the 1970s led to the construction of more modern houses, reflecting the evolving needs of contemporary society. The flooring is typically parquet or ship-lap, the bathrooms are an integral part of the house, and the furniture is modern. The houses are equipped with contemporary appliances.

**c) Construction of a Weekend Settlement(Vikend Naselje).** In the 1980s, Knez Selo was swept by a new wave of house building and yard landscaping. By increasing the standard of the population, the frequent trips of Knez Selo members and the overall opportunities in the village such as the construction of better infrastructure and the

connection with the town of Niš, the expansion of the village of Knez Selo to the south and east of the Sanatorium occurs. This settlement has over 100 houses and is an integral part of Knez Selo, with the difference that it is new, modern and planned. In this neighborhood, many houses are used only for vacations, but there are also many who live there permanently. The construction of the Weekend settlement and the style of the houses at that time also influenced the construction of new houses in the traditional rural settlement, so in this section the analysis of the houses refers to the style and construction of both houses. On average, the houses are all well-designed architecturally and functionally. They were built without a specific and clearly defined style, usually according to the owner's taste. (Fig. 7) Houses are built in two and three levels. The terraces are spacious, and the fences on them are decoratively processed and decorated. The windows are made of PVC of various shapes and sizes with double glazing. The facades are simply plastered and painted in different colors. The roof is usually pitched, and several houses have solar panels.



**Fig. 7**. Modern houses in Weekend settlement (author)

**d) The settlement around the Sanatorium.** It is important to note that the residential structure of the village was formed through the development of the residential settlement around the Sanatorium. Despite the fact that the sanatorium is no longer operational, the entire complex of the sanatorium settlement was previously of significant social, economic, and developmental importance for Knez Selo. In addition to the principal hospital facilities, the Sanatorium settlement comprised ancillary commercial premises, retail outlets, a swimming pool, sports facilities and residential accommodation. The residential area was constructed with the express purpose of providing accommodation for the workers at the sanatorium. However, the apartments are now in private ownership. The central block of buildings, constructed in 1946 as a hospital, comprises five levels. The adjacent annex has one level. In 1955, a three-level building was constructed due to the expansion of the hospital's capacity. The entire settlement comprises approximately 50 residential units, which are distributed across a range of categories and apartment types.[4]

## 4. Discussion

Marasović, by the term architectural heritage, means "immovable and movable cultural assets created by human labor from prehistoric times to modern architectural achievements." This term covers historical cities and settlements or their parts, old buildings, their fragments, as well as archaeological objects, and according to their purpose they are divided into iconic, military, monumental, residential, public, commercial buildings and infrastructure [8] Nenadović points out that today, architectural heritage means everything that was built in the past, and has monumental values, which valorize it

and determine the need for its preservation. [9] The defining characteristic of these objects is their possession of a multitude of values, including historical, age, cultural, artistic, ambient, ethnological, technical, original, and others. [8] [9]

The majority of rural architecture in Serbia, with the exception of those structures constructed from stone, is comprised of less durable materials, resulting in a reduced lifespan. Nevertheless, as long as construction persists in its original forms, these structures maintain their cultural and architectural significance. [9] The residential architecture of Knez Selo, as observed in the initial and subsequent phases of construction, evinces considerable architectural heritage value, reflecting a multifaceted architectural history. Primarily, the houses possess historical value, as they reflect historical continuity and serve as a testament to the evolution of the architectural ensemble from the 19th and early 20th centuries. The age and artistic value of these structures are reflected in their preservation, which has been achieved through the use of local materials, functionality, and simple yet aesthetically harmonious forms. Their ambient value stems from their adaptation to the local landscape, which has resulted in the creation of a balanced rural space. With regard to the value of originality, the buildings from the first and second phases of construction contain a considerable number of original elements, both in terms of the materials used (Wattle and daub, (in Serbian: *"čatma"*) and wood) and the construction technique employed (Bundwerk system), which is specific to this climate. As illustrative examples of Morava domestic architecture, these buildings serve as conduits for local traditions and a crucial subject of inquiry from a scientific perspective. The combination of these values demonstrates the crucial need to safeguard the architectural heritage of Knez Selo, particularly the houses from the initial and subsequent construction phases, which play a pivotal role in maintaining the local identity and cultural heritage. Nevertheless, this undertaking is not without its challenges. The restoration and maintenance of traditional houses often necessitates considerable effort, as they frequently require specific construction techniques and materials to ensure their authenticity. The analysis of traditional residential architecture in the village has revealed a number of challenges currently facing the preservation of these houses. These include neglect and lack of maintenance, non-compliance with modern architectural trends, and changes in function and modern needs.

### 4.1. Causes of the threat and degradation of buildings

The architectural heritage of Knez Selo is facing a significant decline due to a combination of factors. As Marasović asserts, "From the outset, each object is susceptible to a multitude of external factors that potentially jeopardize its intrinsic or accumulated design, spatial, structural, aesthetic-artistic, functional, economic, and other values." [8] The term "degradation of cultural heritage" is used to describe the gradual deterioration or loss of value of cultural assets due to various factors. The causes of the endangerment and degradation of buildings are numerous and varied, manifesting in a multitude of forms. These include, but are not limited to, complete or partial demolition of buildings, changes of purpose, damage to the environment, and other aspects. The causes of endangerment and degradation can be classified as either long-term, which have been present since the creation of the object, or immediate, which are caused by sudden changes. Two principal forms of long-term degradation of built heritage can be identified. The first is related to natural factors, including weathering, erosion, moisture, and climate change. The second is caused by human action, including negligence, inadequate protection, urbanization, and vandalism. Degradation can affect the material structure of buildings, their aesthetic and functional characteristics, and also the loss of symbolic and historical value, which further complicates the process of protection and preservation. The implementation of timely and

meticulously devised protection and revitalization measures is imperative for the prevention of degradation. [8] [9]

Evolutionary natural decay is most often the basic form of decay of houses in rural areas, which is also the case with the analyzed settlement. However, a major role is also played by the unconscious degradation of architectural heritage, often caused by carelessness in maintenance, which causes the deterioration of buildings. First of all, houses from the first and second phases of construction, which carry great historical, cultural and economic value, are often neglected and left to the natural process of degradation, which leads to their deterioration, and thus to the loss of their value. The lack of adequate maintenance and financial resources for restoration leads to the deterioration of the materials and structure of these buildings, especially those built from traditional materials such as wattle and daub and wood, which are susceptible to weather influences and natural disasters. The neglect of the architectural heritage, which is a frequent phenomenon in many historical units, has not bypassed old houses in rural areas such as Knez Selo. Changes in the social structure of the population, migration from villages to cities, as well as the economic degradation of rural areas have led to the neglect of regular maintenance of traditional houses. The absence of constant care for these objects results in their accelerated deterioration, and dilapidated structures often cause collapse and loss of cultural value. (Fig. 8)[8] [9]



**Fig. 8.** The deterioration of residential properties in Knez Selo is a consequence of a variety of degradation processes. (author)

### 4.2. The Discrepancy with Contemporary Architectural Trends

Modernization and the introduction of new architectural styles often result in mismatched buildings that damage the ambient and urban value of the village. (Fig. 8) It is a rare case that units with ambient rural or urban values are completely free of objects that do not have these values, whether they are ancillary buildings or modern houses. [9] Modern interventions in Knez Selo often do not respect the original character and harmony of the settlement, thereby further endangering the authenticity of local architecture, creating an impression of overcrowding and disharmony, and disrupting the traditional building style. The main characteristics of folk architecture remained unchanged for a long time, with minor variations, until new materials, such as brick and concrete, appeared. [10] The introduction of new styles in the period after the Second World War led to the construction of larger and more monumental houses, which often differed from the original appearance of the village. When the use of bricks was fully accepted, and the then bundwerk construction ceased to be used, there was a change in the appearance of residential buildings in relation to indigenous architecture. Modern houses and new styles

increasingly dominate the village, often deviating from the traditional appearance of the village and the created ambience.

### 4.3. Change in function and modern needs

In rural settlements, traditional houses frequently encounter obstacles in adapting to new functional and aesthetic standards in light of the modern way of life. This often results in the demolition of these structures. In Knez Selo, this phenomenon is particularly evident in the courtyards of households where, in addition to traditional houses, there are also modern houses constructed from solid materials, which are used as permanent residences. Consequently, aged edifices are predominantly left uninhabited or repurposed as ancillary spaces, predominantly for the storage of belongings. This situation not only endangers the preservation of local culture and identity but also affects the overall structural homogeneity of the community. Furthermore, the alteration of the space between old and new structures results in a visual and functional discord, which can impact the local residents' experience and awareness of their heritage.

## 5. Developmental directions of protection of traditional houses

The protection of traditional village houses is an important aspect of preserving cultural heritage and local architecture. In the modern context, the protection of architectural heritage in rural settlements such as Knez Selo represents a significant challenge and requires a multidisciplinary approach. "Although, the term "protection" could mean only the preservation of the existing state, this term includes all possible interventions, such as restoration, renewal, reconstruction, revitalization, resuscitation and other possible forms of intervention in the historical environment, which are carried out for the purpose of preservation of cultural assets and their evaluation in modern life." [8] The settlement, rich in historical layers of architecture, presents different types of houses from three stages of development, reflecting changes in style, function and materials over time. In Knez Selo, the lack of adequate active protection and revitalization programs poses a serious threat to the survival of traditional architectural values. In order to preserve the authentic houses and the ambience of the village, it is necessary to develop plans that will ensure the full protection of the architectural heritage in accordance with the principles of sustainable development. The preservation of the authentic houses and the ambience of the village implies, first of all, the introduction of legal protection measures and the marking of these objects as cultural assets, with the aim of highlighting their importance as an important part of the historical heritage, in accordance with the principles of sustainable development.

A modern approach to conservation must meet two key objectives: to preserve the cultural and architectural potential of Knez Selo in perpetuity, while ensuring the development of functions that meet the needs of modern life. The key challenge lies in the use of natural, local materials in the renovation of old buildings, as well as the careful integration of new materials in new buildings. It is important that the new construction does not dominate the existing traditional structures, but respectfully fits into the space and preserves the authentic spirit of the village. According to architect Zoran Petrović, "In new interventions, it is best to preserve the spirit of the place (*genius loci*), because it corresponds to the specifics of the climate, the architectural tradition, the characteristics of the materials and the cultural dimension of the atmosphere". [11] The preservation and improvement of the architectural heritage in Knez Selo can be promoted by the development of tourism and the revival of local activities, which would make the village attractive for visitors and revitalize it. In protected cores it is necessary to avoid contents that could contribute to their degradation and to develop those that allow their full integration into modern life flows.

**5.1. Proposals for the protection and revitalization of rural houses**

Active preservation differs from traditional conservation in that it embraces the broader historic environment and considers architectural heritage as part of a living organism. [8] The most important recommendations and **measures for the protection of traditional village houses** contained in the books on the protection of architectural heritage by Marasović and Nenadović include the following:

**Documentation and Research:** The first step in protecting traditional houses is to document and research their historical and architectural characteristics. This includes gathering data on the age of the house, architectural style, materials used in construction, and significance in the local context.

**Assessment of condition and restoration needs:** An analysis of the current condition of the house is necessary to determine what is needed for preservation. This may include assessing structural problems, damage to facades and roofs, and the condition of original materials.

**Revitalization of traditional houses:** An adequate approach to the revitalization and protection of the historical architectural heritage imposes the need to preserve its authentic urban-architectural, artistic-aesthetic and environmental values**.** [8] The foundation for preserving buildings made of less durable materials is regular maintenance. [10] Modern approaches to the restoration and reconstruction of existing buildings, as well as the construction of new ones, are aimed at preserving the traditional physical structures of rural settlements. The realization of these concepts should be guided by precise guidelines in order to enable the proper revitalization of the traditional architecture of this area. First of all, it is crucial to carry out adequate structural repairs, especially on the roof structure and covering, as well as on windows, doors and facades. In addition, attention should be paid to the ground floor of the house, the fence and the paving of the property. The preservation of the original dimensions of the buildings and the careful design of the new volumes are essential so that each intervention contributes to the creation of a unique and homogeneous whole. In the materialization of the buildings, traditional materials should be used for walls, roofs and openings, as well as traditional construction techniques whenever possible. This may include the use of wood or other local materials, as well as traditional techniques such as bondruk construction.

**Applying modern solutions in harmony with tradition:** In some cases, it may be necessary to apply modern solutions that improve energy efficiency and safety, while respecting traditional appearance and materials.

**Use and Adaptation:** Some traditional houses can be adapted for contemporary uses, such as museums, tourist facilities, or residences, which can help maintain and preserve them for the future.

**Multidisciplinary approach and public participation:** A multidisciplinary approach to heritage protection requires the participation of experts from different disciplines who work together to prepare scientific and professional documentation and plans before any intervention is undertaken. In the process of protecting traditional houses, cooperation with architects, restorers and other experts with experience in working with historic buildings is of great importance. Active protection also seeks to increase public participation in the process of preserving and managing cultural heritage, thereby raising awareness of the importance of protection. Educating and raising the awareness of local people about the importance of preserving traditional houses can contribute significantly to their protection. Local communities can play a key role in the preservation and maintenance of these sites.

## 6. Conclusion

Traditional folk architecture is not only an architectural style, but a way of thinking and relating to the world, nature, life and the spirit of the place. It is an attitude towards life processes, the use of materials and respect for climate and authenticity. Building in harmony with nature achieves a balanced ecological rhythm of life, emphasizing adaptation to climatic and topographic conditions, as well as to the spirit of the place (*genius loci*). Although modern urbanization is gradually erasing the ambience of traditional architecture, the specifics of this architectural expression, especially in residential architecture, remain a strong source of inspiration and a catalyst for future architectural solutions based on the preservation of local and regional identity. The conclusion of this paper shows that the goal defined in the introduction has been achieved through a detailed analysis of the typology of houses in Knez Selo and the identification of the challenges facing their preservation. The research confirmed the importance of these traditional buildings for the preservation of local identity and cultural heritage, but also pointed out that the process of their protection and revitalization is complex and requires a multidisciplinary approach.

The typological analysis revealed different phases of construction, from the Morava style in the first phase, through the houses built between the two world wars, to more modern interventions. These houses have historical, artistic and environmental value, but they are facing significant challenges in the form of degradation due to lack of maintenance, unfavorable climatic influences, as well as modern architectural trends that often do not respect the original spirit of the place. The causes of the threat and deterioration of the buildings are numerous, including both natural and human factors, and the results suggest that the preservation of these buildings is necessary to maintain the cultural continuity and authenticity of the rural landscape. This task is further complicated by population migrations and changes in the function of buildings, with old houses often left abandoned or converted into auxiliary buildings. Development directions for the revitalization and protection of traditional houses should aim at adequate legal protection, reconstruction using local materials and techniques, and the introduction of new functions that will enable their integration into modern life. This includes improving energy efficiency while respecting the original architectural values.

## Acknowledgement

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# ANALYSIS AND REFURBISHMENT OF A WW2 RC-BRIDGE ACROSS RIVER LYS IN GHENT (B)

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***Abstract**: Ghent's Verlorenkost Bridge spans the Leie River and has a rich history, having begun as a timber bridge during the Middle Ages and evolving into an impressive stone arch. In order to provide the river with the greatest possible vertical clearance, the current bridge was constructed as an RC portal frame during World War II. Even the military load imposed by the occupying forces was significantly less than the present design load, according to design reports from 1941. It was determined whether this bridge is appropriate for LM1's typical road traffic or other kinds of loads using a solid FE element simulation. The action of LM 1 is not resisted by the bridge deck with varying depth. As a result, the NAD permits an LM 5, which was taken into consideration. This translates into a frequent traffic load that is reasonable. The bridge meets the standards, except in a few specific sections. To strengthen this bridge, CFRP-strips can be employed in certain locations, particularly on the lower side. For the top side, a thin concrete overlay combined with near-surface reinforcement is advised.*

***Key words**: portal frame bridge, alternative structural use, historic loads, CFRP-strengthening, smooth rebars, wartime construction.*

## 1. Introduction : bridge's history

The Verlorenkost bridge in Ghent spans the river Leie, with the eastern bank being higher than the western side. A bridge has been built at this location since 1429 to allow traffic from outside the city in the direction of the mount Blandijn. The name Verlorenkost seems to come from the slope and the height of the banks of the Leie, so that the inhabitants could not reach the water to scoop it and therefore could not earn a living there. More precise sources [1] indicate that a narrow wooden swing bridge was installed in 1754. This was replaced further, first in 1811 and then in 1836 and in 1856. Finally, in 1857, the last swing bridge was built, which was only 4 m wide. This bridge is displayed in Figure 1. In 1899, the Verlorenkost road was widened to 12 m and a monumental stone bridge was built. This was decorated with statues by the artist Domien Van den Bossche. These statues represented shipping and labour. The bridge from 1899 is exhibited in Figure 2. The statues are displayed in Figure 3.

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**Fig. 1**. 4m wide swing bridge dating 1857




**Fig. 2**. Widened (12 m) stone arch bridge dating 1899




**Fig. 3**. Decorations and statues on stone bridge

On May 23, 1940, the invading occupant army blew up the stone bridge. The destruction was total. Because the connection is of great importance and after the complete occupation, the design and later the construction of a new bridge was started.

Like many bridges in the city of Ghent, the Verlorenkost bridge is also a portal frame. This type of structure allows to ensure a larger vertical clearance below the construction. Probably because steel was scarce due to the war conditions, this bridge was built with RC. This also explains why the quality of the reinforcement steel is low. Figure 4 exhibits an overall view of the structure.



**Fig. 4**. Present Verlorenkost Bridge

**2. RC Portal frame bridge**

Only partial design documents of the bridge survive, including complete and detailed plans and incomplete design reports.

As far as it was possible to find out, the design load outside the roadway appears to be a uniform pressure of 400 kgf/m² (expressed in dimensions used at that time). For the roadway itself, the so-called lorry of 32 tons was used [2], which consists of 2 axles of 4 tons, 2 axles of 6 tons and one axle of 12 tons. The bridge has been verified for loads imposed by the occupant. These are [3]:

- A 'followed vehicle' corresponding to a load of 40 T to be spread over 6 * 5.5 m² of surface area
- A truck with a load of 12 T, to be spread over 6 * 2.5 m²
- A distributed load of the 'crowd' type of 500 kgf/m²

The latter is still applicable in EC 1991-2.

It should be noted that the design and verification calculations of 1941 were made using influence lines for frames, taking into account that the frame feet are freely rotatable and possibly not taking into account the variable stiffness due to the variable height of the slab and vertical members.

The strength of the concrete is not mentioned in the remaining documentation. Therefore, 15 cylindrical cores were drilled, mostly to determine the reinforcement and the concrete cover. The compressive strength of the concrete was also determined for 3 cores. This determined a characteristic value of the concrete strength according to EN 1990 - Annex D [4], which corresponds to class C 35/45.

Taking test samples of the reinforcement was not feasible. Therefore reference was made to the literature [5]. It appears that the use of rebars with improved bond only occurred from the 60's of the previous century. According to the available plans, smooth rebars with hooks were also used in this case. An extract from such a plan is exhibited in

Figure 5. From the aforementioned broad research, a yield stress of 230 MPa was common in this period. Taking into account the partial factor of $\gamma = 1.15$, $f_{yd} = 200$ MPa was also assumed.

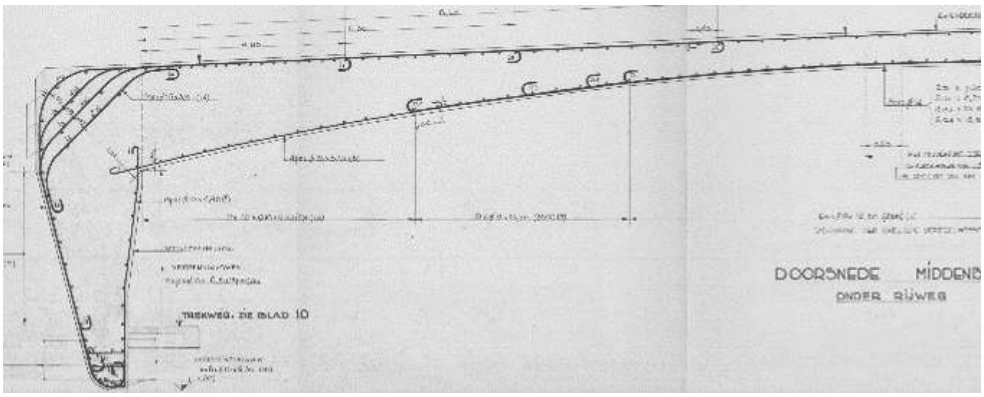



**Fig. 5**. Detail from reinforcement plans (1941)

**3. Further use of bridge**

In the period 2023-2024, a thorough inspection of the bridge was carried out. In addition to superficial damage to the facings of the abutments and slight corrosion to the metal parapets and the crash protection lath, tests were mainly carried out on the concrete. The carbonation only reaches a depth of 10 mm at most and the attack by chlorides is virtually nil. In addition, no alkali-silica reaction was discovered. Therefore, the structure is generally in a relatively good condition. Only in one place was exposed reinforcement found over a distance of 30 cm with slight oxidation.

There are 3 longitudinal cracks that have been found, which are noticed at the bottom of the concrete slab. These can be seen in Figure 4. The crack width is between 0.6 and 1 mm. These cracks indicate a possible defect.



**Fig. 6**. Longitudinal cracks in lower side of the bridge deck slab

The main concern of the bridge owner is the load-bearing capacity. Since the end of WWII, traffic has increased rapidly, both in intensity and in weight. In addition, it is in the context of the renovation of a number of access roads to the City, to thoroughly change the road network. For example, the number of lanes is being reduced to 1, but with a concrete roadbed of 0.15 m thickness. Therefore it was necessary to verify the load-bearing capacity, both for the current design loads and for real vehicles. Thus the bridge manager had two questions.

- What is the load-bearing capacity of the bridge (compared to current design models of road traffic) taking into account the new layout that will be realised during the road works;
- Is it sufficient to renovate the bridge without providing additional structural measures that increase the load-bearing capacity? If not, which structural measures could be applied to increase the load-bearing capacity?

This report is primarily concerned with answering both of these questions.

## 4. Load-carrying capacity

### 4.1. Initial situation

Because the bridge is a solid concrete structure, it was decided to assemble the model entirely from volume elements. This allows taking into account the variable height of the deck and the actual shape of the styles. In addition, a distribution of wheel loads, according to a spreadingn down to the middle plane of the cross-sections, can be implemented. Furthermore, the solid element model allows defining the actual course of the axis lines and the curvatures they exhibit, as well as the actual shape of the nodes and representative length of the deck and styles.

A known disadvantage is that the stresses cannot be used directly, because concrete is in essence an inhomogeneous material. A conversion must therefore be made from elastic stresses to normal forces, bending moments and shear forces.

The determination of the load-bearing capacity must first be done according to the requirements of EN 1991-2 [6] with the loads provided therein. This includes the dead load of the structure, the fixed loads of the footpaths and the roadway pavement, the traffic load on the footpaths of 2.5 kN/m², the LM 1, the braking forces and the wind load. The combination formed is done with the relevant combination and partial factors.

To determine the wind pressure according to EN 1991-1-4 [7], the lowest natural frequency is needed to determine the dynamic factor $c_s c_d$. The latter is for most bridges = 1 but in this case it appears to be 1.023. Figure 7 shows the mode corresponding to the lowest frequency of 4.61 Hz. The critical wind speed of 61.6 m/s is much higher than the peak wind speed of 28.4 m/s. The value of the actual wind pressure then becomes 1.46 kN/m².

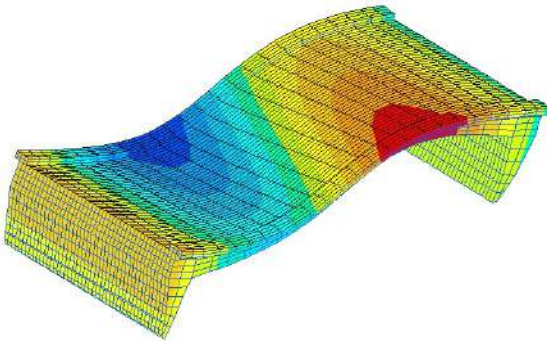


**Fig. 7**. Lowest mode natural vibration $f_e$ = 4.61 Hz

In order to meet the requirements of LM 1, it quickly becomes apparent that the reinforcements of the bridge deck slab are inadequate. In the middle of the field, 47% more bottom reinforcement would be needed. This is without taking into account the necessary top reinforcement at the nodes of the portal, where there is a shortage of 85%. For that reason, the existing situation, which is certainly not satisfactory, is not discussed further.

**4.2. New situation**

As part of a larger project to renovate the southern access to the city's historic centre, the plan is to further reduce motorised traffic on the bridge to a single lane and to widen the southern footpath as a lead-in to a planted area. A plan of the new situation is exhibited in Figure 8.



**Fig. 8**. New arrangement of road.

Since the structure cannot support LM 1, the asset manager has agreed to adopt national annex (2011) of EN 1991-2. In this annex, which refers to annex M of the basic standard, an LM 5 is included, which actually considers FLM 2 as a real traffic load. The 'permissible class' of bridges for local traffic then considers the most adverse vehicle of FLM 2, where a reduction factor of 0.80 can be combined with a dynamic factor of 1.30 for a single axle and the partial factor $\gamma = 1.20$ may be used. Roughly stated, in ULS the most detrimental lorry of FLM2 is to be multiplied by 1.20.

Because the road has a different composition, the uniform loads on the sidewalks, the larger fixed load on the pavement and lorry 4 or 3 of FLM2 are a bit more complicated and are represented in Figure 9.

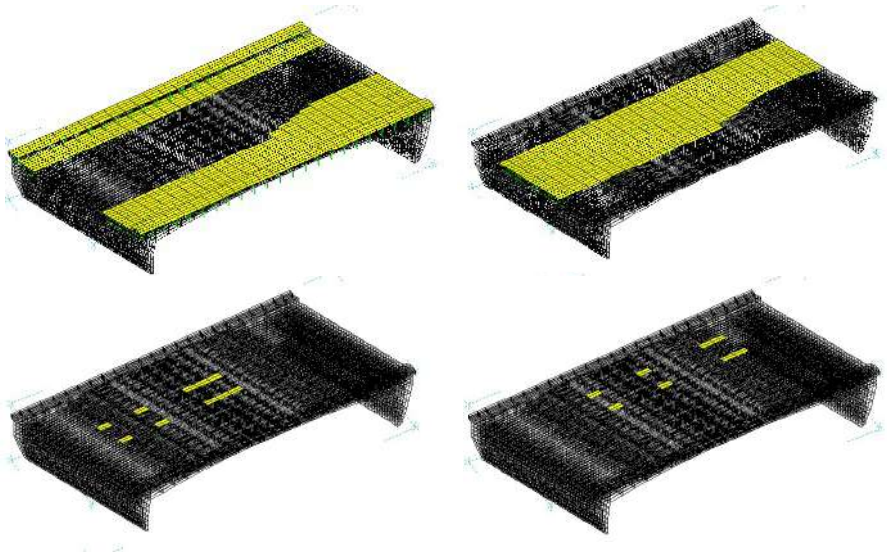


**Fig. 9**. New composition of loads.

The various simulations have shown there are 4 critical locations where the available reinforcement is insufficient, or the value of $f_{yd}$ would be exceeded.

The transverse distribution reinforcement at the bottom of the roadway in the central span field is insufficient. 1395 mm²/m is needed and only 509 mm²/m is available

The top longitudinal reinforcement at the footpath connection to the higher post is insufficient, since 7585 mm² is needed, since some of the rebars do not reach sufficiently far from the vertical member. Only 3048 mm²/m is available.

The top reinforcement at the clamping of the roadway area in the vertical posts is insufficient. 6159 mm²/m is needed and only 3 types of bars are available, which is 3936 mm²/m.

The top distribution reinforcement at the ends of the slab deck in the zone of the clamping in the vertical members is insufficient. Only 12 bars of 9 mm/m or 763 mm²/m are available, whereas 2463 mm²/m is required.

The relatively largest shortage of reinforcement is found in the transverse lower reinforcement in the field of the concrete slab. This is due to the character of the original design load, which contains relatively light axes and consists mainly of large areas of uniform load. During the period of the construction of the bridge, relatively light distribution reinforcements were also used, which usually did not comprise more than a quarter of the main reinforcement. In addition, the design was made on the basis of influence lines for hinged or clamped single portal frames. Obviously, this is a 2-D calculation, which is unable to detect transverse bending. Therefore, an underestimate of the latter has occurred. The latter also applies to the upper distribution reinforcement at the ends of the slab deck in the area of the clamping in the posts. The shortage in this type of reinforcement reaches 323%.

Both insufficiencies of longitudinal, upper reinforcement in the area of the connection of the bridge slab and the vertical posts is also due to the use of self-constructed influence lines. For instance, Figure 8 exhibits the influence lines for the bending moment and shear force at the bridge slab centre, taken from original documents.

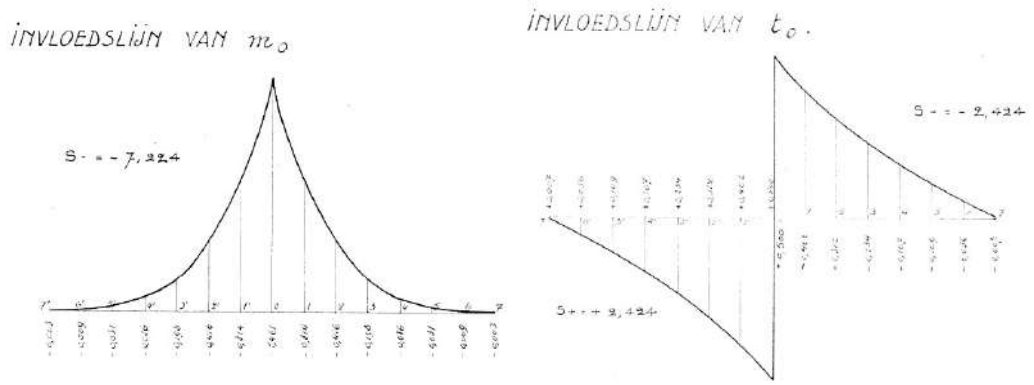



**Fig. 10**. Hand-made influence lines for bridge slab.

It will be noticed, the influence of the posts does not appear and neither does the effect of the height difference of these vertical members.

Clearly, the positive effect of compression force has been taken into account. However, near the connection of the slab and the posts, the normal force changes sign and thus further increases the demand for reinforcement.

Concerning the cracks at the lower side of the bridge slab, as the shortage of reinforcement is considerable, in SLS the rebar stress may reach up to 399 MPa. This probably means the bars were broken and there is no active transversal reinforcement, which certainly must have yielded. Assuming the rebars are not completely broken, the crack width consists of a part due to crack formation, while the steel bars remain un-yielded and a second part, due to post-yielded elongation by the rebars. The first part can be calculated by the equations of section 7.3.4 of EN 1992-1-1, whereas the following part must be derived from typical stress-strain curved of historic reinforcement steel. The

results are a crack distance of 262.91 mm and a total strain of 0.0084 S, leading to a crack width of 1.58 mm. This crack width is somewhat higher than the measured maximum value of 1 mm. It is well known that the equations of EN 1992-1-1 overestimate the crack width, since in the new version of this standard [8] lower values are indicated. Recalculating the former results by the equations 9.11 to 9.15 of this standard renders a crack width of 1.01 mm, which is close to the measured value of 1 mm.

Concerning the rotating base of the supports, the hinge should function properly, as a 10mm gap is left between the base plane and the concrete fillet at the bottom of the post. This is visible in Figure 11-left. It is not clear whether this opening always remains free of rubbish and dust. Figure 11-right exhibits the reinforcement. Verification of the concrete contact stress does not work out by applying Hertz contact theory, since both curved surfaces are in conformal contact.

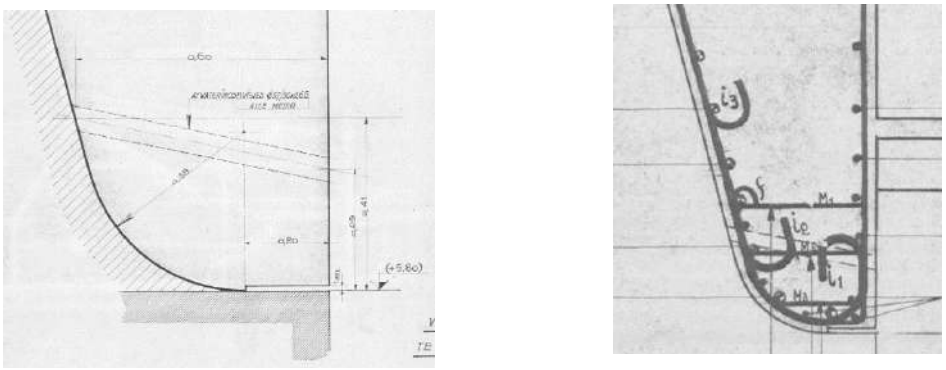


**Fig. 11**. Concrete hinge (left) and reinforcement (right).

In these cases the Persson theory [9] for conformal contact might be applied. According to the latter, the maximum contact pressure of 2 cylinders with radius R and contact angle 2α can be found through equations (1) and (2).

$$c = \tan\frac{\alpha}{2} \tag{1}$$

$$\frac{R\,L\,p_{max}}{F} = \frac{2\,c}{\pi\sqrt{c^2+1}} + \frac{\ln\left(\sqrt{c^2+1}+c\right)}{\pi\,c^2\,(c^2+1)} \tag{2}$$

The resulting ULS-reaction, composed of a vertical reaction and a horizontal thrust force equals 7976 kN, the contact angle being 58.76°. As exhibited in Figure 11 the radius R = 380 mm and the total length of the hinge equals 11.3 m. This results in a maximum compression of 2.07 MPa, which is a small value.

The vertical member also has sufficient horizontal shear reinforcement to resist the effect of the thrust force. This reinforcement is quite light and looks negligible, as exhibited if Figure 11-right. However, the vertical compression force balances and compensates the effect of shear.

Should the hinged support get blocked, due to dirt or any other reason, the influence on the demand for reinforcement is almost inexistent. This is due to the small angular rotation, which does not exceed 0.0036° in SLS. Hence the results above are confirmed and the necessary refurbishment and reinforcement have been reliably determined.

**5. Refurbishment options**

There are several possibilities to apply reinforcements to the slab deck. Applying additional reinforcements is not obvious, but for old structures, and with easy access to areas to be reinforced on the top of the bridge, one can consider using a 'near surface

reinforcement' (NSM). This technique involves cutting out V-shaped grooves, placing the additional reinforcements and then filling the joints with cement mortar, or preferably a strong bonding epoxy.

Usually such reinforcement is done with CFRP wires which are very expensive. The FRP wires are used, so that the grooves do not have to be made too deep. Hence, the groove depth can always remain smaller than the existing concrete cover. Usually such reinforcement is done with CFRP wires which are very expensive. FRP wires are used to limit the depth of the grooves, thus not exceeding the existing concrete cover. Measurements of the concrete cover show that in the affected areas this is at least 30 mm. However, after discussing the various options, the following schemes were adopted.

The lack of lower reinforcement in the transverse direction of the bridge deck is mainly due to the axles of the vehicles. It is therefore a local shortage and is mainly present in the middle of the slab deck. At the bottom of the latter, it is difficult to work with NSM or other reinforcements, which is why the only option appears to be to glue CFRP strips. This is shown in the plan view of Figure 12. The number and type of strips have been determined in such a way that not only the lack of reinforcement has been compensated for, but that the entire demand has been covered, because the existing reinforcement has probably broken.

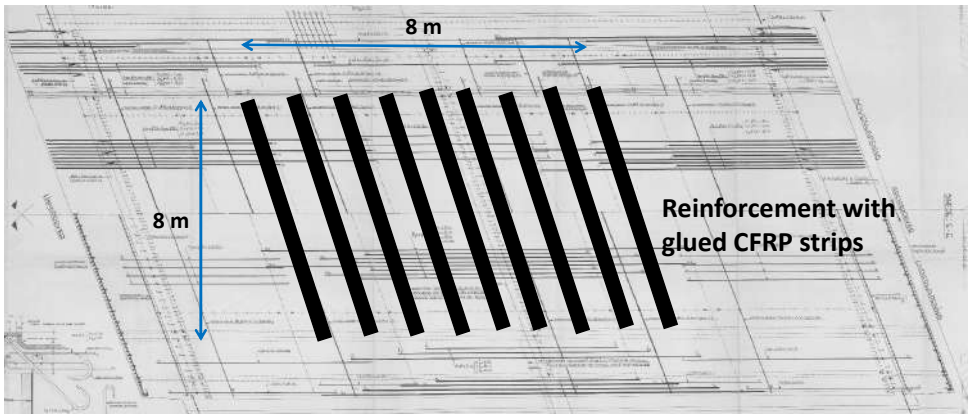



**Fig. 12**. Replacing transverse lower reinforcement by glued CFRP.

For the reinforcement of the upper reinforcement of the raised footpath edges, both NSM and CFRP strips are possible. The first alternative is probably complicated by the settlement of the parapets. Therefore, only the second option has been retained. Here, only the shortage of reinforcement needs to be provided.

Both the longitudinal reinforcement and the transverse reinforcement at the top of the concrete slab require the greatest reinforcement. The new composition of the footpaths and the roadway is shown in Figure 13, where A refers to the eastern side and B to the western part. The new road surface consists of 0.15 m washed concrete, of which the aggregates become visible after washing. This type is generally used in the City of Ghent. By reducing the thickness of this slab to 0.10 m, 50 mm can be used as filling concrete, in which the additional reinforcement bars can be placed in the longitudinal and transverse direction.

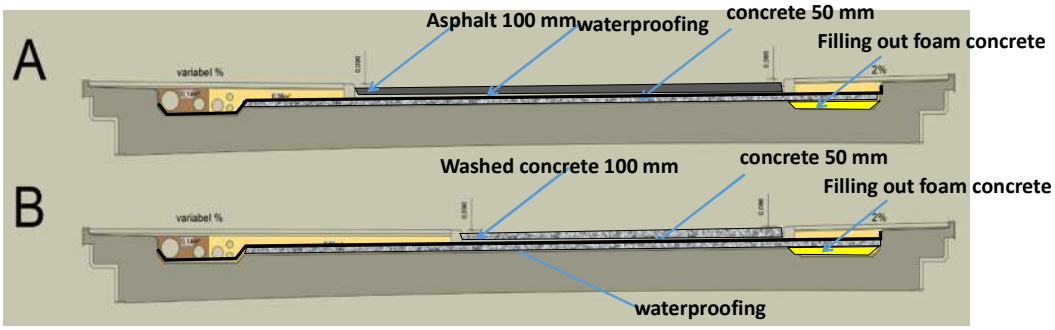



**Fig. 13**. Adding reinforcement at the bridge slab ends

The 50 mm layer with its reinforcements can be anchored in the existing concrete by means of inserted nails. This proposal uses only classical operations and materials and is therefore economical.

Of course, a pertinent question is whether the original reinforcement is not overloaded and whether only supplementary reinforcement is needed, or whether the latter does not have to meet all the demand. It should be noted that ULS does not recognize a structure of different phases. The SLS stresses for the permanent load in the existing reinforcements are not greater than 97 MPa. If the effect of the traffic load is added to this, the steel stress is 112 MPa. In both cases, the material of the bars therefore remains elastic. This is sufficient reason to accept that only the shortage of reinforcement needs to be compensated.

## 6. Conclusion

Building under war conditions is probably not easy. The example of the Verlorenkost bridge shows that concrete of sufficient quality could be produced. On the other hand, the reinforcing steel is of low quality and had to be used sparingly. This is evident from the rapid suspension of some reinforcing bars, which resulted in shortages in many places. Design was done using simple means, such as composing influence lines by the designer, with little consideration for the portal action and the variable stiffness of the bridge deck slab. In this case, it was necessary to use an FE model of the structure, which revealed some shortcomings. However, it can be seen that this bridge did meet the requirements at the time of its construction. The loads, even from wartime vehicles, were much lower than current requirements. The general experience with verifying the load-bearing capacity of historical structures is that they are over-dimensioned. Modern methods allow for more accurate assessments. In the case of the Verlorenkost Bridge, it is likely that wartime conditions necessitated tight dimensioning and economic use of materials.

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# ABOUT THE 57 YEARS HISTORY OF ZDIAKOV BRIDGE IN CZECH REPUBLIC

**Tomaš Roter[1],**

**Продължение на трета част:**

***Abstract:*** Ждяковският мост след повече от 57 години история продължава да представлява един от най-големите и красиви мостове в Чехия. През 2017 г. се навършват 50 години от пускането му в експлоатация и същевременно с приключена точно след този период успешна реконструкция. Ждяковският мост е изпълнен от стомана като двуставна подпряна дъгова конструкция и все още се класира сред най-големите дъгови и красиви мостове по света.

***Key words:*** *arch bridge, 330m span over Zdiakov dam*

## 8.3.1. Мост и пътна настилка

Първоначално е изпълнена изолационна защита под настилката на ширина 1,0 m от стеблото на основния трегер на мостовата пътна плоча, т.е. до оста намоста, като се използват асфалтови ивици. Причината за тази защита беше основно да се осигури достъп на работници, така че движението на хора върху пръсканата изолация на мостовата плоча да бъде напълно изключено. Впоследствие е изпълнена защитата на изолацията под пътя с модифициран лят асфалт MA 11 IV PmB 10/40-65 с проектна дебелина 35 mm, минимум 25 mm, максимум 73 mm. Средната дебелина е 42 mm, **фиг. 47**. Извършено е и изравняване на повърхността на мостовата настилка в слоя от лят асфалт. Полагането е извършено ръчно на секции по цялата ширина от около 10m между ръбовете на бъдещото пътно платно. Монтирани са дървени рамки на местата на водостоците и дренажните тръби. Разписан е ред за движение на превозни средства, транспортиращи асфалтовата смес и за движение на работници по изолацията, което предотвратява разрушаването на изолацията. Тази процедура беше под постоянното наблюдение на техническия надзор на инвеститора.

**КРАЙ НА ВТОРА ЧАСТ НА ДОКЛАДА-ВИЖ СБОРНИК БАНИ2023(стр. 379-393)**

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Фиг. 47 Полагане на лят асфалт -
Фиг. 48 Положени бордюри

Бордюрите са монтирани в суха смес МС 30-XF4, фиг. 48. По искане на института за недвижимо културно наследство са използвани оригиналните каменни бордюри. На местата на водостоците и водосточните тръби е използван дренажен полимербетон с цел отвеждане на влагата под бордюрите в мястото на изпълнения дренажен пластичен бетон. Настилката на моста е изпълнена едновременно по цялата ширина между бордюрите, т.е. 10,5 m. Пътната настилка е изпълнена с напречен наклон от 2%. Върху почистената изолационна защита е нанесен свързващ спрей от модифицирана асфалтова емулсия. Настилката с дебелина 40 mm е от материал АСО 11+ и е изпълнена с валяк - машина. След нанасяне на бондинг спрей е направен абразивен слой от материал SMA 11+ с дебелина 40 mm. Задоволителните резултати от всички необходими тестове са дадени в докладите от инспекцията на двата структурни слоя. Измерването на неравностите на пътната настилка е извършено с летва в надлъжна и напречна посока, като резултатите от неравностите не надвишават допустимите отклонения. Ситуацията бе различна обаче при измерване на пътната настилка при фугите на мостовете. От двете страни на моста, от страната на Příbramská и от страната на Milevská, на някои места повърхността на абразивния слой бе под повърхността на фугата на моста. Поради това ивици от абразивния слой с ширина от около 500 mm пред и зад фугите на моста са шлайфани и отстранения шлайфан слой бе заменен с лят асфалт. В този случай се изисква повърхността на абразивния слой да бъде от 0 до 2 mm над повърхността на мостовата фуга. В никакъв случай не се допусна оставянето му под повърхността на фугата моста. Уплътнението между износващия слой на пътното платно и бордюра и около водостоците е направено с модифицирана горещо нанесена битумна смес Biguma TL-82. Конструкцията на тротуара между корнизната греда и бордюра е изпълнен от стоманобетон. В частта над главната греда на мостовата конструкция, бетонната плоча е свързана със стоманената конструкция на пътната плоча посредством къси дюбели, заварени към горния фланш на главната греда на мостовата конструкция и посредством анкери, свързващи главната греда на мостовата конструкция към корнизната греда. Дебелината на тази част е около 80 mm. В частта към бордюра върху изолационната защита на асфалтовата лента е положена стоманобетонна плоча. Дебелината на тази част е около 270 mm. Тротоарната плоча е от бетон С30/37 – XF 4 с армировка B500B, фиг. 49. Детайлът на края на бетонната повърхност при корнизната греда е направен така, че изолацията на тротоарната настилка да може да се изтегли под горния фланш на корнизната греда, фиг. 50 и фиг. 51. Бетонната конструкция на тротуара е дилатирана в надлъжно направление през 10,40 m. Примарно изтриващата се изолация на тротуара е с наклон 2% в посока

към бордюра. За изолация е използвана системата PUREA 4840 с двойно анкерно-изолираща лепилна смес от ниско-вискозната епоксидна смола Lena P 100 I и

хидроизолационна полиуретанова мембрана PC 4840 HYBRID PUREA с дебелина минимум 2,2 mm на фирма CZ BAUSAN. Изолацията е удължена допълнително с 30 mm върху бордюра. Системата включва и регулиране на напречната фуга между отделните дилатационни възли на настилката.





Фиг. 49 Армиране на плоча под тротуара
Фиг. 50 Бетониране на плоча под тротуара
Фиг. 51 Детайл под фланша на корнизната греда

При рехабилитацията на долната повърхност на бетонната плоча на мостовата конструкция, цялата повърхност на плочата е почистена с водоструйка (бластирана с вода) под налягане 2000 бара, фиг. 52 и фиг. 53, което е определено на базата на предходните тестове на почистване на съответните повърхности на бетона. Единично откритата армировка е почистена и защитена с антикорозионно покритие SikaTop Armatec-110 EpoCem. Пасивирането е извършено на два слоя с дебелина 1,0 mm. Местата с по-големи увреждания на бетонната повърхност са ремонтирани с 5 до 20 mm дебелина на саниращ слой SikaRep. След саниране на бетонната армировка и грубото саниране на бетонната повърхност, е извършена цялостна тънкослойна санация на повърхността на мостовата плоча със саниращ слой в състав: Sikagard 552 W Aquaprimer, Sikagard 545 W Elastofik и Sikagard 675 W Elastic. Индивидуалните покрития са нанасят с валяк или четка.




Фиг. 52 Устройство за улавяне на отпадъците от почистения материал
Фиг. 53 Долната повърхност на пътната мостова плоча след почистването му.

### 8.3.2 Парапет и корнизна греда

Оригиналният парапет и корнизната греда образуват един конструктивен изцяло заварен детайл, който е закрепен с болтове към челната плоча на конзолата на мостовата напречна греда, фиг. 54. Парапетът в надлъжна посока не е разширяван. Парапетът е изпълнен от профили с кутиеобразно напречно сечение и е изцяло заварен. Вертикалните колонки на парапета в долната им част, т.е. на нивото на

настилката, бе установено, че са значително корозирали, фиг. 55. Горният фланш на корнизната греда също е засегнат от корозия. В DZS поставиха изисквания за

цялостна подмяна на парапета и корнизната греда с нови. Институтът за недвижимото културно наследство в Прага настояваха новият парапет да бъде точно копие на оригиналния, т.е. включително използването на затворени профили за производство на парапети и парапет от циндрична тръба.





фиг. 54 Свързване на корнизната греда към конзолата на напречната греда
Фиг. 55 Корозия на колонките на парапета

**Демонтаж:** Корнизната стоманена греда, включително и парапета, са произведени на части с дължина около 5,2 m. Демонтираната част се окачва на кулокрана и след сваляне на болтовите съединения между челните плочи, демонтираната част се сваля върху пътната плоча на моста, след което се извозва до пункта за скрап, фиг. 56 и фиг. 57.





Фиг. 56 Демонтаж на корнизната греда и парапет
Фиг. 57 Изглед на демонтирана корнизна греда и парапет

При реконструкцията, новата корнизна греда е отделена от парапетната конструкция. Новата корнизна греда е монтирана с болтови съединения с помощта на челна плоча към оригиналната челна плоча на конзолата на напречната греда. Новият парапет е монтиран чрез опорната плоча под колонката на парапета, към корнизната греда.

**Производството и монтажа** на корнизните греди е извършено от фирма OK-BE, spol.s r.o. Произведени са обикновени части с дължина 5190 mm с предвидено разстояние от 10 mm между отделните части. В напречно сечение двустенната част е отворена отдолу и е асиметрична. Височината на напречното сечение е 650 mm, а ширината е 212 mm. Външното видимо стебло на гредата е с постоянна височина от 635 mm. Вътрешната стена е с височина 150 mm, която е увеличена до 570 mm в мястото на конзолата на напречната греда в мостовата пътна конструкция. В точката

на свързване има заварена диафрагма. Горният фланш на напречното сечение на корнизната греда е с ширина 250 mm и напречен наклон 4% в посока навън. В горния фланш в местата на бъдещото свързване на колонките на парапета има

подготвени болтове, на които е монтирана опорната плоча на колонките на парапета. Монтажната връзка на отделните части на корнизната греда е реализирана с болтови съединения. Горният фланш и външната стебло са свързани. По време на производството, приемането в цеха се извършва в черно състояние и след извършването на производството на РКО от четирислойно покритие, същото като на стоманената конструкция на моста, следва процедура изяснена по надолу в текста. Монтажът на корнизните греди е предшестван от регулирането на челните плочи върху конзолите на напречните греди, фиг. 58. Контактните повърхности са повторно шлифовани и обработени с РКО. Също така от външната страна на главните греди на моста и включително конзолите на напречните греди е извършен цялостен РКО, фиг. 59, фиг. 60 и фиг. 61. Елипсовидните отвори във връзката на корнизната греда с челната плоча на конзолата осигуряват необходимото ректифициране на отделните свързващи се елементи от констркцията на моста. Основният критерий за сглобяване бе геометричната точност на линията на горния външен ръб на корнизната стоманена греда. За корнизните греди са използвани общо 217 t стомана S235 J0.





Фиг. 58 Челна плоча на напречната конзола преди ремонт
Фиг. 59 Модификация на челната плоча и главната греда на мостовата плоча отвън





Фиг. 60 Свързване на корнизната греда към конзолата на напречната греда
Фиг. 61 Монтажна връзка на корнизната греда

**Производството и монтажа на парапетите** също е извършено от фирма OK-BE, spol. s.r.o. Производството е извършено съгласно преработената проектна документация, съгласно изискването на института за националните паметници, съгласно което новият парапет трябва да бъде копие на оригиналния парапет, т.е. включително използването на затворени профили. Основният проблем, произтичащ от това изискване, беше закрепването на елипсовидната тръба към парапета. Производителят решава проблема, като използва специално адаптирана преса за производство на елипсовидна по конфигурация тръба, от тръба с кръгло напречно

сечение с необходимата точност на формата. Частите на общия парапет са произведени с дължина 7785 mm и с предвиден луфт от 15 mm на мястото на монтажната болтова връзка, фиг. 62. Всяка отправна производствена марка за

парапета притежава три колонки. Освен стандартните части в наличност са и нетипични части на местата на пасарелките по пилоните и по крилата. Височината на стоманения парапет е 1068 mm, което осигурява необходимата височина от 1100 mm над нивото на повърхността за ходене, тъй като основната плоча е разположена по-високо. Дръжката е изработена от елипсовидна тръба TR 154×83. Колонките са заварени от два профила UPE 120 с наклон 4% навън. Пълнежът между стълбовете е от затворени профили TR 50×40×3, или TR 40x20x3.





Фиг. 62 Детайл от края на монтажната част на парапета
Фиг. 63 Парапети в черно състояние като доставка

Тази стоманена част е изцяло херметически заварена, с цел предотвратяване навлизането на влага в затворените профили. Монтажната болтова връзка на ръкохватката е решена с помощта на специална втулка. Ръкохватката е с затворени крайща от двата си края с планки. По време на производството приеманията в цеха се извършват в черно състояние, фиг. 63 и фиг. 64, а след изпълнението им следва направата на РКО от четирислойно покритие с обща дебелина 360 μm.







Фиг. 64 Парапети с грунд за приемане
Фиг. 65 Детайл на свързване на парапета към корнизната греда
Фиг. 66 Детайл на монтажната връзка - контакт

Парапетът е монтиран към корнизната греда при монтажа, фиг. 65. Между основната плоча на стълба на парапета и горния фланц на корнизната греда е поставена пластмасова вложка с дебелина 4 mm, изработена от UV-устойчив материал. Вложката прави възможно изравняването на наклона на стойката на парапета, така че надлъжната линия на парапета да е в права линия. Монтажът се извършва на етапи, при което ръкохватката на всяка нова част се вкарва във втулката, монтирана в предходната част на ръкохватката. Възможна е надлъжна дилатация в мястото на

всяка монтажна фуга, фиг. 66. За парапета са използвани общо 65 t стомана S235 J0, фиг. 67 и фиг. 68.





фиг. 67 Сглобен парапет
фиг. 68 Преход на парапета от моста към опората

### 8.3.3 Подпори

Както бе упоменато по-горе, в резултат на дълготрайно водо-изтичане през пропускливите мостови фуги настъпват постоянни процеси на деградация на горната част на опорите, т.е. в опорните прагове, затварящи стени и камери в горната част на корпуса на опорите. Проявление на наблюдаваната деградация бе наблюдаваното значително просмукване на вода, придружено с появата на значителни локви по повърхността на бетона. В DZS се наложи премахване на цялата горна част на опорите и подмяната им с нова конструкция, съобразно изискванията за поставяне на нови преходни фуги на моста. Горните части на крилата също бяха част от реконструкцията. Първо, земната маса зад подпорите е изкопана на дължина от около 6,0 m и на дълбочина от около 5,7 m. Изкопът е извършен по цялата ширина между съществуващите крила. Основните греди на мостовата настилка бяха поддържани от временни подпори, изработени от материал PIŽMO, които бяха поставени близо до лицето на опорите върху равнината на панела, фиг. 69. Главните греди са повдигнати с помощта на хидравлични преси с цел да се разхлабят лагерите върху опорите и да се отстранят. Действителната височина на повдигане е определена от проектанта. Стеблата на главните греди над пресите са укрепени с добавени вертикални ребра. След демонтирането на оригиналните мостови фуги, горната част на опората е разрушена до нивото на пода на камерата в опората. Разрушена е и горната част на крилата, фиг. 70. По време на разрушаването стана ясно, че качеството на бетона, използван за подпорите и крилата, е по-лошо, на места значително променливо, отколкото предполага проектната документация. Поради това беше необходимо да се увеличи обемът на дейностите по разрушаване.







Фиг. 69 Поддържане на главните греди на мостовата плоча
Фиг.70 Разрушено крило при опората на десния борд
Фиг. 71 Дюбели по опората и по крилатаю

Разрушената повърхност е почистена с вода под налягане и са пробити дупки за укрепване на закотвящата армировка. Дюбелите от армировъчна стомана с диаметър ø 12 mm са от стомана B500B и са залепени с помощта на лепилната система Hilty HIT-RE 500. Същите са подредени в няколко реда на разстояние 250 – 500 mm по целия периметър на лявата част на опорите или крилата, фиг. 71. Фугата получена от разликата в нивата между новото и съществуващото строителство е узаконена от приемателната комисия.Формата на новата част на опората, особено позицията и формата на главата на крайната стена, е направена по такъв начин, че да позволи плавен преход от опората към носещата конструкция на моста, използвайки новата мостова фуга. Горната част на опорите и крилата е направена от бетон C30/37-XF4 с армировка B500B, фиг. 72. Кухината вече не се реализира в новата част на опорите. Дренажът е отведен към задната част на опората през стеблото на опората. Върху горната повърхност на опорния праг са изготвени опорни блокове за монтиране на ремонтираните лагери под главните греди на мостовата плоча, фиг. 73.





Фиг.72 Кофраж и армировка на опора и крила
Фиг.73 След отстраняване на кофража

**Санирането на опорите** се състои от рехабилитация на обратната им страна и пълна рехабилитация на бетонната повърхност в лицето на оригиналните части на опорите. В зоната на прехода е изкопана почвата до нивото на съборената част на подпорите, т.е. около 5,7 m. Обратната страна на опорите и крилата е снабдена с асфалтово изолационно покритие 1 × ALP и 2 × ALN. Изолационният слой е защитен с геотекстил. Всички работни фуги са снабдени с дълбоко проникващо изолационно покритие придружено с дълбоко просмукана изолационна лента. Крайната стена е снабдена от обратната си страна с допълнително изолационно покритие. На повърхността на почвата след изкопаването и е направена бетонна плоча и върху нея е положен PE филм, вижте ал. 8.3.4, който отвежда просмукващата се вода към дренажната тръба DN 150, преминаваща през шахтата на опората. Въпреки това в почвата под фолиото се появява влага, която прониква в оригиналната запазена част на подпората. Затова в шахтата на опората са направени дренажни кладенци на две височинни нива. Във всеки ред са направени по 10 кладенчета. Тръба от неръждаема стомана DN 50 беше монтирана в края на сондажа, за да се предотврати стичането на вода по лицето на опората. Бетонът на останалите оригинални части на подпорите беше изцяло покрит с мазилка, фиг. 74 и фиг. 75. Тази мазилка беше отстранена и

бетонната повърхност беше изчистена с вода под налягане. Основите на подпорите бяха изложени на дълбочина от около 0,5 m под нивото на земята. Бетонната повърхност на оригиналните части на подпорите бе рехабилитирана с тънкослойна

санация, както и повърхността на пилоните - виж пар. 8.3.13. Освен това е извършен ремонт на фугите на каменната облицовка на откосите под крилата, фиг. 76.





Фиг. 74 Отлепване на мазилката от лицето на опората
Фиг. 75 Оригинален дренажен отвор
Фиг. 76 Ремонт на фугите в облицовката на наклона на крилото

### 8.3.4 Преходни зони

Преходната зона представлява изкопната зона за изграждане на новата горна част на опората, виж пар. 8.3.3. На дъното на изкопа е направен подложният бетон на дренажа и върху него е положено уплътнително PE фолио с наклон 5%. По дължина на подпората и по крилата са положени дренажни тръби, които бяха свързани по оста на подпората към тръба DN 150, минаваща през стеблото на подпората и отвеждаща цялата вода от преходната зона. Дренажните тръби са бетонирани с дренажен бетон, други части са покрити с натрошен рециклиран материал. Защитен пълнеж зад гърба на опората и по протежение на крилата на ширина мин. 0,6 m е направен от трошен камък фракция 0/32. Защитният обратен насип бе наслоен с максимална тежест от 0,3 m едновременно със слоевете обратен насип и непрекъснато уплътнен с машина. В горната част на преходната зона се създава преходен клин от междинен бетон с дебелина 1,0 m зад опората и издигане с дебелина 0,5 m в края на преходната зона, фиг. 77.





Фиг. 77 Преходен клин от междинен бетон
Фиг. 78 Крайно състояние на преходната зона
Фиг. 79 Лагер на опора в оригинално състояние

Отводняването на пътното платно зад упорите се извършва с два водостока, разположени до бордюра, непосредствено преди мостовата фуга. Водата от тези водостоци се отвежда през надлъжен канал в две шахти, които са в края на крилата. Водата от шахтите се извежда под основата на крилото в улея на предната площадка.

Това решение гарантира, че само минимално количество вода ще бъде прехвърлено през мостовата фуга при двете подпори, фиг. 78.

### 8.3.5 Лагери на опори

Върху двете опори са монтирани по два лагера под главните греди на мостовата плоча. Те представляват цилиндрични лагери, движещи се в една посока, които осигуряват дилатацията на фиксираната точка от основните греди на мостовата плоча, която е в горната част на арката, и пренася вертикалната реакция от съседната част на главните греди към опората. Действителната дилатация в лагера е ± 75 mm, фиг. 79. Според DZS е било необходимо лагерите да се демонтират и в зависимост от действителното им състояние да се извърши основен ремонт или да се заменят с нови такива. Както вече бе упоменато, под двете основни греди и на двете опори са изградени временни опори от скеле на PIŽMO. Оста на временните подпори бе на разстояние около 2,0 m от лицето на мостовите опори. С помощта на хидравлични преси двете главни греди се повдигат координирано, така че лагерите да могат да бъдат отстранени. Максимално допустимата сила и вертикален ход за повдигане се определят от проектанта. След отстраняване на лагерите, основните греди на мостовата плоча се спускат надолу в процеса на изграждането на временните опори върху друга временна опора с плъзгащ лагер. Стеблата на главните греди на мястото на временната опора са стабилизирани отвън със заварени ребра. След свалянето на лагерите се установява, че състоянието им е доста добро и лагерите могат да бъдат ремонтирани. Всеки лагер се състои от горна лагерна плоча, цилиндър, фиг. 80, а от долната носеща плоча фиг. 81. И в двете плочи имат водачи, които влизат в жлеба на цилиндъра. От двете страни на цилиндъра има зъби, които влизат в гребен разположен отстрани на лагерните плочи. Предмет на основния ремонт беше леко престъргване на контактните повърхности на двете плочи. Цилиндрите са само почистени. Отделните елементи на лагерите бяха с нанесена с PKO. Върху контактните повърхности на плочите и цилиндъра не е нанесено PKO. Долната повърхност на долния фланш на основната греда на мостовата плоча на мястото на опорната повърхност на горната носеща плоча на лагера беше механично почистена до необходимата чистота.





Фиг. 80 Цилиндъра преди ремонт
Фиг. 81 Долни носещи плочи преди ремонт
Фиг. 82 Лагер след рехабилитация

Към долната носеща плоча на лагера са заварени 5 дюбела с ø 19 mm и дължина 100 mm. Долната носеща плоча на лагера се монтира в отворите за дюбелите в подложния блок на необходимата височина. Дебелината на подливката е 40 mm. За подливката се използва материалът PCI Repaflow от производителя BASF „Строителни материали“, ČR s.r.o. Горната носеща плоча на лагера бе прикрепена с

високоякостни болтове към долния фланш на главната греда на мостовата плоча. Цилиндричното тяло на лагера бе монтирано преди пускането на конструкцията в крайната и позиция, с настройка в зависимост от температурата на мостовата конструкция в момента на активиране. Монтираният цилиндър и опорните

повърхности на плочите са покрити с графитен вазелин преди спускането му, фиг. 82. За спускане на основните греди върху лагерите проектантът определя максималните и минималните сили в пресите. Максималната сила остава същата както при повдигане. Минималната сила трябва да гарантира, че основната греда не е поставена твърде ниско, което може да предизвика напрежение на опън върху комбинираната стомано-стоманобетонна пътна на моста. Спускането на носещата конструкция е синхронизирано в двете основни греди на мостовата плоча при непрекъснат контрол на наляганията в пресите.

### 8.3.6 Крайни напречни греди

Съществуващите крайни напречни греди трябваше да бъдат структурно модифицирани за анкерирането на новите преходни фуги на моста. След отстраняването на първоначалните мостови фуги става ясно, че повърхността на крайните напречни греди, в съседство на оригиналните преходни фуги на моста, са силно засегнати от корозия, фиг. 83, фиг. 84 и фиг. 85. Бе установено, че в обратната, страната на моста, почти липсва корозия. Премахнати са ребрата в горната част на напречната стена. Стената, двата пояса и ребрата в долната част на стената са песъкоструени и консервирани. След като се установи, че стоманата, използвана за крайните напречни греди, е подходяща за заваряване, към стената на напречната греда под опората на бъдещия мост е заварена мощна конзола с размер 665 mm. Тази конзола бе укрепена от нови вертикални ребра, снабдени със съответните заваръчни съединения, фиг. 86 и фиг. 87. От вътрешната страна на напречната греда, която лежи върху долния фланш на надлъжните греди (Те са единствено само в първия участък на мостовата плоча на моста - Žďákov), е монтирана по - малка конзола. След монтажа на крайната преходна фуга на моста, същата се бетонира в анкерен блок с размери 650 × 750 mm, който е свързан към стоманеното напречно сечение на напречна греда, и същевременно силно армиран, фиг. 88 и фиг. 89. Така възниква достатъчно корав елемент, който може да устои на въртящия момент от ексцентрично действащия товар от мостовата, затваряща се преходна фуга. Статичното поведение беше проверено върху модел на плоча на стена, включващ крайната напречна греда, първата вътрешна напречна греда и надлъжните греди в първото поле на моста. Бяха анализирирани вътрешните усилия и оразмерени свързващите дюбели в детайла. В критичните точки на подсилената напречна греда бяха установени възникналите напрежения. РКО се извършва с четирислойно покритие от системата Hempel с обща дебелина 360 μm.





Фиг. 83 Изглед на крайната напречна греда
Фиг. 84 Детайл от крайната напречна греда над опора на левия бряг

Фиг. 85 Детайл на крайната напречна греда над опората на десния бряг.

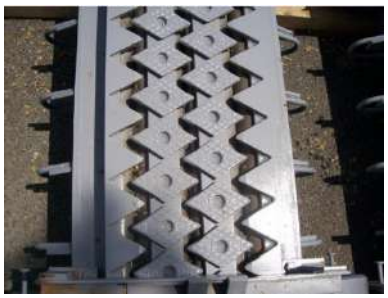





Фиг. 86 Поставяне на нови ребра
Фиг. 87 Крайна напречна греда след ремонт
Фиг. 88 Модификация на горния фланш на крайната напречна греда
Фиг. 89 Регулиране на армировката на затварящите стени и на крайната напречна греда

### 8.3.7 Мостови фуги

Новата мостова фуга представлява многоламелна водоустойчива конструкциа изпълнена в безшумна версия за приложение. Това е заключението на компанията Maurer AG Мюнхен, фиг. 90 и фиг. 91. Доставчикът е Cirmon s.r.o., който е сертифициран за пазара на Чешката република. Използвани са едни и същи затвори XL 300 и за двете опори, които отговарят на изискванията за корозионна агресивност на средата С4 и експлоатационен живот от 30 години. Уплътнението на фугите на затворите се осигурява от гумени хлорпренови ленти. Мостовите затвори са изпълнени като индивидуална конструкция по проектно изискване. На приемането на конструкцията в черен вид, присъстваха представители на инвеститора и клиента. Мостовите преходни фуги са доставени на строителната площадка с РКО.

Фиг. 90 Мостови фуги Maurer
Фиг. 91 Подробности за модификацията при тиха версия на изпълнение

Монтажът на преходните фуги на моста е извършен от Cirmon s.r.o. Ширината на мостовата фуга е определена в зависимост от средната актуална температура на главната носеща конструкция на моста, фиг. 92. След като височината и посоката на фугата бяха регулирани, същата бе заварена в определените за тази цел джобове с армировката, стърчаща от бетонния блок на крайната напречна греда и крайната стена на опората, Фиг. 93 и фиг. 94. В този момент монтажните скоби се освобождават и бе проведено геодезическо замерване. Най-накрая на изпълнението бе извършено бетониране в зоните за закотвянете на преходните фуги, фиг. 95 и фиг. 96.





Фиг. 92 Настройване ширината на преходната фуга на моста
Фиг. 93 Монтиране на преходната фуга на моста
Фиг. 94 Заваряване на преходната фуга на моста към армировката на крайната напречна греда




Фиг. 95 Преходна фуга на моста след бетониране
Фиг. 96 Изглед отдолу на преходната фуга на моста

По време на реконструкцията на моста на Žďákov ширината на двете преходни фуги на моста от лявата и дясната страна на пътя бе измерена на равномерни интервали, фиг. 97. По този начин беше демонстрирана правилната функция на мостовите фуги в зависимост от температурата на конструкцията на моста.




Фиг. 97 Изглед на монтирана преходна фугата на моста
Фиг. 98 Изглед на лагера върху  пилона

### 8.3.8 Лагери на пилони

В двата опорни ст.бет пилона са поставени под всяка главна греда на мостовата плоча, единични цилиндрични лагери, които прехвърлят вертикалните реакции от мостовата греда към ст.бет.пилон. Тези лагери са в перфектно състояние, дори след 50 години експлоатациа , фиг. 98. Поради това е извършено само тяхното почистване

и консервация с графитна замазка. Гредата на моста се подпира освен това и върху пилоните в напречно хоризонтално направление. Гредата може да се върти в хоризонталната равнина около вертикалните болтове поради натоварването от вятъра, фиг. 99 и фиг. 100. Мощната дюбелна конструкция е в перфектно състояние преди реконструкцията, и поради тази причина бе песъкоструена и снабдена с нова РКО.





Фиг. 99 Лагер върху пилона преди рехабилитация
Фиг. 100 Лагер върху пилона след рехабилитация

**8.3.9 Дъгови конструкции**

Основната носеща конструкция на моста Žďákov представляват две стоманени дъгови конструкции, обединени в пространството с ПВВ. Дъгите са изпълнени с кутиеобразни напречни сечения, които са проходими. По долния и горен пояс, дъгите са укрепени със съответните надлъжни, стабилитетни ПВВ и така също и с вертикални ПВВ разположени в радиалните равнини на дъгите. Стоманените дъги, включително усилващите елементи, са в перфектно състояние почти 50 години след пускането им в експлоатация. Същото важи и за петите на сводовите греди. Локално появяващата се корозия по дъгите е само повърхностна, без никакви загуби от корозия и тя е отстранена по време на цялостното възстановяване на РКО. За да не може водата да остане в някои от свързващите пръти с кутиеобразни сечения на ПВВ, същите са пробити. Друг проблем е гнезденето на птици в някои възли на моста. Това беше предотвратено чрез монтиране на мрежи от РЕ материал, които бяха опънати с кабели от неръждаема стомана и закрепени към стоманената конструкция със скоби.

**8.3.10 Антикорозионна защита**

Подновяването на антикорозионната защита (РКО) на всички стоманени елементи бе една от основните причини за реконструкцията на моста Žďákov. Подновяването на РКО беше извършено на всички стоманени елементи на моста Žďákov, т.е. върху външните повърхности на гредите на дъгата, включително техните усилващи елементи, върху стойките, върху главните греди на мостовата пътна плоча и върху напречните елементи. РКО на вътрешните повърхности на дъгите не беше предмет на реконструкцията на моста Žďákov. Сегашното състояние на РКО е задоволително и стабилно в дългосрочен план. РКО възстановяването на вътрешните повърхности на арките ще бъде извършено отделно през следващите години. Въз основа на корозионно изследване [25] бе предложено цялостно възстановяване на

антикорозионната защита [40], което се състои в премахване на оригиналната РКО и направа на ново четирислойно покритие: ТКР 19В "Антикорозионна защита на стоманени мостове и конструкции" предписва РКО само за нови конструкции, поради което подновяването на РКО не се разглежда тук. Поради това беше

изготвена оценка на предложената система за покритие за възстановяване на моста РКО - Žďákov, която беше изготвена от компанията SVÚOM Praha s.r.o. Оценката, включваща влиянието на хлоридите от пътната сол при зимно поддържане, определя степента на корозионна агресивност С2. Четирислойна покривна система с предварително бластиране до ниво на чистота Sa 2½ е проектирана в състава:
Hempadur Mastic 45880/19870 100 μm ; Hempadur Mastic 45880/12430 100 μm; Hempadur Mastic 45880/19870 100 μm;
Hempathane HS 55610/RAL 7000 60 μm; Обща дебелина 360 μm
Предложената система бе подложена на ускорени лабораторни тестове с положителен резултат и по този начин бе изпълнена основната законодателна предпоставка за използването на тази система при възстановяването на РКО на моста Žďákov. От гледна точка на осигуряване на достатъчен бариерен ефект предлаганата система е много ефективна. Сух абразив бе избран за използване, поради необходимостта да се улови отстраненият материал над нивото на водата на Orlická Prehrady. За този случай на бластиране, Hempadur Mastic 45880 притежава достатъчна защитна ефективност в цялата покривна система. Общата дебелина отговаря на изискванията на ТКР 19В. Срокът на експлоатация на системата за покритие е 20 години. Службата за национални паметници определи цветовете по RAL за отделните стоманени елементи на моста Žďák, както следва:
жълто 1005 – за стълбове и пълнежни пръти за парапети;
син 5003 – за парапети, корнизи и стойки;
сив 7004 – за други конструкции (арка, лагери, стави, укрепване на свода, главни греди и напречни греди на мостовата плоча);
На фиг. 101 до 107 е показан пример за новия вариант в цветове на РКО върху отделни конструктивни елементи на моста.





Фиг. 101 Дъги, ПВВ по горен и долен пояс и вертикални тръбни колони(ТК)
Фиг. 102 Детайл на свързване на ТК в горния си край
Фиг. 103 Укрепване между дъгите




Фиг. 104 Горен пояс на дъгата и свързване на прътите от ПВВ
Фиг. 105 Дъги и укрепване на дъгите близо до върха





Фиг. 106 Напречни греди и греда за ревизионна количка
Фиг. 107 Мостова плоча в мястото на подпирането върху пилона

Изпълнител на РКО на моста на Žďákov бе компанията Proficolor s.r.o. РКО на корнизни греди и парапети беше част от доставката на тези конструкции, която беше извършена от фирма OK-BE spol. s.r.o. За да се потвърди правилността на избраната процедура за бластиране и процедурата за нанасяне на системата за покритие, бяха извършени тестове върху референтни повърхности. В същото време беше изследвано влиянието на метода на бластиране: бластиране с пясък, вода или вода, последвано от пясъкоструене. За изпитване бяха определени 4 позиции на референтни повърхности върху стоманената конструкция на моста: вътрешната страна на стеблото на главната греда на мостовата плоча близо до опората; външната страна на стеблото на главната греда на мостовата плоча близо до опората; стойка монтирана върху терена; горния пояс на кутиеобразното напречно сечение на дъгата близо до опорния лагер. Бяха проведени тестове върху всяка референтна повърхност и за трите метода на бластиране: пясъкоструене при Sa 2½, водно почистване при Wa 2½ и пясъкоструене при Wa 2½ с свръхбластиране при Sa 2½. Същата система на покритие, описана по-горе, беше нанесена върху всички повърхности. Тестовете за отстраняване на покритията след периода на стареене на системата показаха желаното качество на системата за покритие и потвърдиха, че пясъкоструенето е подходящо. Технологичният регламент за възстановяване на стоманената конструкция РКО на моста Žďákov е изготвен от изпълнителя - компанията Proficolor s.r.o. Част от TePř е осигуряването на достъп до стоманената конструкция. За работата по дъгата е използвано скеле, висящ кош върху стойките, за външната страна на главната греда на мостовата плоча, висяща пасарелка на автокран и за напречните греди и за вътрешната страна на главната греда, мобилен ревизионен мост Контролът върху изпълнението на РКО бе непрекъснато осигурен от двама инженери, специалисти по корозия: за TDS Ing. Petr Matoušek и за надзора на Ing. Ярослав Корбеларж. Те редовно представяха отчети за измерване на грапавостта на повърхността след бластиране и измерване на дебелината на отделните слоеве на системата по всички части на стоманената конструкция. За ремонт бяха определени недопустими дебелини. Те също така провериха ефективността на тестовете за откъсване на референтните повърхности. Всички констатации при проверките са записвани в дневника за бояджийските работи. Същият контрол върху РКО е извършен и при изработката на корнизната греда и парапета.

### 8.3.11 Отводняване на моста

Пътната настилка е с напречен наклон 2% и водата от пътната настилка се насочва към бордюрите в надлъжен канал и в чугунени отводнители, покрити с решетки. Оригиналните чугунени дренажи бяха в добро състояние и бяха използвани повторно, фиг. 108. Водата от повърхността на изолацията на мостовата плоча се

стича в коритото между дренажите. Между водостоците има надлъжно дренажно ребро от пласт-бетон в пътното платно, което отвежда водата в надлъжна посока към водостоците. Тъй като надлъжният наклон на пътя на моста е минимален, между водостоците допълнително се поставят дренажни изолационни тръби. Водата от дренажите и дренажните тръби се свързва към надлъжния дренаж чрез фиксирани вертикални тръби. Надлъжните водосточни тръби се изкарват до пилоните и вкарват във вертикални водосточни тръби, разположени на вътрешния ръб на пилоните и се заустват в съществуваща водоспускателна тръба в тялото на пилоните.



Фиг. 108 Отводняване в пътното платно

Надлъжното отводняване от подпорите към пилоните е с наклон 0,7%, а от върха на дъгата до пилоните е с наклон 0,5%. Това са минималните наклони, които могат да се използват, като се приеме редовно почистване два пъти годишно. Под напречните греди на мостовата плоча се поставят надлъжни водосточни тръби. В горната част на свода те са точно под долния фланш на напречната греда, при пилоните долният ръб на надлъжния дренаж е на 1,2 m под долния ръб на главната греда на стоманобетонната плоча на моста. Материалте, използвани за тръбния дренаж на моста на Žďákov, са както следва:
надлъжни водосточни тръби: стъкло-ламинатови GRF тръби с профил DN 200 до 350 mm; вертикална свързваща тръба за водостоци: тръба от неръждаема стомана DN 150 mm ; изолационни дренажни тръби: тръба от неръждаема стомана DN 50 mm;
вертикална водоспускателна тръба вътре в пилона: стъкло-ламинатови GRF тръби с профил DN 400 mm;

### 8.3.12 Пети на дъгите и конзоли

През 2015 г. имаше екстремна суша и нивото в язовир Orlická беше с около 12 m по-ниско. Петите на дъгите и конзолите под ставните устройства, които при нормални условия са под водата, в този случай са над повърхността. Извършен е ремонт на повредените участъци на петите на пилона и конзолите под лагера на дъгата. Местните зони бяха разчистени от повредения бетон а откритите части на армировката бяха обработени с инхибитор на корозията. Санирането е извършено с изравнителна смес от еднокомпонентната смес Redpatch 1 в дебелина мин. 40 mm. На мястото на фугите е отстранен бетон и фугата е почистена с цел, поставянето и на необходимата дълбочина. За вграждане и на дълбочина до 0,6 m е използвана GoeLite 10, което представлява бързо-втвърдяваща еднокомпонентна смес. Повърхността на фугата е снабдена с фугираща смес на циментова основа, фиг. 109.



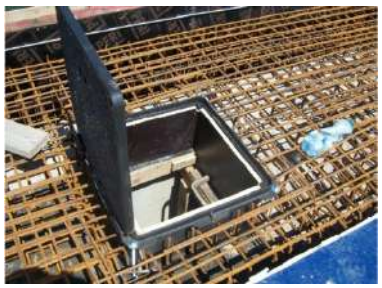

Фиг. 109 Рехабилитация на конзолата
Фиг. 110 Защитна стена в подножието на дъгите

Освен това е санирана сравнително голяма кухина под защитната стена в подножието на дъгата на левия бряг. Кухината бе запълнена с бетон, фиг. 110. Дългосрочното съмнение за алкално-силикатно разпадане (ASR) на бетон, изложен на дълготрайно излагане на вода, по отношение на основите на пилоните и долната част на конзолите, не е доказано. Пробити са сондажи и са взети проби за лабораторно изследване. Опасността от ASR ще продължи да се следи в дългосрочен план.

### 8.3.13 Пилони

**Платформи и глави на пилони**

Оригиналните площадки на главите на пилоните, които оформяха тавана над входовете на пилоните, бяха силно деградирани и затова са отстранени, фиг. 111, и заменени с нова стоманобетонна конструкция, анкерирана с дюбели към пилоните, фиг. 112 и фиг. 113.


Фиг. 111 Разрушаване на главата на пилона
Фиг. 112 Армировка за новата площадка включително входа на пилона
Фиг. 113 Площадка над пилона

**Корпус на пилона**

За разлика от DZS, където се предвиждаше бетониране на цялата повърхност на шахтите на пилоните с дебелина от 100 до 150 mm, беше извършена тънкослойна санация на шахтите на пилоните. Целта на санирането беше да се увеличи покритието на армировката на бетонните заготовки на изгубения кофраж, като се използва пълна антикарбонизираща и хидроизолационна замазка. На всеки пилон е

монтирано скеле за рехабилитация, фиг. 114. Разрушеният бетон е разбит с леки чукове за разрушаване, разкрити са корозирали части от армировката. Бетонът е продухван по цялата площ с водна струя под налягане 2000 бара, фиг. 115. Свързващият материал между сглобяемите части е отстранен до такава дълбочина,

че е възможно да се уплътни фугата. Ширината на фугата беше от 10 до 40 mm. Корозиралата носеща армировка се отрязва с шлайф. Впоследствие е извършено локално репрофилиране на места след изкъртения бетон. Около санирания участък са поставени рамки с дебелина на дъските от 6 до 12 mm. Пространството между рамките беше запълнено с хоросан MonoTop-412NFG в един слой. След като материалът се влоши, дървените рамки бяха премахнати. Това създаде т.нар. покрития, от 6 до 12 mm над нивото на оригиналното лице на бетона, фиг. 116. Краищата на ръбовете на покритията бяха регулирани на ръка в плавен преход. Останалите зони, които не са били локално санирани, бяха импрегнирани с повърхностно нанесен инхибитор на корозията на армировката Sika Ferrogard-903+, нанесен в два до три слоя. Това забавя началото на корозията и разрушаването на повърхностните слоеве през следващите години. Върху фугата между сглобяемите части се полага уплътнителна ивица от чакъл и се поставя уплътнително PE въже. Впоследствие уплътнителят Sika Hyflex-250Facade се вкара във фугите с помощта на пистолет. Шпакловката се заглажда на повърхността на ръка. По този начин бяха допуснати фугите между сглобяемите части.



фиг. 114 Скеле около пилона



Фиг. 115 Повърхността на пилона след разрушаване на некохезионния бетон



фиг. 116 Покрития

### 8.3.14 Пети под стойките

Под тръбните колони, подпиращи главните греди на мостовата плоча извън моста се изпълнени бетонни основи, фиг. 117. Обектът на рехабилитацията на тези фундаменти беше цялостно бластиране и разрушаване на дефектиралия бетон с леки пневматични чукове. Разкритата и оголена армировка е обработена с инхибитор за корозията. Неравностите са изравнени с еднокомпонентна смес Redpatch 1 в дебелина от 5 до 40 mm, фиг. 117. На места с по-голяма дебелина са направени междинни сондажи.



Фиг. 117 Пета на стойката

**8.4 Производствени срещи и дни за проверка**

По време на цялата реконструкция се провеждат редовни технически срещи и контролни дни, в които участваха представители на изпълнителя, инвеститора, проектанта и надзора. Основната тема на срещата бе уточняване и допълване на техническата подготовка, проверка на всички документи и проверка на изпълнението на графика. Преговорите се водеха на строителната площадка. Участниците в срещата редовно инспектираха строителната площадка. За всички срещи се водят протоколи. Въз основа на поръчката на ŘSD CR бе сключен договор за извършване на независим контрол на качеството и надзор по време на реконструкцията на моста Žďákov между ŘSD CR и Факултета по строително инженерство на Чешкия технически университет в Прага. Надзорът се проведе по време на реконструкцията на моста Žďákov. А именно надзорът беше осигурен от:
Доц. инж. Томаш Ротер, CSc. – за стоманени конструкции
Доц. инж. Владислав Хрдоушек, CSc. – за бетонни конструкции
инж. Ярослав Корбеларж – за PKO .

**8.5 Резултат**

Реконструкцията на моста Žďákov между 2015 г. и 2017 г. постигна поставената цел: „Извършване на такива ремонти на моста, които да гарантират безопасността на движението и да елиминират началните процеси на деградация на отделни елементи на конструкцията, които биха могли да доведат до намаляване на товароносимостта на моста в близко бъдеще." Тази цел беше напълно постигната. Приемането на моста Žďákov след завършване на реконструкцията му се състоя на 30 септември 2017 г. От реконструкцията на моста Žďákov бе натрупан сериозен опит, който би могъл да се използва и за други реконструкции на големи мостове. На първо място, трябва да се има предвид, че дори и най-задълбочената диагностика не е в състояние да разкрие реалното състояние на мостовата конструкция. Трябва да се разчита предварително на полагането на повече работа, но и с изискването за полагане при възможност и на по-малко работа. Това води до препоръка за търсене на нови законодателни мерки, които поне донякъде да премахнат тромавостта на договарянето на промени по време на строителството.

**9 Заключение**

Žďákovský most е част от важния път I/19, който осигурява връзката между Пилзен и Табор. Неговата транспортна функция е важна и затова бе редно да се извърши реконструкцията му. След завършване на реконструкцията е напълно оправдано предположението, че мостът Žďákov ще бъде безопасен и надежден за няколко

десетилетия напред. Конструкцията на моста е перфектна от техническа гледна точка и е доказателство за инженерното майсторство на чешките мостостроители в средата на миналия век. Следователно наше задължение е да се грижим правилно за такова произведение и да го поддържаме внимателно. Мостът Žďákov също се откроява със своята архитектура. Той е много чувствително вграден в пейзажа, а отраженията му във водната повърхност на язовир Orlická са незабравимо преживяване, фиг. 118



Фиг. 118 Изглед към моста

Край на трета –последна част:

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# CAKIRAGA KONAGI, IN BIRGI/ ODEMIS/ IZMIR/ TURKIYE, A SMALL BOUTIQUE HOTEL IN PAST, 300 YEARS AGO, HAVING SIMILARITIES WITH RILA MONASTERY, IN BULGARIA

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***Abstract**: In Turkiye, in Izmir, there are 30 special districts, to have characteristic settlements and Odemis is one of these 30 special places, has a neighbourhood, called Birgi, 10km far from Odemis.*
*In Birgi, there is a characteristic village textures, composed by wooden frame houses. Some of them are having one storey,some of them two storeys and some of them more storeys.*
*Cakiraga Konagi , Fig. 1., is a large house, having three storeys in height. First floor is constructed with stone, and the upper 2 floors are built in timber frame. In fact, in the courtyard, there are wooden columns to carry the loads of three storeys height.*
*In the paper, the structural characteristics of these large house, will be defined together with its unique architectural plan, as a very important landmark, having a life time for more than 300 years. Also the similarities with Rila Monastery will be discussed in the paper to understand the function of the building better.*

***Key words**: Cakiraga Konagi/ Birgi/ Turkiye, wooden frame building, Rila Monastery/ Bulgaria*



Fig. 1. The view of Cakiraga Konagi from the courtyard (photo taken by Y. K. Aktuglu on 25.08.2024)

## 1. Introduction –

The Cakiraga Konagi is has a typical Turkish House architectural planning solution [1], [2], [3], [4], [5] . There are rooms, connected with each other through an open space, where everybody meets at each floor. Mostly, there are bath tubes inside the closets, inside the rooms. They have large eaves to protect the body of the building from sun and also rain. There are also some closed spaces, in cantilevered position on the frontal facades of the buildings. These are called as "Cumba" or "Cikma" in Turkish Architecture Literature, Fig. 2. . The facade of the open spaces towards courtyard, have stairs in wooden contruction, while the Cakiraga Konagi is constructed in 3 storeys, ground floor is built as a masonry construction with stone, and the next two upper floors are having wooden framing system to carry the loads and to transfer the loads to the foundations Fig. 3..



Fig. 2. The view of Cakiraga Konagi from the courtyard with eaves (photo taken by Y. K. Aktuglu on 25.08.2024)



Fig. 3. The outer frontal view of Cakiraga Konagi with three Cikma from the building (photo taken by Y. K. Aktuglu on 25.08.2020)

The Rila Monastery has more floors as totally four floors [6]. From the courtyard, both buildings are having similar facades with stairs on the facades towards courtyard, Fig.

4. .It is clear that there should be a familiar architectural approach, while designing such kind of buildings, both Turkish and Bulgarian.

For the building in Rila Mountain, is called a monastery, it could be thought that the Cakiraga Konagi, may be thought as a monastery 300 houndreds year ago. Or because of the bath tubes in the closets in the rooms, could give a service as a boutique hotel today and as a Kervansaray at that time, where the trademen came here and stopped for a night or more.

The reason for this idea is that there are iron railing in the windows, esp the ones who are towards the open meeting space at the floors, that connects the rooms naturally, and after restoration, those railings are constructed in wood, Fig. 5. .



Fig. 4. The view of Rila Monastery towards courtyard
( https://www.travelsewhere.net/seven-rila-lakes-rila-monastery/ 08.12.2024)



Fig. 5. The inner view of a suit room with bath tube in the closet at the right side and having railings on the windows towards open meeting space (photo taken by Y. K. Aktuglu on 26.08.2023)

## 2. Structural Details –

The Cakiraga Konagi is a legend about masonry structure and wooden structure of a building. Due to its long past, for 300 years, the building is still standing up with its real function, today as a museum. The perimeter outer wall for ground floor and first floor are constructed in masonry with stone and the outer wall at second floor is constructed with wooden structure. There are fireplaces in every room for heating. There are extra windows over main windows to get daylight in, while the window covers, both inner facade towards

open meeting space and outer facade are closed. Also the security as iron railings over windows for the inner spaces are more than outer windows. The construction of the stairs, from first floor to second floor has a very important structural detail, not only the construction of the stairs, but also the support of the upper floor with the wooden columns over the wooden beams of the stairs. And the balcony, cantilevered after the columns with diagonals between columns and the slab of the balcony, at first floor, supporting the upper balcony at second floor, cantilevered more than the other one downstairs. Also it has long eaves, Fig. 1. , Fig. 6. .



Fig. 6. The inner view of a suit room with bath tube in the closet at the right side and having railings on the windows towards open meeting space (photo taken by Y. K. Aktuglu on 25.08.2024)

**3. Conclusion**

As a conclusion, it could be said that from the point of courtyard views of Cakiraga Konagi and Rila Monastery may have architectural design similarities, Fig.7. . The balconies over and over, esp in Cakiraga Konagi has a very special design, after two columns over the ground, the other floors are in cantilevered positions, supported by bracings, from two wooden columns at ground level over a stone capital as single foundations over the slab on earth. In Rila Monastery, there are more floors, but the last floor has similarities with Cakiraga Konagi and also its balcony planning, supported by bracings from the columns, has the other similarities. Through the most important unique design of the rooms with fireplaces and also closets, having bath place, may cal us that in past Cakiraga Konagi could serve as a small boutique hotel, we call is Kervansaray in past. Or there may be another thought that Cakiraga Konagi may be a kind of monastery in past. There were some ruins as church, with a single story, nearby the Cakiraga Konagi, now under the foundation of a new house, built some years ago. These thoughts arrived due to the protections over the windows towards the inner space, connecting the rooms, composing the courtyard. And also not only there are solid covers over the windows on the outer walls but also there are solid covers over the windows on the inner walls, separating the rooms from the open spaces, looking to the courtyard.

In the paper, these important points are wanted to be underlined to start a new discussion or a new research to learn the connection between Cakiraga Konagi and Rila Monastery in past [1], [2], [3], [4], [5], [6] .



Fig. 7. The view of the building towards courtyard (photo taken by Y. K. Aktuglu on 25.08.2024)

**Acknowledgement**

I want to thank to Prof. Doncho Partov, that he made us visit Rila Monastery, in 2012.

I want to thank to my colleagues and friends, architect Arda Filibelioglu in 2021, engineer Servet Balcioglu in 2022, neighborhood Zeynep Aksoy in 2024, and myself in several times, that we made visits to Birgi, and Cakiraga Konagi several times together. With their partnership, the visits became more important.

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[6] Technical visit to Rila Monastery, in 2012, with Prof. Doncho Partov

# REVITALIZING A 120-YEAR-OLD RC WATER TOWER STRUCTURE

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***Abstract**: Since their inception, reinforced concrete structures have been continually improved in light of new knowledge, technologies, and/or materials, making older structures like the subject in question significantly different from today's common solutions in their design and implementation. This makes their revitalization a demanding and multidisciplinary task. This paper provides a brief excerpt from the revitalization project of one of the oldest engineering RC structures in Vojvodina – the water tower within the cement factory in Beočin. The facility stands as a very important monument of construction heritage, but over its 120 years of use, it has suffered significant damage that even jeopardize its bearing capacity. Numerous activities that conditioned or accompanied the design process are summarized, such as geometry identification, detailed visual inspection, in-situ and laboratory testing, repair and rehabilitation measures for elements, with the main focus given to numerical analysis and adopted structural solutions.*

***Key words:** Water tower, industrial heritage, damage, in-situ testing, assessment, structural analysis, strengthening of RC elements*

## 1. Introduction

The reinforced concrete 200m3 water tower, designed by Szilard Zielinski, a Hungarian engineer (1860-1924), is situated within the "Lafarge BFC" cement factory in Beočin. It was erected at the beginning of the 20th century, by company "Hennebique", with construction believed to have been completed between 1902 and 1906, although the data is not reliable. The water tower has not only become a symbol for the factory and the entire town but has also been recognized as a significant industrial heritage construction by the Institute for the Protection of Monuments. It stands as one of the most important examples of the early use of reinforced concrete in industrial structures in the wider region. The water tower has been in continuous use ever since. To evaluate the water tower's structural condition and select necessary repairs for its revitalization, the following activities were undertaken: 1) In-situ identification of dimensions; 2) Visual inspection to detect defects and damage; 3) In-situ extraction of concrete cores from columns to estimate compressive strength and the depth of carbonization; 4) Numerical analysis of the water tower's load-bearing structure; and 5) Analysis of all collected and calculated data, and assessment of the state of the load-bearing structure as a whole and its elements. The paper

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addresses the condition assessment and rehabilitation of the water tower [1], with particular emphasis on structural and numerical aspects

**2. Water tower basic data and damage of elements**

The water tower has a typical skeletal form, partially braced by walls, and is entirely designed and constructed in reinforced concrete. Vertically, the structure comprises distinct parts: the foundation level; the tower section, spanning from elevation ±0.00 (ground floor) to elevation +27.15m (6th floor); the reservoir section, extending from elevation +27.15m to the elevation of the roof slab at +32.51m; and the roof segment, reaching up to elevation +35.50m. The tower is formed by 12 columns, arranged at the vertices of a regular octagon (complex trapezoid-like cross section with maximum dimension of 61/25cm) and four internal ones (chamfered square cross section 38/38cm). External columns are prolonged in the form of buttress walls, gradually tapering from the foundation upwards (Figure 1). Below the external columns (with buttresses), radially oriented individual foundations are constructed, while the internal columns are founded on a common footing. At the floor levels, solid reinforced concrete slabs are constructed, supported by beam elements connecting the perimeter columns, by beams connecting the internal columns, and by radially oriented beams (classified as diagonal and orthogonal). The floor slabs are 10cm thick, while the bottom slab of the reservoir is 15cm thick. The cross-sections of beams vary, with the most significant dimensions as follows: radial and peripheral beams on floors 1 to 4 measure 20/40cm, with tapered ends (up to 65cm); internal beams connecting internal columns measure 22/40cm; beams supporting the reservoir slab measure 25/55cm; the reservoir ring beam has a complex 40/35cm section. The walls of the water tower can be divided into four groups: Facade walls, located on the ground floor and from the 5th floor up to the last roof slab, vary in thickness (from 8 to 12cm), length, or height; Internal walls, in the form of infill walls (7-8cm thick) between internal columns, extend from the first to the fourth floor to form the mechanical installation shaft, and on the 5th floor to accommodate the spiral staircase; Tank walls: the outer, 4m in radius cylindrical wall, with a thickness of 12cm, and the inner, 10cm thick, wall constructed between inner columns to provide square space for the spiral staircase; Parapet walls (railings) with variable thicknesses and complex geometries. They are constructed from the first to the fourth floor and on the roof slabs. There are two types of staircases. A single-flight segmented staircase extends from the ground to the 5th floor. The segments follow the geometry of the octagonal base and intersect each other at the column locations at an angle of 135°. The width of the staircase slab is 100 cm, and the thickness is 12-14 cm. Second one is spiral staircase within a square base extends from the 5th floor (passing through the reservoir) to the roof slab. It is constructed of prefabricated cantilevered steps connected to a central circular column with a diameter of 16cm. A more detailed depiction of the structural elements is provided in [2].

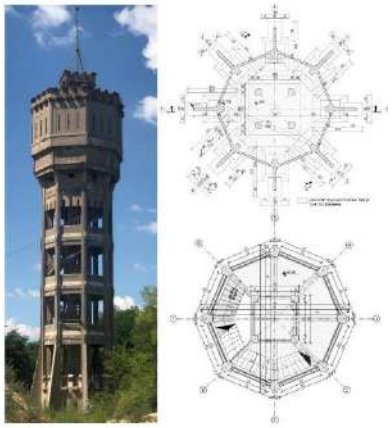


**Fig. 1.** Water tower, foundations and floor plan



**Fig. 2.** Characteristic of damage

After more than 100 years of exposure to environmental influences, similar damages (albeit of varying intensities) have been observed on all accessible RC elements (Figure 2). Characteristic damages to the reinforcement bars and stirrups include steel corrosion, often accompanied by volume expansion, significant reduction in sectional area, and even fracture of individual bars/stirrups. These issues have resulted in cracks in the concrete cover along the bars and stirrups, disruption of adhesion between the concrete matrix and the reinforcement bars, as well as delamination and detachment of concrete pieces from the cover and matrix. The most prevalent defect is either an excessive or insufficient thickness of the concrete cover. Particularly severe damage has been observed in the staircases. Additionally, significant traces of biological and chemical corrosion (such as deposits of calcium carbonate) have also been identified [2]. Laboratory testing on concrete cores has determined that a concrete strength of 20MPa can be used for assessing structural capacity. The depth of carbonation tests on extracted concrete cores, after laboratory sample preparation, showed that the depth of the carbonated layer within buttresses varies from 4.0 to 9.6cm, while in columns it averages 7 cm. This indicates compromised corrosion protection of the reinforcement, as the carbonation front has penetrated the protective layer, the cross-section matrix, and even part of the concrete core. To determine the type, number, and diameter of the embedded reinforcement, either a magnetic method or direct measurement was employed. Predominantly, plain bars with diameters ranging from Ø10 to Ø28 were used as the main reinforcement. For shear reinforcement in the columns, stirrups made of plain reinforcement with a diameter of Ø6 were utilized, while in beams, steel strips with dimensions of ≠30x2(3)mm (placed only on the lateral sides) or plain bar Ø8 stirrups were most common. The mechanical characteristics of the installed reinforcement likely correspond to the structural iron commonly used at that time. These tests determined the specific quantity of embedded reinforcement in the structural elements, at least in those accessible for inspection.

### 3. Numerical analysis of existing structure

Since there is no project documentation for the water tower available, the global and local dimensions of the tower and all structural elements were determined by manual measurement and by drone "point clouds" surveying. Based on the data obtained in this manner, a "digital twin" (3D geometrical model) of high accuracy was created (Figure 3a) and represent a significant specific result of the investigations performed. Once formed, this model establishes the complete geometry of the facility. For numerical analysis, which is conducted entirely in accordance with Eurocode norms, a detailed 3D numerical model

(Figure 3b) of the structure was created. The modeling, computations, and dimensioning were conducted within Radimpex Tower software environment, closely adhering to the established geometry of the facility and its elements. The model is formed by line and surface elements arranged in horizontal levels corresponding to the floors of the structure (slabs and beams, as well as spiral staircases) and in vertical planes (columns, plane walls, buttresses, and cylindrical reservoir walls). All modeled elements are assigned physical, and mechanical characteristics determined by in-situ testing and represented by concrete class C20/25. All elements are modeled in their original dimensions, acknowledging the unavoidable need for repairing and rehabilitating the elements. The effects of cracks in concrete on stress distribution and on deformations during seismic events are addressed by reducing the flexural, shear and torsional stiffness of all elements according to SRPS EN 1998-1 [4] recommendations. The support is modeled at the foundation level using Winkler soil idealization. The modulus of soil reaction for the vertical direction is adopted at a value common for the subject location – 20MN/m3.

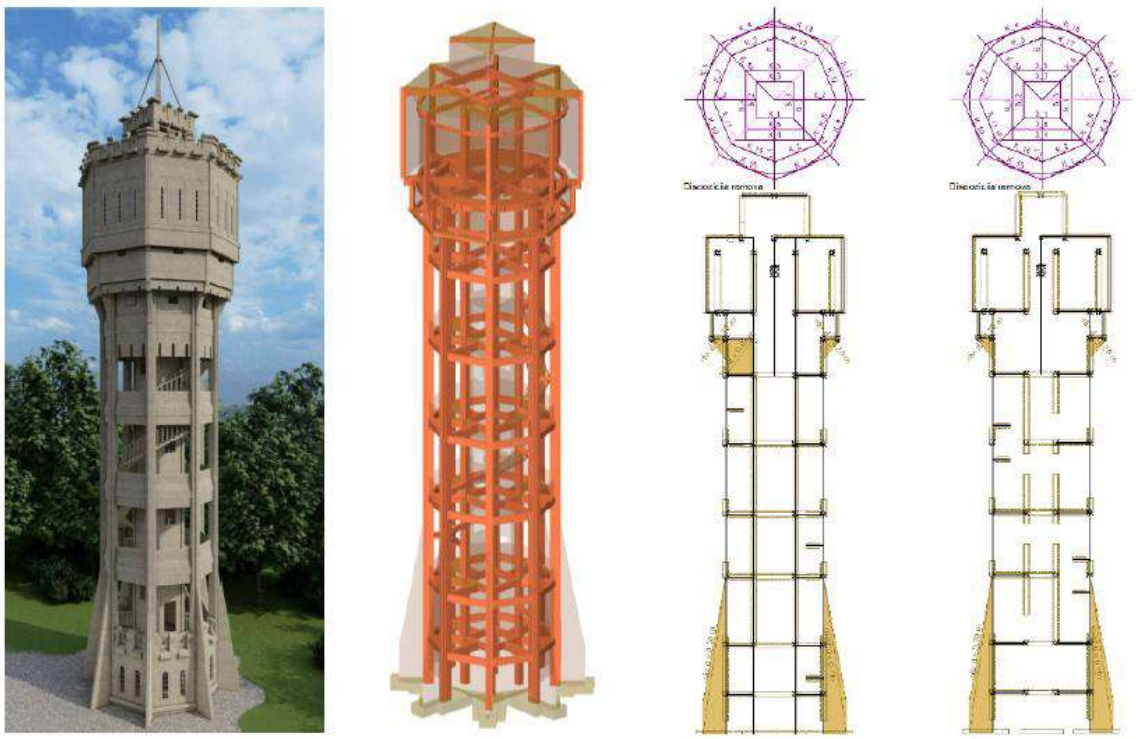


**Fig.3.** Digital twin (rendered view) and numerical model of the water tower structure

Since the water masses (corresponding to the impulsive and convective parts of the inertial load), necessary for modal and seismic analysis, are located at levels with no modeled elements, the masses are applied to a "dummy" ring encircling the central column (the quarters of a mass is applied in its quadrant points). The lower, "impulsive" mass is rigidly coupled, while the higher, "convective" mass, is elastically connected to the wall using appropriate link elements. Masses, their locations and link properties are calculated in accordance with the SRPS EN 1998-4 [4]. The load analysis comprised the following basic load cases: Dead load (self-weight of all structural and non-structural elements); Live load in a form of distributed loads on floor slabs and on stairs (1.0kN/m2 on roof slab and 2.0kN/m2 for rest of surface elements); Snow load distributed on roof slab; Vertical and horizontal static water pressure; and seismic load. Seismic action, as most important, includes the inertial pressure of the liquid (via determined masses adequately joined to

reservoir's wall), beside inertial forces from quasi-permanent weight. It is analyzed in accordance with SRPS EN 1998–1 [4] through two orthogonal horizontal components of action (0° and 90° in horizontal plane) which were determined by use of multi-modal spectral analysis, preceded by determining the dynamic properties of the structure (modal analysis resulted with 1.21s first, and 0.27s second directional period; Figure 4). Seismic action is generated automatically by the software used and cannot be represented in the form of floor forces. The following data are provided for generating this action: Soil category B (taken from the seismological zoning map of Serbia by Geological Information System of Serbia); Reference peak ground acceleration for the location – 0.1g; Importance class II; Spectrum type I; Damping correction factor of 1.0, related to 5% viscous damping. Considering the obligation to consider the simultaneous action of seismic components, it was adopted, as more rational than SRSS method, to combine components by the rule of summing the effects of one component's action and 30% of the effect of the other component. This way, two seismic actions are formed (from the previously determined components). Finally, the 1.50 behavior factor was used. Since the analysis concerns an existing structure that was certainly not designed for ductile behavior and, among other things, due to the reinforcement layouts or quantities, plastic behavior of any level cannot be reliably employed, the structure is considered suitable only for a low ductility class (DCL "approach"). Hence, the adopted value of the behavior factor. After calculation of effects in elements, using software automation, the necessary reinforcement amounts in all modeled RC elements were determined to be compared with the amounts of embedded reinforcement. The design settings assumed concrete class C20/25, reinforcement with a newly-formed type of steel, corresponding to the installed iron (yield strength 200MPa, modulus of elasticity 180GPa), and the reinforcement layouts in the cross-section which correspond to the determined layouts of the installed reinforcement. Considering the selected ductility class, DCL, all elements are designed for the ultimate limit state considering all relevant design combinations, in accordance with Eurocode 2, and therefore, the additional requirements from Eurocode 8 are omitted.

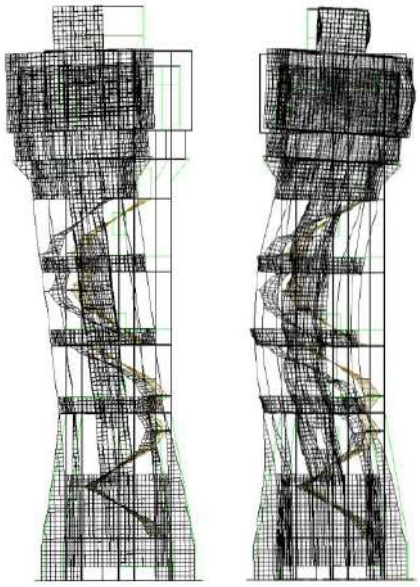


**Fig. 4.** First two mode shapes

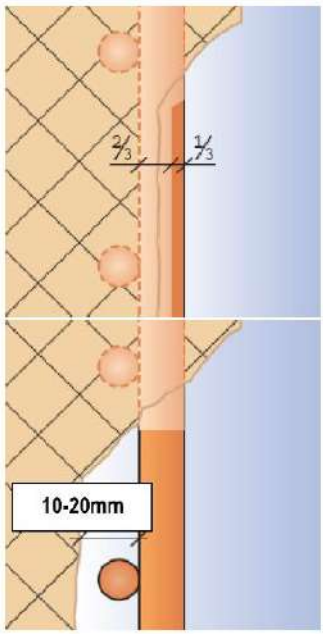



**Fig. 5.**Concrete chipping

The results of the comparison of reinforcement amounts (required vs. embedded), sorted by types of elements, are as follows: Due to the structural layout, the requirements

for longitudinal reinforcement in the columns is either nonexistent or less than the amount of embedded reinforcement. However, for the interior columns, along the part where they behave as "short" (the section of height between the top of the reservoir and the roof slab, where the columns are not "supported" by core walls, bears the majority of the roof's inertia), a deficiency in transverse reinforcement was noted (installed as UØ6/20cm).
Practically in all radial beams, in the first five floors, a deficiency of both longitudinal and, especially, transverse reinforcement was noted. These beams are reinforced with a relatively small amount of longitudinal reinforcement (±4Ø16), while installed transverse reinforcement in these beams consists of side flat bars that encompass only the "outer" longitudinal bars. From the standpoint of current knowledge about the desirable behavior of transverse reinforcement, this arrangement is of low efficiency and poorly anchored (even if it were not in poor condition in many beams). In the perimeter beams on the first five floors, the need for longitudinal reinforcement is relatively small and is covered by the installed reinforcement. However, a deficiency in transverse reinforcement was also noted here, and it is also formed from flat bars. Unlike the perimeter ones, the interior beams, which are mostly integrated in core walls, show a very small required reinforcement, with the need for transverse reinforcement even completely absent. Therefore, no structural intervention is necessary for these beams. The reservoir bottom radial beams are overhanging ones where cantilever supports part of the reservoir load and, in general, the shell around the reservoir. The calculation determined the lack of only transverse reinforcement, with the note that, due to inaccessibility, the amount of longitudinal reinforcement installed in the upper zone could not be determined, but embedded reinforcement is most likely sufficient. The remaining beams at the same level, as well as the ring beam, do not require strengthening. For all slabs, both intermediate and roof, as well as for the reservoir slab, it has been determined that, due to small spans, there is a low requirements for reinforcement, which quantity has been exceeded by the embedded reinforcement. For all elements where a deficiency in the reinforcement was identified, strengthening has been designed. With the adopted repair solution, the geometry of some elements undergoes minor changes, and as the newly designed solution slightly differs in the analysis of permanent loads from the previous one, the newly designed structure was also considered through a new numerical analysis. For reference, the fundamental natural oscillation periods of the two models do not differ by more than 1.5%. It resulted with relevant amounts of required reinforcements, and based on these, specific profiles have been adopted.

## 4. Repair solutions

To ensure the load-bearing capacity and durability of the structure, two sets of remedial works have been planned, broadly classified as structural and non-structural repairs, both being extensive in scope. Guidelines from the SRPS EN 1504 [3] standards were consulted for selecting repair methods, procedures, and materials properties, as well as for recommendations on design, execution, and concrete structure protection. Non-structural repairs categorize damages as shallow and deep. Shallow damages affect the protective layer of concrete with partially exposed reinforcement, while measures involve concrete and reinforcement preparation (Figure 5a; chipped concrete layer when the reinforcement bar is partially affected by the corrosion process, but adhesion is preserved), application of active coating on reinforcement bars, and reprofiling of the section by manually applying repair mortar. Deeper damages seize the matrix around the bars, and, in some cases, the core of the section, while reinforcement may suffer reduction in cross-section along with compromised adhesion. The non-structural repair method for these damages involves preparing the concrete (Figure 5b; chipped concrete layer when the reinforcement bar is

affected by the corrosion all around, and adhesion is compromised) and reinforcement, locally replacing corroded reinforcement bars or adding new ones, applying anti-corrosion protection to visible reinforcement bars using an active coating, and manually reprofiling the section by applying mortar. For structural elements, repairs are carried out with mortars of higher, while for non-structural ones, those with lower mechanical characteristics are used. Due to the large number of elements with insufficient bearing capacity and the numerous damages registered on these elements, structural repair has been designed in a relatively "radical" form. Specifically, it includes:

Removal of the existing and construction of new radial, both diagonal and orthogonal, beams on the first five floors, which showed insufficient reinforcement quantities (Figure 6; the same principle has been applied to the beams of the next three floor). This solution was chosen as the simplest from a practical standpoint since all solutions aimed at strengthening the existing beams are very complex to execute. Due to extremely severe damage that has significantly reduced their bearing capacity, the replacement of the core beams on the first floor is also planned. Work on constructing new beams comprises: supporting the slab in the areas between the beams, carefully cutting the RC slab closely along the edges of the removed elements, removing the 'detached ' beams by chipping, including parts of the sound concrete of the supporting elements to expose the reinforcement, drilling and dusting the holes for the installation of new reinforcement, installing the reinforcement and filling the remaining space with injection mixture, cleaning the surfaces formed by demolition and coating them with agents providing anti-corrosion protection and concrete bond, installing formwork and concreting new beams with three-fraction (dmax=16mm) C30/37 concrete, and reprofiling the columns. The concreting is followed by appropriate concrete curing.

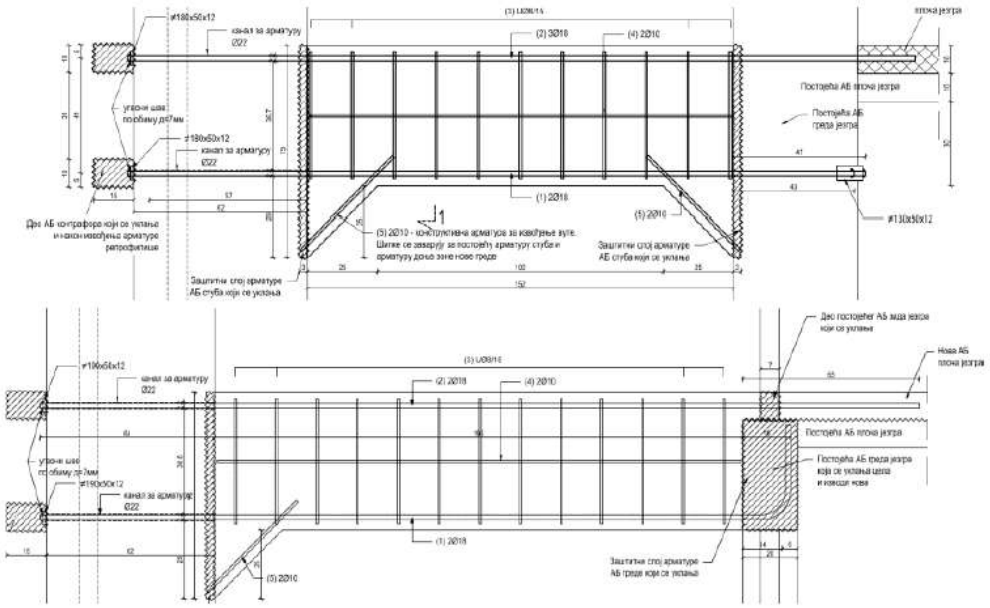



**Fig. 6.** Newly designed diagonal and orthogonal radial beams of the 1st floor

Construction of new RC slabs on the first five floors. In the previous 'step,' only the beam elements were removed, not the parts of the existing slab between the beam reinforcement connection of these slab parts to the supporting beam elements was cut, the adopted solution involves designing new RC slabs that are constructed over the existing ones (Figure 7; as an illustration, the reinforcement of the lower zone is given). The new slabs are 10 cm thick and are reinforced in such a way that they alone, without the

interaction of the existing slabs, accept and transfer the load (the existing slab parts are used only as formwork for the new RC slab). Strengthening of the columns of the 6th floor by adding additional transverse reinforcement (after removing the entire concrete cover and after exposing the external surfaces of the longitudinal bars from the column's section being strengthened), applying anti-corrosion protection (active coating) to visible reinforcement bars, and reprofiling the section by manually applying mortar.

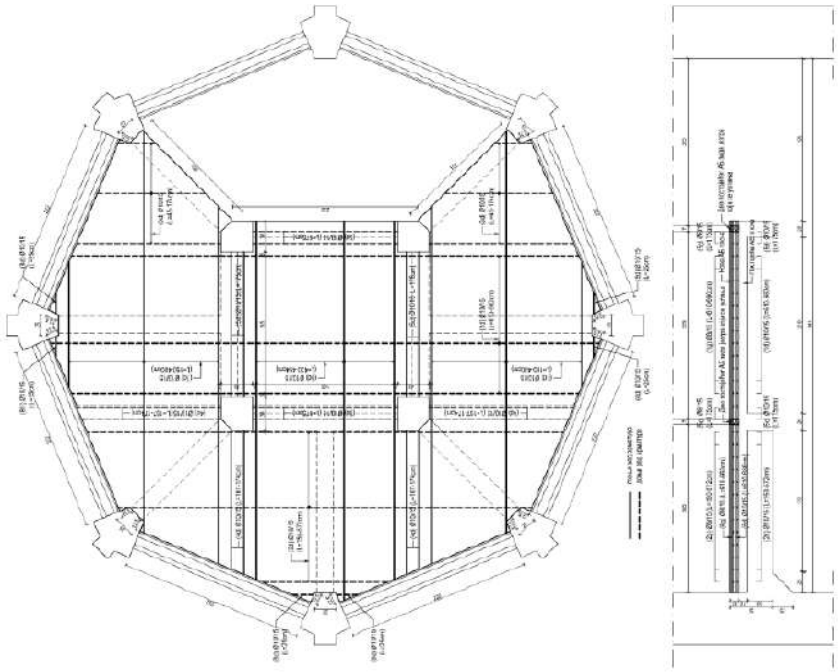


**Fig.7.** Newly designed RC slab – bottom reinforcement (rotated plot)

Strengthening of the radial RC beams, both diagonal (Figure 8) and orthogonal ones, of the 6th floor (reservoir's bottom) involves reinforcing by bonding steel plates and reinforcement with plates anchored into the existing structure.

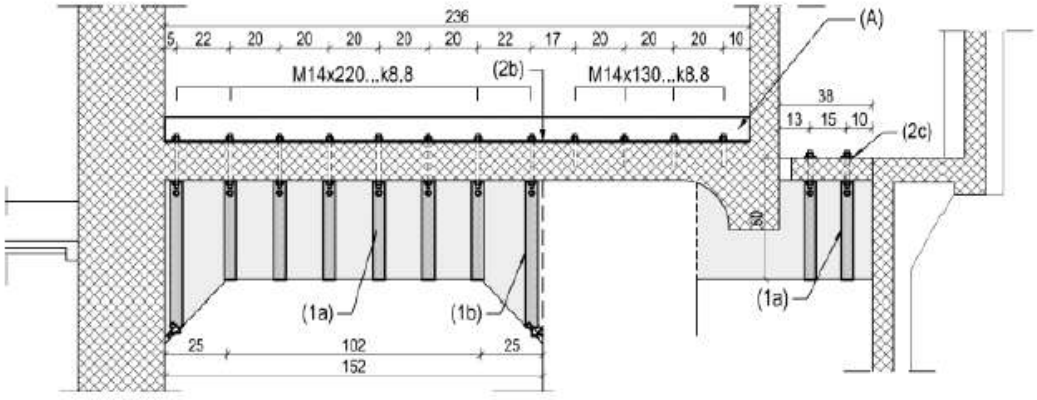



**Fig.8.** Strengthening of the diagonal radial beams (bottom of the reservoir)

Replacement of the existing single-flight segmented RC staircase with new ones entirely. Given that the staircase elements have a complex geometry, partially cantilevered support, and have suffered the most significant damage in the structure, a 'radical' solution of replacing the elements was adopted. Analyzed alternative solutions, which involved repairing the existing elements, proved to be extremely demanding and costly to execute.

The new elements have retained the geometry of the original ones entirely (Figure 9; as an illustration, the reinforcement of the lower zone of the staircase slab for the 1st to 5th floors is shown). Along with the staircase, the cantilevered supporting beams are also replaced.

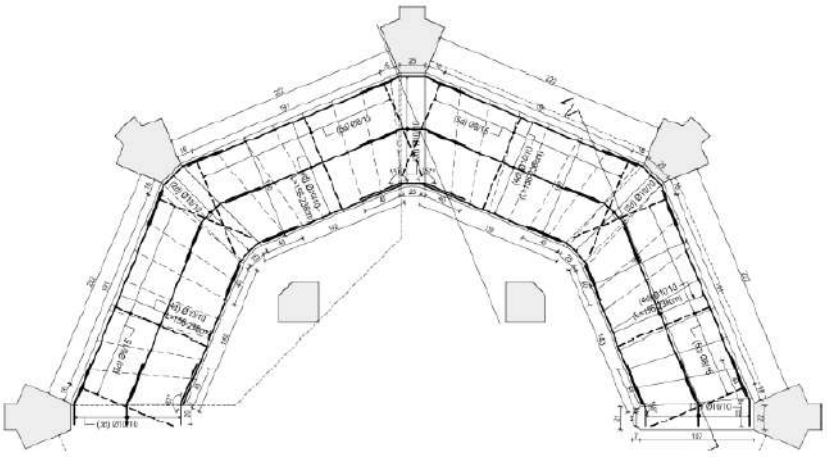


**Fig.9.** Newly designed single-flight segmented RC staircase – bottom reinforcement

**5. A few final notes**

The water tower in the Beočin, besides being an important example of architectural heritage and early use of reinforced concrete in complex structures, also bears witness to a time when structural design was guided by engineering reasoning and intuition. It's a rational design, with short load transfer paths, and from a layout perspective, it's optimally composed for the resources (knowledge, materials, experience, etc.) available at the time of construction. The 120-year continuous use of the facility confirms this more than anything else. On the other hand, such a long period of exploitation without significant investment in maintenance has left consequences that
jeopardize the structural integrity. The current condition of the facility indicates the urgent need for rehabilitation and strengthening, especially considering that the plan is for the facility to remain part of the production process in the future.

Rehabilitating a structure of this age and condition is an extremely complex and large-scale task, that even involves 'sacrificing' certain original elements and replacing them with new ones, while finding optimal solutions is not a one-way path but involves constant reevaluation of advantages and disadvantages, collaboration with experts from various fields, and confrontation of opinions.

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# ЗНАЧЕНИЕ НА СЕИЗМИЧНОТО ИНЖЕНЕРСТВО ПРИ ПРОЕКТИРАНЕ НА СГРАДИ - С АКЦЕНТ ВЪРХУ СВЕТОВНОТО АРХИТЕКТУРНО ИСТОРИЧЕСКО НАСЛЕДСТВО

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***Abstract**: В този доклад авторите правят опит да подчертаят значението на сеизмичното инженерство при проектирането на сгради, способни да издържат на въздействието на силите, генерирани в периода на земетресение, предотвратявайки повреди и разрушения, които могат да доведат до загуба на човешки животи и имущество. В този доклад са обсъдени накратко строежът на Земята, тектоничните движения в нейните недра, значението на сеизмичното инженерство при проектирането на сгради, включително неговата история, цели, методи и практически приложения, както и връзката му с физиката на Земята.*

***Ключови думи:** сеизмично инженерство, земетресение, сеизмични вълни, сеизмични изолатори, абсорбиране на енергия*

## 1. Общи данни

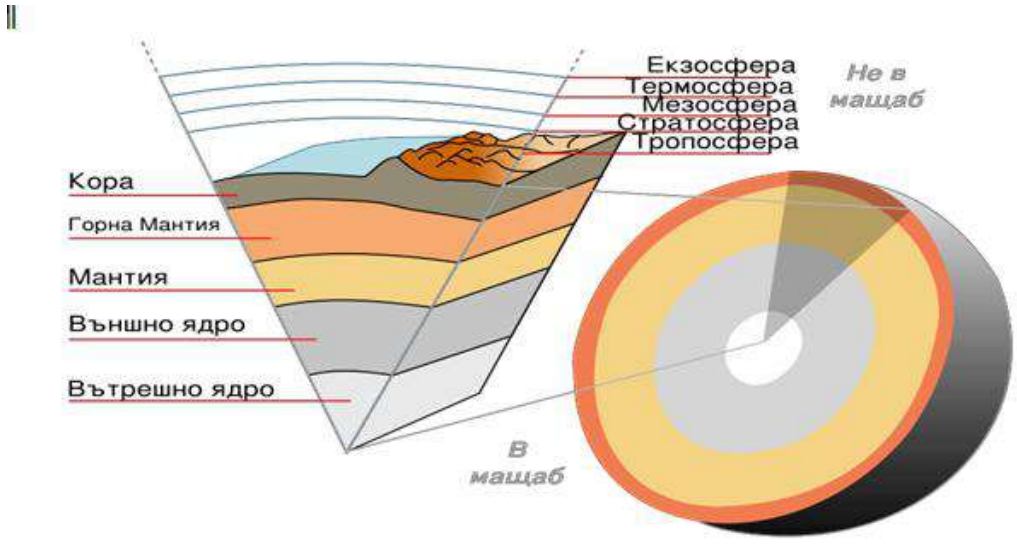
Сеизмичното инженерство, известно още като земетръсно инженерство, е специализирана област в строителното инженерство, която включва проектиране и конструиране на сгради и съоръжения, способни да издържат на въздействията на сеизмични, ветрови и други хоризонтални сили, възникващи в строителните конструкции. Сградите трябва да бъдат проектирани така, че да издържат на силите, генерирани по време на земетресение, предотвратявайки повреди или разрушения, които могат да доведат до загуба на човешки животи и имущество. В този доклад е накратко обсъден строежът на Земята, тектоничните движения в нейните недра, значението на сеизмичното инженерство при проектирането на сгради, включително неговата история, цели, методи и практически приложения, както и връзката му с физиката на Земята. Сеизмичното инженерство и физиката на Земята са взаимосвързани области, които работят заедно за разбирането и смекчаването на ефектите от земетресенията върху конструкциите и инфраструктурата. Физиката за строежа на Земята осигурява основата за изучаване на сеизмичните вълни, генерирани от

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земетресения, докато сеизмичното инженерство прилага тази информация, за да проектира и изгради структури, които могат да издържат на тези сили.

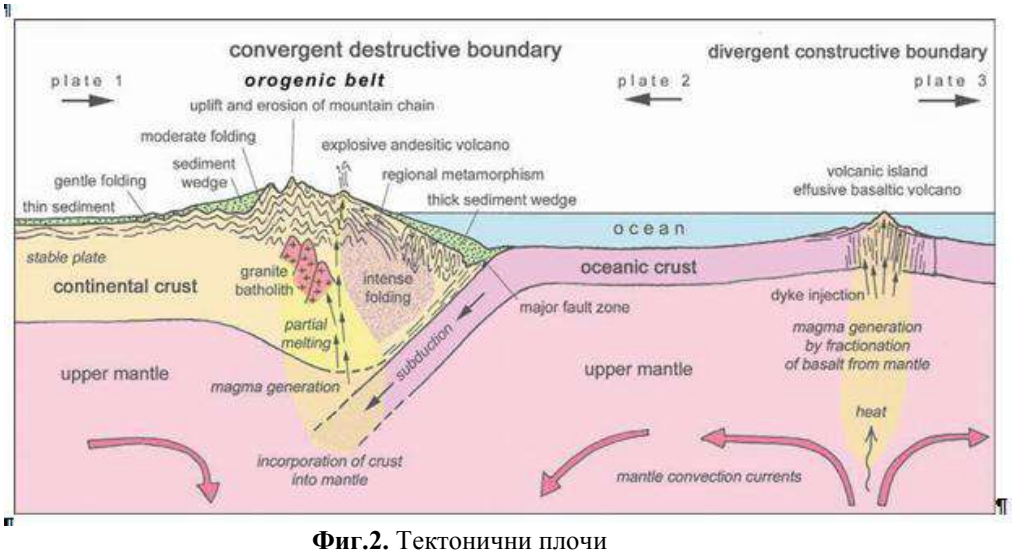
## 2. Строеж на Земята и тектонични движения

Земята е планета от Слънчевата система. Образувана е преди около 4,7 млрд. години. Земята има форма, близка до ротационния елипсоид, наречена геоид, която представлява мислено продължената повърхност на Световния океан и под континентите. Във всяка точка от тази повърхност силата на тежестта е насочена перпендикулярно към повърхността. Радиусът на Земята е около 6371 km. Средна плътност 5,52 g/cm$^3$. Вътрешната структура на Земята се определя чрез измерване на скоростта на разпространение на сеизмичните вълни във вътрешността на Земята. Състои от от три основни концентрични обвивки, наречени геосфери(**Фиг.1**):
1) земна кора (литосфера - от гръцкото литос - камък), 2) мантия и 3) централно ядро. Земната кора представлява 0,8 % от масата и 0,8 % от обема на Земята. Има средна плътност 2,7-2,8 g/cm$^3$. Тя е отделена от мантията с т. нар. граница на Мохоровичич (сеизмична граница), която под континентите се намира на дълбочина около 70 km, а под океаните се намира на дълбочина от 5 до 10 km. Под тази граница сеизмичните вълни увеличават скоростта си. Земната кора е най-горната и "най-динамичната" част от твърдото тяло на Земята. В общ вид тя има слоест строеж и се състои от 3 основни комплекса скали: седиментни, метаморфни и магмени.

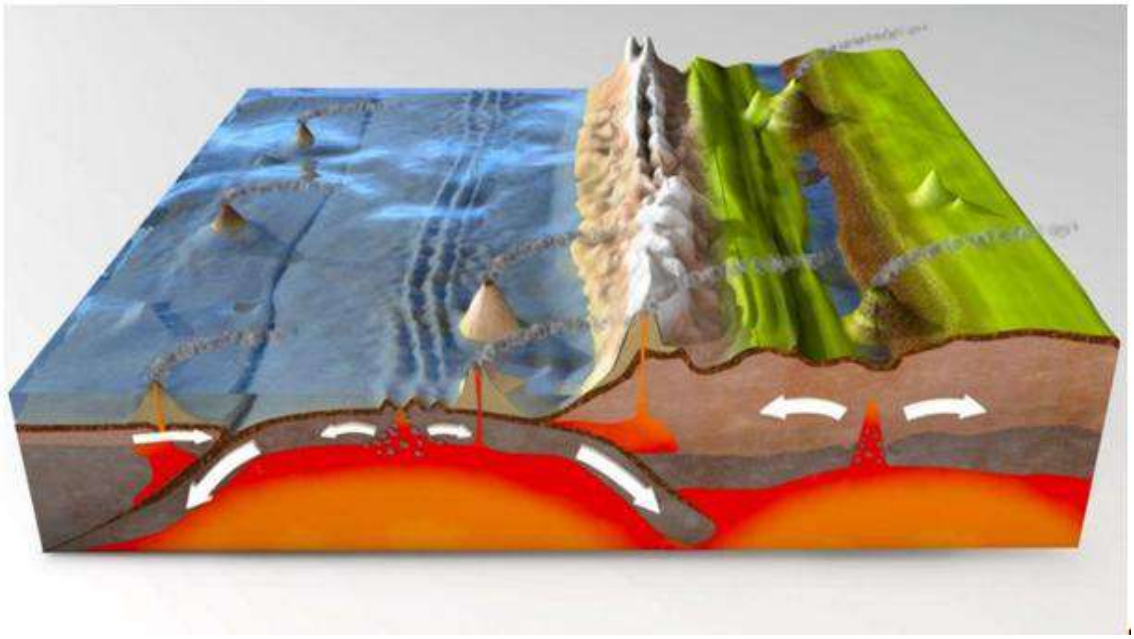



**Фиг.1**. Схема на строеж на Земята

Преместванията в земната кора предизвикани от тектонични сили се наричат тектонични движения. Младите тектонични движения се наричат неотектонични (Горен Неоген – кватернерен). Земната кора се деформира от два основни вида тектонични сили: радиални - по направление на земния радиус и тангенциални – спрямо земната повърхност(Фиг.2,3).




**Фиг.2.** Тектонични плочи



**Фиг.3.** Движение на тектонични плочи

### 2.1. Сеизмични вълни

Сеизмичните вълни са вибрации, които преминават през Земята или всяка друга планета, луна или естествен спътник поради внезапно освобождаване на енергия, обикновено под формата на земетресения, вулканични изригвания или ядрени експлозии. Тези вълни пренасят енергия от една точка на Земята до друга и могат да причинят разрушителни ефекти върху конструкциите и инфраструктурата.
Има два основни типа сеизмични вълни: надлъжни (или P-вълни) и напречни (или S-вълни).

**2.1.1.** Надлъжни (P-) вълни: Тези вълни карат частиците в земята да се движат напред-назад по посока на разпространението на вълната. Те са първите, които достигат до сеизмографите и следователно често се наричат първични вълни.

**2.1.2**. Напречни (S-вълни): Тези вълни карат частиците в земята да се движат перпендикулярно на посоката на разпространение на вълната. Има два вида напречни вълни: S-вълни, които се разпространяват през твърди тела, и R-вълни, които се разпространяват през течности и газове. Сеизмичните вълни се движат с различни скорости в зависимост от материала, през който преминават. Например, те се движат по-бързо през твърди скали, отколкото през течна магма или разтопена скала. Тази разлика в скоростта кара вълните да се огъват или изкривяват, докато пътуват през слоевете на Земята, феномен, известен като сеизмична рефракция. Изследването на сеизмичните вълни ни помага да разберем вътрешността на Земята, нейната структура и състава на нейните слоеве. Сеизмолозите използват тази информация, за да изучават тектоничната активност, да откриват минерални находища и дори да намират скрити кухини или пещери. Освен това разбирането на поведението на сеизмичните вълни е от решаващо значение за проектирането на сгради и инфраструктура, устойчиви на земетресения, както и за прогнозиране на потенциални земетресения и оценка на техните последици

## 3. Начини, по които сеизмичното инженерство и физиката на Земята са свързани

### 3.1. Генериране на сеизмични вълни:

Физиката на Земята обяснява как се генерират сеизмичните вълни по време на земетресение. Когато има внезапно освобождаване на енергия в земната кора, възниква трептене, което създава сеизмични вълни. Тези вълни се движат през Земята и предизвикват вибрации в близките конструкции. Разбирането на природата на тези вълни е от съществено значение за сеизмичното инженерство, тъй като помага при проектирането на структури, които могат ефективно да поемат и разсейват енергията на тези вълни.

### 3.2. Сеизмични скорости:

Физиката на Земята определя скоростта, с която се разпространяват сеизмичните вълни през различните видове скали и материали. Тази информация е от решаващо значение за сеизмичното инженерство, тъй като позволява на инженерите да предвидят как ще се държат конструкциите при различни условия на земетресения. Като разбират сеизмичните скорости, инженерите могат да проектират структури, които могат да издържат на вибрациите и напрежението, причинени от тези вълни.

### 3.3. Интензивност на сеизмичните вълни:

Физиката на Земята също така изследва как интензивността на сеизмичните вълни варира в зависимост от разстоянието от епицентъра на земетресението и дълбочината на източника. Тази информация е важна за сеизмичното инженерство, тъй като помага на инженерите да определят кои зони са най-изложени на риск от земетресения и съответно да проектират структури, които могат да издържат на тези сили.

### 3.4. Методи за измерване:

Физиката на Земята разработва различни методи за измерване на сеизмичните вълни, като например сеизмометри и акселерометри. Тези инструменти се използват от сеизмичните инженери за събиране на данни за сеизмичните вълни, генерирани от земетресения, които след това се използват за проектиране и оценка на структурната цялост на сградите и съоръженията.

### 3.5. Устойчивост на конструкцията:

Сеизмичното инженерство използва информацията, предоставена от физиката на Земята, за да проектира конструкции, които могат да издържат на сеизмични сили. Това включва избор на подходящи материали, оптимизиране на формата и размерите на конструкцията и включване на сеизмични изолатори или устройства за абсорбиране на енергия, за да се намали въздействието на сеизмичните вълни върху структурата. Земетресението и сеизмичното инженерство са тясно свързани, тъй като земетресенията представляват значителен риск за инфраструктурата и безопасността на хората в райони, предразположени към тях.

## 4. История на сеизмичното инженерство

Сеизмичното инженерство има своите корени в древни времена, когато хората започват да строят структури, които биха могли да устоят на природни бедствия като земетресения. Древните римляни, например, са използвали техника, наречена „opus incertum“, която включва подреждане на камъни с различни размери и форми, за да абсорбират напрежението и да намалят риска от разрушаване по време на земетресения(**Фиг.4**). През 16-ти век архитектът Андреа Паладио въвежда концепцията за "контрафорси" - външни подпори, използвани за укрепване на стените срещу странично въздействащи сили.



**Фиг.4.** Подреждане на камъни с различни размери и форми

През 20-ти век напредъкът в технологиите и научните познания доведе до развитието на съвременното сеизмично инженерство. През 1933 г. Калифорнийският институт за технологии (Caltech) преживява опустошително земетресение, което подчертава необходимостта от по-строги строителни норми и стандарти. Това събитие води до създаването на Комисията за професионална практика в областта на гражданското строителство (APPC), която разработва първия сеизмичен кодекс на САЩ през 1973 г. Днес сеизмичното инженерство продължава да се развива, тъй като учените придобиват по-добро разбиране за поведението на сградите по време на земетресения и разработват нови материали и техники за подобряване на тяхната устойчивост.

### 4.1. Цели на сеизмичното инженерство

Основната цел на сеизмичното инженерство е да гарантира безопасността на хората и имуществото чрез проектиране на сгради, които могат да издържат на силни земетресения. За постигането на тази цел сеизмичните инженери използват комбинация от теоретични знания, експериментални изследвания и компютърно моделиране, за да разберат как различните структурни системи реагират на сеизмични въздействия. Те също така работят в тясно сътрудничество с архитекти, геолози и други специалисти, за да идентифицират потенциалните рискове от земетресения във всеки даден район и да разработят подходящи стратегии за смекчаване на тези рискове.

## 5. Методи на сеизмично инженерство

Има няколко ключови метода, използвани от сеизмичните инженери за проектиране на устойчиви на земетресения сгради:

**5.1. Анализ на динамичното поведение**: Този метод включва използване на математически модели за симулиране на поведението на структурите под въздействието на сеизмични сили. Чрез анализиране на тези модели инженерите могат да определят критичните точки на структурата, където може да възникне повреда и да проектират укрепвания или модификации, за да предотвратят такива повреди.

**5.2**. **Изследвания на пълзящ анализ**: Пълзенето е бавното, линейно движение на земята по време на земетресение, което може да причини натрупване на напрежение в структурните елементи. Чрез провеждане на пълзящи анализи инженерите могат да оценят способността на сградата да издържа на тези сили без прекомерно огъване или разрушаване.

**5.3.**Оценка на сеизмичната уязвимост: Тази техника включва оценка на

вероятността дадена сграда да бъде повредена или унищожена по време на земетресение въз основа на фактори, като възрастта на сградата, използваните материали и местоположението й спрямо известни разломни зони. След това инженерите могат да предложат мерки за намаляване на сеизмичния риск, като реновиране или укрепване на съществуващи структури или прилагане на по-строги строителни норми за нови конструкции.

**5.4**. Проектиране на конструктивни системи: Сеизмичните инженери разработват различни типове конструктивни системи, предназначени да поемат и разсейват енергията, генерирана по време на земетресения. Тези системи включват рамкови конструкции, дисперсни системи и полутвърди конструкции, всяка със свои собствени уникални предимства и ограничения.

**5.5.** Усъвършенствани изчислителни инструменти: Напредъкът в компютърната технология позволява на сеизмичните инженери да създават сложни модели на сгради и околна среда, което им позволява да тестват различни дизайни и сценарии на земетресения, преди да построят действителната структура. Тези инструменти помагат на инженерите да оптимизират дизайна на сградата за максимална устойчивост на земетресения, като същевременно минимизират разходите и въздействието върху околната среда.

## 6.Приложение на принципите на сеизмичното инженерство в строителната практика

Прилагането на принципите на сеизмичното инженерство в строителната практика е от решаващо значение за изграждането на безопасни и надеждни сгради в райони с висок сеизмичен риск. Няколко конкретни примери за успешното прилагане на тези принципи са дадени по-долу в текста[1,2,3]:

### 6.1. Сан Франциско, Калифорния

След опустошителното земетресение в Сан Франциско през 1906 г., градът приема строги строителни норми, изискващи използването на стомана и бетон в новите сгради вместо дървен материал. Тези промени значително намаляват броя на жертвите и разрушенията по време на следващото голямо земетресение през 1989 г,. в Токио(**Фиг.5**), Япония. Японският град е особено чувствителен на земетресения поради разположението му върху активна разломна зона. Въпреки това, чрез прилагане на строги строителни норми и използване на иновативни конструктивни системи като стоманени рамки и дисперсни системи, Токио успя да сведе до минимум щетите от няколко големи земетресения през миналия век.



**Фиг.5**. Земетресение в Токио,1989

### 6.2. Нова Зеландия

След поредица от опустошителни земетресения в началото на 2010 г., новозеландските власти предприемат широкообхватни реформи в своите строителни норми, за да подобрят устойчивостта на сградите към сеизмични събития. Тези реформи включват изискването всички нови обществени сгради да бъдат проектирани да издържат на земетресения с магнитуд 7,5 по скалата на Рихтер. Докато земетресенията могат да причинят значителни поражения върху конструкциите на исторически сгради, директното разрушаване на такива структури от земетресение е сравнително рядко. Това е така, защото тези сгради обикновено са внимателно проектирани и конструирани, за да издържат на сеизмични сили, особено ако са разположени в райони, предразположени към земетресения. Въпреки това има случаи, когато исторически сгради са били сериозно повредени или дори частично разрушени от земетресения.

### 6.3. Земетресението в Япония през 2016 г.

Замъкът Кумамото е исторически замък в град Кумамото, префектура Кумамото, Япония. Построен през 15 век, той е един от най-старите и добре запазени замъци в страната. Замъкът е бил свидетел на няколко обсади и битки през своята история, включително обсадата на Кумамото по време на периода Сенгоку и обсадата на Кумамото по време на периода Едо. На 16 април 2016 г. силно земетресение с магнитуд 7,3 удари южната част на Кюшу, което доведе до значителни щети на различни исторически обекти, включително замъка Кумамото(**Фиг.6-Фиг.10**). Земетресението причинява сериозни повреди на замъка, като стени и покриви се разрушава, а някои части от конструкцията са напълно унищожени.




**Фиг.6 и Фиг.7.** Исторически замък в град Кумамото




**Фиг.8 иФиг.9.** Исторически замък в град Кумамото



**Фиг.10.** Исторически замък в град Кумамото

След земетресението японското правителство обявява, че ще отпусне средства за възстановяване на историческите обекти, включително замъка Кумамото.

Реставрацията започва през 2017 г. и завършва през 2020 г., отбелязвайки 450-годишнината от възстановяването на замъка.

### 6.4.Земетресението в Непал през 2015 г.

Кулата Драхарахара, историческа наблюдателна кула в Катманду, е сериозно повредена по време на земетресението в Непал през 2015 г. Кулата е построена през 1834 г. и е доста популярна туристическа атракция, предлагаща панорамна гледка към града и околностите му(**Фиг. 11 и Фиг.12** ).




**Фиг.11 и Фиг.12.** Историческа наблюдателна кула в Катманду

При земетресението кулата претърпва сериозни структурни щети, включително срутване на горната й част. В резултат на това кулата е съборена за поради изсиквания за безопасност. Въпреки загубата на оригиналната структура, усилията за възстановяване започват скоро след това. Новата кула Драхарахара е официално открита през декември 2018 г., запазвайки оригиналния си дизайн и функция като наблюдателна точка. Реконструкцията включва използването на традиционни строителни техники и материали, за да се запази автентичността на обекта. Земетресението засегна сериозно културното наследство на Непал, причинявайки значителни щети или унищожаване на множество исторически обекти и архитектурни забележителности, особено в района на Катманду, който е обект на световното културно наследство на ЮНЕСКО. Някои от най-засегнатите обекти включват площад Дурбар, дворецът Хануман Дхока, храмът Сваямбунат и храмът Боднат.




**Фиг.13 и Фиг.14. З**асегнатите обекти площад Дурбар, дворецът Хануман Дхока, храмът Сваямбунат и храмът Боднат.

### 6.5. Земетресението в Мароко през 2017 г.

По време на земетресението в Мароко на 26 февруари 2017 г. няколко исторически сгради в Маракеш са повредени или разрушени. Един от най-забележителните случаи е джамията Кутубия, една от най-старите и известни джамии в Мароко. Джамията претърпява значителни щети, включително пукнатини по стените и паднала мазилка. Други исторически обекти, като медресето Бен Юсеф и двореца Бахия, също така претърпяват щети, макар и не толкова тежки(Фиг15 и Фиг.16).




**Фиг.15. и Фиг.16.** Исторически сгради в Маракеш са повредени или разрушени.

Сеизмичното инженерство играе жизненоважна роля в проектирането и изграждането на сгради, които могат да издържат на високите стойности усилията, генерирани по време на земетресения. Като разбират поведението на сградите при сеизмични условия и разработват иновативни конструктивни системи и строителни техники, сеизмичните инженери помагат да се защитят хората и имуществото от опустошителните ефекти на тези природни бедствия. Тъй като нашето разбиране за земетресенията и строителните материали продължава да расте, можем да очакваме по-нататъшен напредък в областта на сеизмичното инженерство, което ще ни помогне да създадем по-безопасни и по-устойчиви сгради за бъдещето[1,2,3].

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# 55 YEARS HISTORY OF MERRISON RULES – THE ANSWER OF THE DISASTROUS FAILURE OF STEEL BRIDGES WITH BOX SECTION

In Memoriam
Prof. Eng. Antonin Schindler DSc (1920-2008)
Prof. Dr.Eng Dr.Eng. E.h. Joachim Scheer (1927-2020)
Assoc. Prof. Dr. Eng. Borislav Bankov(1912-1992)

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**Abstract**: *The aim of this paper is to help prevent the repetition of disastrous mistakes in the design and construction of load-bearing capacity of steel bridges with box sections, and contribute to engineering practice in this field. The cases describe there, show that the main causes of catastrophe are bad workmanship and a failure to recognize and think through accident scenarios. This theme put the questions whether our engineering students are getting the education they need for their future work. In the days before engineering science made it possible to predict the behaviour of load-bearing structures, failures were the main source of education and progress for builders. In the same way today, load-bearing structures must prove themselves in practice. Machine and particularly car makers can run a pilot series to remedy defects before going into production, but the one-off nature and size of building structures make it impossible to test their loadbearing capacity and remove defects before construction. The paper shows the significant influence of the Merrison Rules for the explanation of the collapses of the steel bridges with box section.*

**Key words**: *steel bridges, box sections, load-bearing capacity, disastrous mistakes,*

## 1. Introduction

When analyzing the causes of structural failures many investigators find, *that there is hardly any case which could have been prevented by more detailed calculation*, according

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to [1]. Other authors (J. Scheer [1], D.W. Smith [2], and O. M. Hahn [3], Fr. Faltus, M. Škaloud [19] and J. Pechar [20]) have looked into this problem and came to the same conclusion. The basic cause of most of catastrophic failures was one of the following: - possibilities of failure were never even considered during design; - conditions were not thoroughly investigated or *recklessness* during design or construction *(rashness* or even *foolishness)*. On some occasions, successful structures have also been the cause of failure in later structures *when seemingly unimportant changes,* such as in size or slenderness, turned secondary factors into major influences [4]. According to [1], a collection of structural accidents might easily lead to the conclusion that construction work very frequently involves failure. There is no doubt that accidents happen too often and it cannot be *denied* that certain catastrophes could have been avoided. Nevertheless, the number of failure occurrences must be measured against the huge number of structures. When discussing the individual cases of bridge failure, the authors have mostly *deliberately* refrained from repeating well-documented investigations. We merely make reference to them, except in cases where our own deliberations have caused us to reach different conclusions [1]. As engineers continuously produce technical innovations with increasingly challenging load-bearing structures such as bridges with wider spans, of lighter design and new materials, it can happen that due to the limitations of their standard of knowledge, they fail to identify *hitherto* unknown phenomena and dangers. Many bridge collapses have been prevented only by the fact that the circumstances were fortunate and we can often learn as much from these cases as from the major disasters.

## 2. Case Study

Progress in welding technology enabled the steelwork industry to make economic use of the torsional stiffness of the box girder combined with its aesthetic and maintenance advantages. Eccentric loads were largely absorbed by the two main girder walls and it was possible to build cable-stayed bridges suspended only in the middle. There were further advantages in trapezoidal box girders because their narrow lower width was good for the piers while their wide upper width allowed a generously proportioned road deck. The bearing of flange compressive forces in the wide, mostly longitudinally stiffened bottom flanges of the box girders was something new. The buckling theory had developed beyond the current codes of practice at the time but it was too little known, or even recognized, that the post-critical reserves, which are generally available in webs, only apply to flanges under certain circumstances and above all that imperfections there are of far greater significance. The result was that compressed and stiffened flanges were designed and constructed, in most cases unknowingly, with smaller failure probabilities than are usual in bridge building.

### 2.1 The 4th Danube Bridge in Vienna

The series of incidents with large steel box girder bridges began in 1969 with the 4th Vienna Danube Bridge. *The failure was initiated by temperature actions that had not been taken into consideration and an additional factor was oversimplified assumptions regarding the distribution of dead weight, which led to underestimation of the stresses at the points of failure (Fig.1a,b,c). However,* the bridge, with individual spans of: 120m - 210m - 82m did not collapse because, as a continuous beam over 3 spans, it retained its load-bearing capacity as an almost statically determinate system even without significant bending moments in the two buckled areas of the compressed bottom flanges.

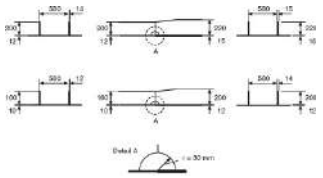
a)  b)  c) 

**Fig.1,a,b,c.** 4th Danube Bridge, Vienna, 1969 [1], a) Failure of stiffened, compressed flanges of box girders, b) Weld seam of longitudinal stiffeners-configuration in buckled areas, c) Similar seam in a less severely buckled area.

The approx. 7.5m wide compressed bottom flanges of the two adjacent box girders were strengthened here with flat steel longitudinal stiffeners 580mm apart (Fig. 1c). In the area of one of the two bulges their cross section changed from 160 x 12 for the 10mm thick floor plate on the one side of the joint to 200 x 14 for the 12mm floor plate on the other. At the other failure point the 12mm floor plate was strengthened with 200 x 14 stiffeners and the adjacent 15mm plate with 200 x 15. The joints are shown in Fig. 1b, and one of them can be seen on the left hand side of the photograph 1c. In the area of the 10mm floor plate, the single spans had a load bearing stress of approx. 73% yield stress with w/d = 580 and obviously buckled before the failure of the entire span. Fig. 2a shows the buckling of the single span in close proximity to the main damage.

a)  b) 

**Fig. 2a,b**. 2th Danube Bridge, Vienna, 1969 [1] a) Buckling areas near failure point, b) Sharp fold in seam,

The joint led to a displacement of the axis of gravity by approx. 1 cm. It is surprising that, to our knowledge, none of the investigations remarks on the cut-outs to be seen on the left-hand side of Fig. 1c. The value r = 30mm is derived from this photograph and is probably accurate. The cut-out weakened the smaller 160 x 12 profile and, calculated according to the German code DIN 18 800/2, Element 301, gave the floor plate an effective area of approx. 413 x 10, approx. 95%. This localized weak spot due to the cut-out and the displacement of the axis of gravity corresponds to the failure profile (Fig. 2b) with the sharp fold at the joint location. In addition to this, the relatively slender flat steel stiffeners with w/d up to approx. 13 had already been deformed laterally by welding of the joint (4 to 6mm according to [5]), which further limited their stiffening effect (see detailed investigation in [5]).

### 2.2. Case Study: Cleddau Bridge in Milford Haven, Wales,

Nine months after the failure in Austria, the Cleddau Bridge in Milford Haven, Wales, collapsed during erection. The 819m bridge with individual spans of 77m - 77m - 77m - 149m - 213m - 149m - 77m, was built with trapezoid box girders 6.1m high, 12.5m wide at the top and 6.7m at the bottom. The road deck projected at both sides and was 20.3m wide. During cantilever erection, the ninth element was to be attached to a section already projecting 59m to reach the second pier. While this 17m long section, weighing approx. 100 t, was being extended, the transverse girder of the bearing over the first pier failed. The cantilever arm broke off and fell to the ground (according to [5]). The cause of the collapse was false assessment of the loading capacity of the large bearing plate and with this the failure to appreciate the importance of the eccentricity of its stiffeners, together with the unusual force flux resulting from the inclination of the webs. The fact

that the structure was severely under-dimensioned becomes apparent in that the highest support force in later service life of the bridge was to be 55% higher than at the time of failure. Although the failure mode might suggest failure of the box girder (Fig. 3), author in[1] emphasize that the damage in fact had nothing to do this. In [1, 19] authors find this important because this accident is frequently grouped with those of other box girders, whose failure was due to the failure of stiffened plate flanges.



**Fig. 3.** Cleddau Bridge in Milford Haven, state after failure. 1970 [1]

### 2.3 Case West Gate Bridge, Melbourne

Only about four months later, the West Gate Bridge in Melbourne, Australia, collapsed during its erection (Fig. 4a).

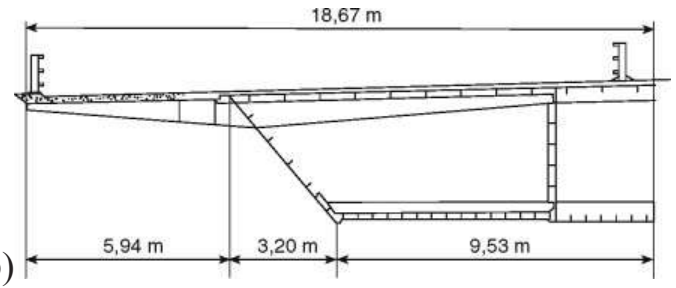
a)  b) 


**Fig. 4,a,b.** West Gate Bridge, Melbourne, collapsed span, half cross section [1]

The 848m bridge with span lengths of 112m - 144m - 336m - 144m - 112m had a three-cell, trapezoid cross section (Fig. 4b). The bridge beam was to be cable-stayed in the three inner spans. The unusual mode of erection, the inappropriate measures taken to remedy difficulties caused by faulty procedure and finally the collapse itself are described in [6, 7]. Figure 5a shows that the superstructure was first erected in two sections and Figure5b shows the large and varied deformations to the longitudinal joint, which had to be removed to enable the parts to be connected. The superstructure collapsed when this attempt was made.

a)  b) 

**Fig. 5a,b**. West Gate Bridge, Melbourne, longitudinal joint. 1970 [1], a) View from below before joining; b) State during joining

The accident had nothing at all to do with the buckling problem of box girder flanges. One of the reasons for the failure was overload of the box girder during attempts to align the camber by ballasting the box girder, which was being erected in halves and thus had a considerably reduced load-bearing capacity. The publications about the collapse [8, 19, 20]

and about the reconstruction [9,19] contain further sources and information about the accident and give details of the defects in the original design of the bridge.

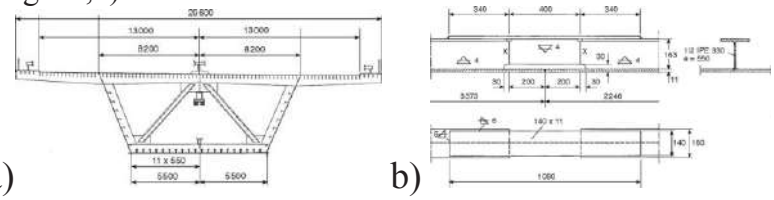
### 2.4. Case study: The Koblenz-Horchheim bridge over the Rhine in Germany

The Rhine Bridge in Koblenz, Germany **(Fig.6a,b.c)** is another typical example for the failure of stiffened compression flanges too. The Koblenz-Horchheim bridge over the Rhine in Germany collapsed during erection in 1971, exactly one year after the accident in Melbourne, and once again the bridge that failed had a large trapezoidal box girder. The structure was designed as a three-span bridge with a total length of 442 m. The 103m side spans were to be constructed first followed by the middle span which was to be assembled cantilevering from both sides without temporary support. Using an approx. 100 t derrick positioned at the tip of the cantilever on the left bank side, 104m of the middle span had been constructed when the bridge girder collapsed approx. 50m from the pier in the left side of the Rhine.

a)  b)  c) 

**Fig. 6,a,b,c.** Rhine Bridge, Koblenz. 1971 [1] a) Bridge after collapse, b) Bridge before collapse; b) Bridge during collapse

This occurred during lifting of the first part of the last section on the left side of the Rhine and resulted from exhaustion of the bearing capacity of the longitudinally stiffened plate bottom flange (Fig. 7a,b).




a) b)

**Fig. 7a,b.** Rhine Bridge, Koblenz, construction in failure area [1] a) Cross section; b) Erection joint in bottom plate

The failure was mainly due to the detail of the bottom flange joint at the point of failure [10]. Fig. 7a shows the cross section of the bridge and Fig. 7b shows the joint in the floor plate with the longitudinal stiffeners. As the initial plan was to weld the cross joint in the floor plate automatically, a 400mm gap had been left between the ends of the longitudinal stiffeners 1/2 IPE 330. This gap was closed in the area of the stiffening webs by a fitting piece not connected to the bottom plate and by a flange splice rib welded to it. There remained a 30 + 400 + 30 = 460mm *long window without support in the bottom plate, which was 11mm thick in the failed joint.* Welding deformations contributed significantly to the weakness of the joint cross section with a slenderness ratio between 460/(0.289) = 145 for the plate member with hinged supports and 145/2 = 72 for the plate member with fixed ends. Although the plan to use an automatic welding machine was later abandoned, the joint configuration designed to suit it was not changed. Tests carried out as part of the expert report into the collapse [1] show how the joint cross section failed (Fig. 8a,b). When construction of the bridge recommenced, the extreme cantilever portion of more than 100m was avoided by lifting the 600 t middle section of the main span from the now much shorter cantilever arms (Fig. 8b). The course of the accident is described in [8,19] and also in [11, 12, 6,19].

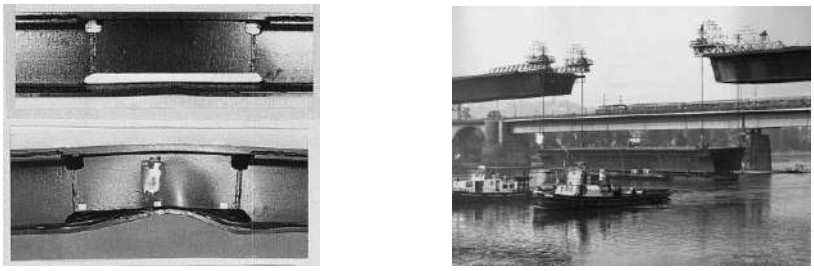


**Fig. 8a,b.** Rhine Bridge, Koblenz [1], a) Failure in welding seam (experiment), b) Rebuilding with shorter cantilever

### 2.5. Case Study: Zeulenroda road bridge over Weida valley in Thuringia

The accident occurred during a cantilever erection in the second span, after two sections had already been assembled to form a 31.5m cantilever (Fig. 9b) and the third, approx. 14m long section, which was to be placed on temporary supports, was being prepared for positioning. The engineering world allegedly only heard many years later about the collapse of the Zeulenroda road bridge over Weida valley in Thuringia, East Germany during its erection in 1973, according to [1], H. P. Ekardt, provided a detailed report on this incident combined with generally valid observations about the responsibility of engineers [13] (1998), according to H. Elze who had dealt with this failure in a lecture in 1996 [14]. After completion of the bridge, the valley was to be flooded to serve as accumulation. The 6-span, 362m long bridge with 55m side spans and 63m middle spans had a trapezoidal box girder 2.15m high with an upper width of 5.4m and 4.0m lower width. The bridge deck with sidewalks was 11m wide and projected 3m at each side. The bottom flange was stiffened with 5 125 x 20 flat steel longitudinal stiffeners and with 150 x 10 flat steel stiffeners between the cross frames (Fig.9a). The box girder failed due to exhaustion of the compressive strength of the bottom flange in the second span directly in front of the pier (Fig. 9c).



**Fig. 9a,b,c.** Bridge, Zeulenroda reservoir,1973 [1], a)View of stiffened bottom plate, b)Before the failure, c) Broken cantilever

It must, however, be pointed out right from the beginning that in spite of the errors described in the assessment of the load bearing capacity of the stiffened flanges, defects of constructional details were always the primary cause of failure. K. Roik [9] therefore correctly identified the cause of the occurrences in Vienna, Milford Haven, Melbourne und Koblenz, with the words "**In all cases the main cause lay in defects in constructional detailing".** The first four of the five incidents have been reported, sometimes as summaries, in publications: [7, 19] and [5, 20]. For this reason they are only briefly described here while placing emphasis on general aspects of the cases.

### 3. Consideration about mentioned failure of the Bridge construction

According to [1] the authors of the Zeulenroda Bridge have been unable to obtain for aforementioned failure of the Bridges any details of the forces and moments at the failed cross section, any measurements, such as the panel thickness or frame spacing, or the configuration of the high-tensile bolt joints. All he can do is to summarize the details

contained in [13] and [14] as follows: the bridge had been designed in 1968, i.e. prior to the failure of the 2nd Danube bridge in Vienna. In accordance with building regulations, a global safety factor of only 1.15 had been determined. For this purpose the load-bearing capacity of the stiffened flange under compression was obviously overestimated by equating it with the ideal buckling load. The pressure on the project schedule also seems significant. Although the Koblenz failure two years earlier should have served as a warning to check all assumptions used for the structural analysis, time was running out and this was omitted. The total separation of erection planning from structural design also played a role. Witnesses have reported – off the record – that discussions in professional circles often mention the suspicion that the failure might have been due to defects in the steel supplied from the USSR according to the GOST standards. *Another suggestion was that unusually strong sunshine on the day of the accident might also have caused an extreme difference in temperature between the top and bottom flange.* As in Koblenz, the load on the end of the cantilever arm was avoided during reconstruction by use of a mobile crane standing on the floor of the valley. The incidents in Vienna, Milford Haven, Melbourne, Koblenz and Zeulenroda have often been quoted as grounds for experimental and theoretical research into the buckling problem. The failures occurred in longitudinally stiffened steel box girders, but this does not mean that the accidents are to be assigned fully to the breakdown of the buckling theory, in spite of the errors that occur in practice. The accidents can be assigned to the following causes [1]: **The 4th Danube Bridge in Vienna:** *temperature effects, simplified assumptions on dead weight distribution, construction: flat stiffeners, joint eccentricities, weakening at joint, welding deformations*; **Cleddau Bridge in Milford Haven, Wales**: *Failure of bearing cross girder due to under-dimensioning;* **Case West Gate Bridge, Melbourne:** *Uncontrolled erection procedure*; **The Koblenz-Horchheim bridge over the Rhine in Germany:** *Design detailing: weak joint configuration*; **Zeulenroda road bridge over Weida valley in Thuringia:** *Insufficient safety margin during erection and false assessment of load bearing capacity of the stiffened bottom flange of the box girder.* The statement "*nevertheless… in the end even the slightest sign of low buckling stability, which would again be dealt with during erection, contributed to the disaster*" is certainly correct according to [1] U. Krüger´s assessment [15]. In spite of information being available in engineering literature, there was little knowledge of when post-critical reserve strength was available to allow these formally slight buckling stabilities relating to the ideal buckling load to be justified or, on the other hand, when ideal buckling loads greater than failure loads made it necessary to base the assessment on other factors and include appropriate safety margins. *Failure of structures almost always results in injury and loss of life.* Structural safety is therefore of primary importance right from the beginning of conceptual design and should not be influenced or affected by other objectives such as cost, aesthetic shaping etc. Structural failures – and many partial failures – are often caused by one careless mistake arising because a vital problem has not been recognized, has been underestimated or carelessly treated. A bridge is never designed and built by only one engineer. A competent team is a fundamental requirement for the successful completion of a structure, according to [1]. At the same time every person involved must be prepared to support his colleagues even beyond his own particular field of action. Standardized safety is the basis of design. It must cope with shortcomings in design and construction, the development of the live load, the material strength and finally, the loss of resistance due to potential corrosion. Standards are established for "normal" cases and sometimes they are not suitable for a particular project. Clearly, the safety requirements must be different for a simple, well-protected structure from those for a sensitive, exposed structure. For example, essential safety may be carefully modified for the assessment of an existing construction provided that any new parameters are considered and the condition of the construction is thoroughly inspected. Any structure in

which local failure could lead to a total collapse must be subjected to a higher degree of design safety. The examples of failures in this article, due to lost of load-bearing, does not aim to lecture the people involved in their design. For this reason, the incidents here are described without names of the concerned parties, in order to be fair to the affected colleagues, while at the same time learning from their mistakes.

**3. Collapses Failures and Merrison Rules**

According [18] the UK Merrison Committee [17,19,20] was set up after the fatal 1970 collapses at Milford Haven Bridge, (Fig. 2a,b,c) when 4 people died, and West Gate (Yarra) Bridge when 34 people died. Key members were Prof Horne and Dr Flint who were charged with examining the reasons for failure, setting up major programmes of theoretical and experimental research on box girder behaviour and rapidly producing the detailed interim design and workmanship rules (IDWR) [18]. Prof Horne and Dr Flint, aided by the transport authorities, BSI Bridges Committee chaired by Dr. Kerensky [18], the steel research, consultancy and contractor community, produced radical new design and assessment rules IDWR in 2 years. This was remarkable and contrasts with the slow fragmented process for the Eurocodes. On Milford Haven, Dr Merrison drawing on, the now largely inaccessible, reports by Shirley-Smith, Pugsley, Jones of RAE and BAC states that *"The primary case of the collapse of the Milford Haven Bridge was a failure of the diaphragm over Pier 6, and that this failure was certainly not primarily due to manufacture of the bridge or its components. The diaphragm as designed simply was not strong enough to resist the severe compressive forces it was subject to during erection."* There was a full public investigation [19,20] of the failure of the West Gate Bridge. Collapse was attributed to two inadequacies: -the designers failed to make the slender stiffened plates and the details of joints which were strong enough; -the contractor adopted an unsuitable method of erection which triggered the collapse.

Reading the full report should be mandatory for all involved in the design or construction of mega-structures, so that they understand the complexity of interacting technical, contractual and human factors which combined to cause the fatal collapse. Following Milford Haven collapse *full height stiffeners had been added to the diaphragms over the bearings at West Gate, but the failure was elsewhere near mid span at a transverse joint between the half boxes as they were being forced together.* The shortcomings of the original design were highlighted by the extent of strengthening required for both the erection process and for service requirements. One unusual feature of West Gate Bridge was the bolted assembly introducing eccentricities in connections of prefabricated stiffened panels. This choice was to avoid site welding after a failure to communicate the requirements for fabrication of the 1962 King Street Bridge [18] led to the brittle fracture of its girders in service. Others had problems with box girders. Research on box girders became a priority worldwide and international cooperation facilitated the progress.

**5. Influence of the Merrison Committee and International Research on the development of steel box girders in the world**

According to [18] the results of this UK work and similar another from around the world [19-24] is reported in many conference proceedings. The Proceedings of the 1976 Conference on "Steel Plated Structures" at Imperial Collage provided updated and test and analytical results. Further developments were covered at the 1977 "ECCS/IABSE Liege" conference on the stability of steel structures. Other relevant research includes. Proceedings of the 1980 Cardiff conference 'New Code for the Design of Steel Bridges' set out the UK state of the art before the issue of BS5400-3 1982 "Steel Bridges". The simplifications in the BS5400-3 meant that the opportunities for more detailed analysis and

advanced design based on the research programmes and the rapid evolution of finite element analysis were inhibited. In the UK box girders were shunned for 30 years after the collapses, with Dartford (1991) and Second Severn main span (1996) being plate girders. In Germany in 1978 the DASt-Ri 012 „Plate buckling" was published. Around the world box girders flourished including Germany (e.g. K.-Adenauer-Bridge 1972), Czech Republic (1974) [19-24] and Bulgaria (1976 and 1986). The "Asparuhov Bridge" in Varna (Fig.10a,b), Orthotropic Bridge in Sofia(Fig.11a,b,c,d), Viaduct "Hemus"(Fig.12a) and the "Gateshead Millennium Bridge" (Fig.13a), shows what can be achieved by exploiting the strengths **and torsional rigidity of box girders.**





**Fig.10a,b.** a) View of the Asparuhov bridge,1976 b) Erection of the blocks

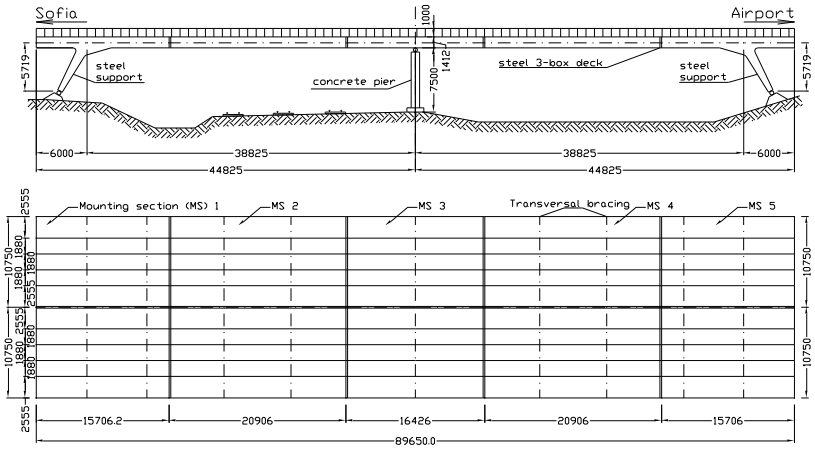



**Fig.11a**. Longitudinal cross-section and top view of the separate sections

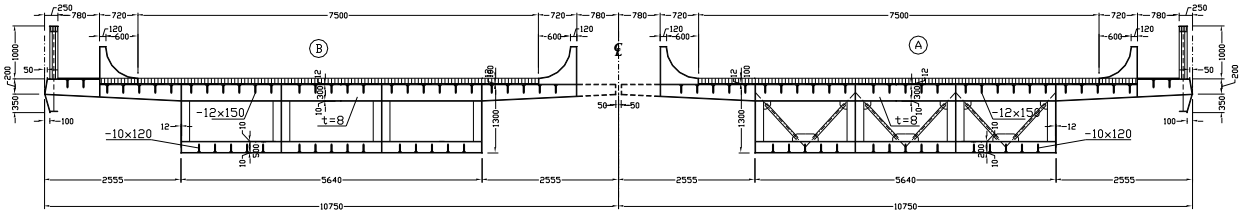



**Fig.11b.** Cross-section of bridge



**Fig. 11c**. A view of the orth. bridge



**Fig. 11d**. A view on the orth.bridge



**Fig. 12a.**. Viaduct 2 "Hemus" highway

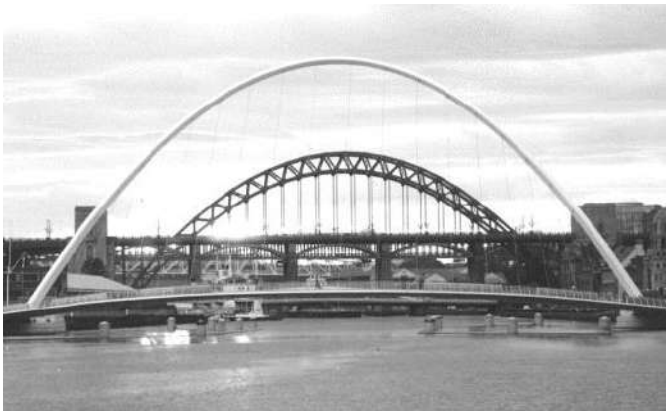


**Fig.13a. a**) Gateshead millennium bridge 1850 to 2000

**Conclusion**

According to [1,19,20,21,22,23 and 24] not one bridge collapse, as reported in this article, was due to inaccurate structural safety analysis. It is also doubtful whether the safety theory based on a probability approach, which is now the basis for all new standards internationally, is likely to reduce the incidence of failure and collapse of structures. This is because the causes are not statistically distributed, but are rather gross errors that do not fit into any probability calculation. Such concepts are perhaps better suited for appraising the serviceability of our structures. They are often forced to extrapolate and to accept the risk this entails [16]. Here the scientific progress in structural engineering has not brought about any radical changes, and hence we agree with H. P. Ekardt [13],*"Construction is in a state of continuous development, progressing through emergency situations and constantly breaking new ground in actual projects, creating something new, and in this respect is removed from state or legal control – the area to be controlled is in itself insufficiently objectified and defined for the requirements of law. What is needed is professional self-control based on knowledge, experience, balanced judgment and responsibility. Control and self-control are the two poles between which the practice of designing innovative load-bearing structures moves, particularly when the area of technology involved is in a state of rapid development..*" The foreword began with a quotation from George Frost [17] and in this sense these descriptions are intended to contribute to the science of engineering. According to J. Scheer´s [1] experience: "*building work is often linked with failure; this has always been the case and always will be"*. Yet if we learn from the circumstances and

mistakes leading up to disasters in the past, we may possibly help to reduce the number of failure occurrences, collapses and catastrophes in the future [1].

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# A MAGNIFICENT NO.7: IVAN MIROSLAV VIEST

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***Abstract:*** *A brief overview of the live and work of a prominent Slovak designer of steel and composite steel and concrete structures: Ivan Viest, who studied at SVŠT (STU) in Bratislava from 1941-1946 and emigrated in USA in 1948. He collected date about the civil engineers (CE), architects (AR) and surveyors (SU) – the graduates of SVŠT in Bratislava who emigrated from 1948 -1989 in more than 12 countries. They are all an integral part of the cultural heritage of The Slovak Republic.*

***Key words****: Slovak structural engineers, emigrants, cultural heritage*

## 1. Introduction

Dr. Ivan M.Viest published a complete list of the names, including the electrical and mechanical engineers, in his autobiography, An Immigrant's story, Xlibris Corporation [3]. He gathered the data together during the period from 1990-1999. His efforts and the support of his friends, acquaintances and a wide circle of emigrants (B. Albrecht, A. K. Skovranek, N. E. Samek, F. Bakeš, J. Závesky, P. Kaiser, B. Sevruk, J. Vlček, P. Lizoň, V. Mocák, etc.) resulted in obtaining very valuable information.

## 2. Dr. Ivan Miroslav Viest, Ph.D

Dr. Viest has been active in the building industry in the USA for 41 years in the field of the design of steel, concrete and composite steel-concrete structural members. He has achieved results which have had a decisive influence on the development of this type of construction both in the USA and other developed countries.

He studied at SVŠT from 1941-1946. In the last year of his study he served as an assistant to a professor of steel structures. He was a member of VRO (the Panslavic Revisionist Organization). Its basic goal was the restoration of the democratic Czechoslovak Republic. He was also a member of the Resistance Movement of the Young

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Generation (Odbojové hnutie mladej generácie) until the liberation of Slovakia in 1945. In addition, he took part in the Slovak National Uprising (SNP). He passed his final examination with honors at the Branch of Construction Engineering (OIS) of the Slovak Technical University in Bratislava. He graduated and obtained the degree of Ing. in1946. In the same year he accepted a job as an engineer with the Slovak construction enterprise Lanna. In March 1947, he was awarded a scholarship by the Rotary Clubs of Georgia for studies in the United States. Due to the events in February 1948, he decided to accept the position of a research assistant at the University of Illinois in Urbana in the Department of Theoretical and Applied Mechanics.



**Fig. 1 Dr. Ivan Viest (10.10.1922, Bratislava – 11.02.2012, Village, Bethlehem, USA)**

His advaned studies were completed with his achievement of the degree of Doctor of Philosophy (PhD.) in 1951. He celebrated the Golden Jubilee of his marriage to Barbara K. Stevenson. He met his wife 1952 as she was completing her studies in Chemistry at the University of Illinois. They were married in May 1953. In the following year he became a member of the Council of Free Czechoslovakia (Rada slobodného Československa).

In May 1953, Dr. Viest was placed in charge of the shear strength of reinforced concrete and the strength of long reinforced concrete columns research. The significant results he achieved have been exclusively used up to the present. In March 1954, he started experimental research into stud shear connectors of composite steel- concrete structural members. The requirements for the design of stud shear connectors, developed by Dr. Viest were adopted by AASHO (the American Association of State Highway Officials) in 1956. The studs were first used in a bridge in the same year.

In 1955, Dr. Viest became a citizen of the United States.

In 1956, he proposed the formation of a committee on composite structures that was established jointly by ASCE (the American Society of Civil Engineers) and ICI (the American Concrete Institute). The Committee's design recommendations were published in 1960. Guidelines for the design of composite structures were published by AISC in 1961. Around 1970, composite design became an accepted practice throughout the United States. The results in the field of repeated loading of bridge members and the achievement of an ultimate limit state were utilized in practice after AASHO issued the Load Factor Design for steel highway bridges in 1971.

After leaving the Bethlehem Steel Corporation in 1982, he opened an independent practice as a consulting structural engineer. He named it IMV Consulting. Dr. Viest organized and chaired the first Engineering Foundation Conference on Composite Construction held in 1987 in New Hampshire. The conference was repeated in 1992 in Missouri, in 1996 in Germany, in 2000 in Canada, in 2004 in South Africa, and in 2008 in Denver. In March 1990, Dr. Viest made his first visit to Slovakia. During this and subsequent visits he re-established personal contacts and contacts with the professional public and universities in Slovakia. Over the years, Dr. Viest has participated in the activities of many national and international professional societies including among others, the NAE, ASCE, AASHO, AISI (the American Iron and Steel Institute), BSSC (the

Building Seismic Safety Council), TRB (the Transportation Research Board), IABSE (the International Association for Bridge and Structural Engineering), RCRC (the Reinforced Concrete Research Council), etc. He has held important positions in many of these associations and has been awarded honours. In 2002, he was honoured with the title Doctor Honoris Causa by the Technical University of Košice. After 1989 visited several times Department of Metal and Timber Structures, Faculty of Civil Engineering, STU in Bratislava. He gave lectures there and donated a collection of professional American journals to the department. He corresponded with the first author for several years.

Dr. Viest has authored and co-authored five books and about 150 articles published in refereed professional journals devoted to: a) Composite Structures [2], b) History of Engineering Foundation [1], Fig.2, c ) his autobiography: "An Immigrant's Story" [3], Fig. 2. There has also been a family tree of the Viests since 1700. He is the son of Ivan G. Viest and Mária Zacharová. His father was a mechanical engineer with the Slovak Railroad and became president of its operations in 1936. His older sister, Zora, died in 2002 and Ivan was survived by his younger sister, Tatiana Maria Šimková, several nieces and nephews in Slovakia. General Rudolf Viest is his uncle and Ivan Šimko, a politician, is his nephew. General Viest, a member of the Czechoslovakia government in exile in London during WWII, became a commander of the Army in Slovakia in 1944. He was captured by the Germans in 1944 and killed in Berlin in 1945.

Some of his publications may be seen in Figs. 2 and 3.

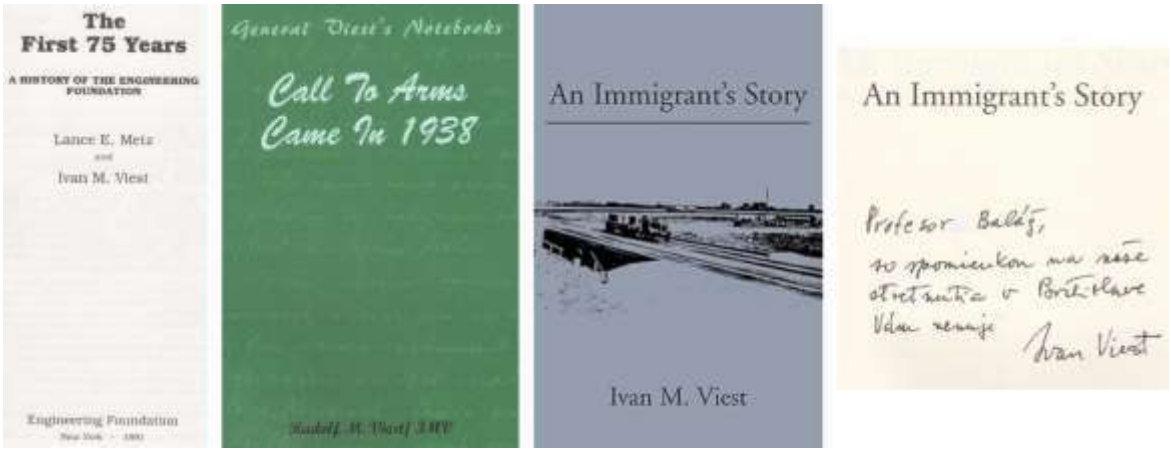



**Fig. 2 Books written by Dr. Viest. From the left: 1991 [1], 2009 [4], 2006 [3]**

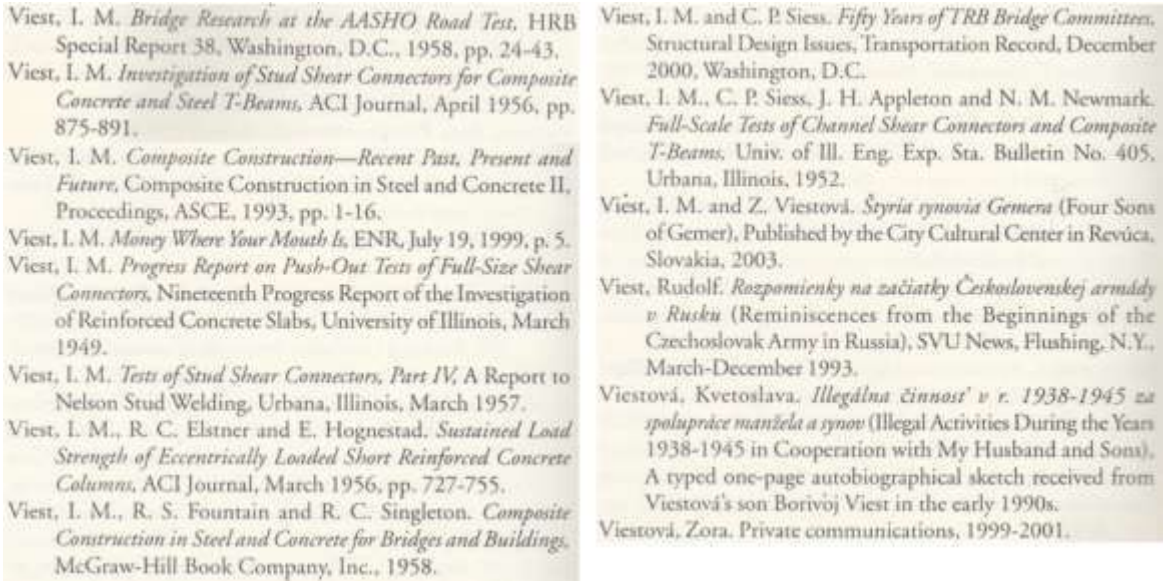

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**Fig. 3 Publications written by Dr. Viest**

## 3. The civil engineers (CE), architects (AR) and surveyors (SU) – the graduates of SVŠT (STU) in Bratislava who emigrated from 1948 -1989

**Table 1 The list of civil engineers (CE), architects (AR) and surveyors (SU) – the graduates of STU (SVŠT) in Bratislava who emigrated from 1948 -1989, where the data about the year of graduation and study fields are known**

| No | Name Surname | Graduation at STU | Field of study | Occupation (institution/position) | Workplace (country) | Year of emigration |
|---|---|---|---|---|---|---|
| 1 | Bohumil Albrecht | 1944 | CE | Univ. of NM/Professor of Mechanical Engineering | USA | 1947 |
| 2 | Juraj Bajgar | 1964 | CE | | USA | |
| 3 | Frank Bakeš | 1958 | CE | Burns & Roe/Hydraulics | USA | |
| 4 | Mária Bakeš | 1960 | CE | N. Massand/Project | USA | |
| 5 | Peter Bart | 1966 | AR | U. S. State Department | USA | |
| 6 | Bruno Beisetzer | 1967 | AR | Private Practice/Project | USA | 1969 |
| 7 | Vladimír Bláha | 1959 | CE | Deutsche Welle/ Television Editor & Author | Germany | 1963 |
| 8 | Boris Boor | 1951 | CE | | Peru | |
| 9 | Dušan Botka | 1966 | AR | | Greece | |
| 10 | Ľubomír Brezina | 1963 | AR | | Canada | |
| 11 | Oldrich Brychta | 1964 | CE | Road & Traffic Authority NSW Australia/Designer | Australia | 1968 |
| 12 | Miroslav Bubak | 1966 | CE | | Canada | |
| 13 | František Bubenko | 1966 | AR | | USA | 1968 |
| 14 | Ján Buzák | 1967 | CE | Architect M. Bolczek | USA | |
| 15 | Ladislav Černý | 1952 | CE | Univ. of MN/Professor of Civil Engineering | USA | |
| 16 | Karol Chlebana | 1979 | CE | U. S. Army Corps of Engineers, / Project Leader | Germany | |
| 17 | Dušan Chovanec | 1958 | CE | Cantonal Gov./Bridges | Switzerland | 1968 |
| 18 | Emery (Imrich) Csintalan | 1953 | CE | | USA | |
| 19 | Peter Danišovič | 1959 | CE | | Canada alebo USA | |
| 20 | Thomas Day-Madunicky (Tomáš Madunický) | 1961 | CE | Greater Vancouver Region. District/Proj. Manager, Consultant & Lecturer | Canada | 1968 |
| 21 | Jozef Dolezel | 1966 | AR | | Canada | |
| 22 | Ladislav Domen | 1967 | AR | Vlastimil Koubek Architects | USA | 1968 |
| 23 | Tomáš Dratva | 1960 | CE | | Switzerland | |
| 24 | Miloslav Drobný | 1973 | CE | H. A. Simons/Structural Engineer | Canada | 1974 |
| 25 | Oldřich Držmíšek | 1962 | CE | | Switzerland | 1968 |
| 26 | Jean Eteny (Ján Heténi) | 1967 | AR | Digital Equipment Corp. International | Switzerland | 1968 |
| 27 | Lubomír A. Farkaš | 1978 | AR | | USA | |
| 28 | Martin Gregor | 1976 | AR | | USA | |
| 29 | Robert Havrančík | 1978 | AR | | | |
| 30 | Ivan Hliva | 1968 | CE | | Canada | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 31 | Irena Hliva rod. Kuliačková | 1969 | CE | | Canada | |
| 32 | Aladár Horský | 1963 | CE | | Germany | 1968 |
| 33 | Peter Horvay | 1961 | AR | | Germany | 1968 |
| 34 | Peter Hron | 1967 | AR | | Germany | 1968 |
| 35 | Ján Hudoba | 1968 | CE | Regional Municipality Hamilton/Struct. Eng. | Canada | 1968 |
| 36 | Otília Hudoba | 1968 | CE | Regional Municipality Hamilton/Struct. Eng. | Canada | 1968 |
| 37 | Štefan Izakovič | 1959 | AR | | Switzerland | 1968 |
| 38 | Valéria Janek | 1966 | AR | | Germany | 1968 |
| 39 | Igor Jeník | 1966 | AR | | Germany | 1968 |
| 40 | Ján Alexander Janovjak | 1961 | CE | Shell Canada Products Ltd./Engineering Coordinator | Canada | 1969 |
| 41 | Ludwig (Ľudovít) Jochmann | 1967 | CE | Hess | Switzerland | 1969 |
| 42 | Alica Juldašová | 1967 | CE | Stahlton | Switzerland | 1969 |
| 43 | Martin Kianička | 1965 | CE | | Switzerland | |
| 44 | Ján Kočí | 1949 | AR | | Austria | |
| 45 | Ivan Kocián | 1964 | AR | Technical University Braunschweig/Architect | Germany | |
| 46 | Mária Korónyiová | 1974 | CE | | USA | |
| 47 | Jozef Košinár | 1961 | CE | | Australia | |
| 48 | Ivan Kot | 1967 | AR | | Germany | 1968 |
| 49 | Ivan Kralovič | 1963 | CE | | Canada | 1968 |
| 50 | Michal Kravec | 1968 | AR | Private Practice | Germany | 1968 |
| 51 | Anton Krivosudský | 1976 | AR | | | |
| 52 | Vlasta Krupková rod. Flamiková | 1966 | AR | Columbia Broadcasting | USA | 1968 |
| 53 | Igor Labuda | 1978 | AR | | USA | |
| 54 | Jana Lebeda rod. Čižmáriková | 1963 | CE | | Switzerland | |
| 55 | Peter Lizoň | 1961 | CE | Univ. of Tennessee/Prof. of Architecture | USA | 1968 |
| 56 | Milan Lojdl | 1965 | AR | Private Practice, Milan Architects Inc. | USA | 1970 |
| 57 | Eva Lojdl rod. Virsíková | 1965 | AR | Private Practice, Milan Architects Inc. | USA | 1970 |
| 58 | Leo Longauer | 1962 | CE | | Switzerland | 1968 |
| 59 | František Lošonský | 1964 | CE | | Germany | 1968 |
| 60 | Helena Macková rod. Lednárová | 1966 | AR | | | 1968 |
| 61 | Mária Maderová rod. Veselá | 1977 | CE | | Switzerland | |
| 62 | Magdaléna Majeská rod. Furdová | 1963 | CE | Ontario Department Transportation | Canada | 1968 |
| 63 | Fedor Maňka | 1961 | CE | | USA | |
| 64 | Anton Mathia | 1976 | AR | | Germany | |
| 65 | Fedor Medek | 1966 | AR | | Australia | 1968 |
| 66 | Tibor Mernický | 1966 | AR | | Canada | 1968 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 67 | Pavol Miklian | 1967 | AR | | Sweden | 1968 |
| 68 | Rudolf Mitura | 1963 | CE | | Switzerland | 1968 |
| 69 | Valér Mocák | 1955 | AR | Private Practice/Expert Consultant | USA | 1969 |
| 70 | Vladimír Fedor Obrcian | 1944 | CE | Ammann & Whitney/Head, Geotechnical Laboratory | USA | 1947 |
| 71 | Ivan Ondruš | 1963 | CE | | Sweden | 1968 |
| 72 | Júlia Ondruš rod. Denčíková | 1964 | CE | | Sweden | 1968 |
| 73 | Oldřich Pajkrt | 1961 | CE | | Netherlands | 1968 |
| 74 | Branislav Pavúk | 1970 | CE | | | |
| 75 | Stanislav Pisončík | 1964 | CE | Holmes & Narver, Inc./Design Leader | USA | 1968 |
| 76 | Ivar Plašil | 1955 | CE | Krup Stahl AG/Head, Design of Engineered Structures | Germany | 1969 |
| 77 | Rastislav Porubský | 1965 | CE | | Switzerland | 1968 |
| 78 | Alena Pospíšilová | 1967 | AR | | Great Britain | 1968 |
| 79 | Milan Ružek | 1963 | CE | | Switzerland | 1968 |
| 80 | Zoltán Šáro | 1974 | AR | | USA | |
| 81 | Angela Schmidt | 1967 | CE | Architektbüro | Switzerland | 1968 |
| 82 | Marián Sečanský | 1964 | CE | | Switzerland | |
| 83 | Boris Sevruk | 1961 | CE | Federal Institute of Technology/Senior Scientist | Switzerland | 1968 |
| 84 | Stefan Simek | 1964 | CE | Ferguson Simek Clark/President & Principal | Canada | 1968 |
| 85 | Františka Sitnaiová (Szitnyaiová) | 1957 | CE | Beatti & Pronse | Australia | |
| 86 | Tomáš Skalský | 1967 | CE | | Switzerland | 1969 |
| 87 | Pavol Slávik | 1966 | AR | | Germany | 1968 |
| 88 | Peter Soldát | 1971 | CE | | USA | |
| 89 | Pavel Stankay | 1967 | CE | | USA | 1968 |
| 90 | Norbert Štibráni | 1958 | CE | Project Planning, Ltd. | Canada | 1969 |
| 91 | Peter Straka | 1964 | CE | Sze Straka Engineers Ltd./President | Canada | 1968 |
| 92 | Charles S. Strelka | 1966 | CE | Kuchar & Strelka | Canada | 1968 |
| 93 | Ladislav Stucka | 1967 | AR | | USA | 1968 |
| 94 | Ján Švihra | 1965 | CE | Keewatin-Aski Ltd./Vice-President | Canada | 1969 |
| 95 | Juraj Sýkora | 1963 | CE | | Canada | 1968 |
| 96 | Darina Sýkora rod. Uhrínová | 1963 | CE | | Canada | 1968 |
| 97 | Dennis S. Tarnay | 1957 | CE | U. S. Department of Energy-Federal Energy Regulatory Commission | USA | 1967 |
| 98 | Ján Teichner | 1962 | CE | | Germany | 1968 |
| 99 | Pavol Timkanič | 1967 | CE | Hackensack Water Co. | USA | 1968 |
| 100 | Peter Toth | 1958 | CE | | Canada | |
| 101 | Martin Trnovský | 1966 | CE | Ground Water Technology Inc./Manager, Caribean Operations | USA | 1967 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 102 | Danica Truchlík | 1965 | AR | Lawrence Berkeley Labs Univ. of California/Facilities Architect | USA | |
| 103 | Boris Uskert | 1966 | CE | Morrison Knudsen Co.-International Engineering Co./Head Architect | USA | 1968 |
| 104 | František Veleba | 1967 | CE | | Germany | 1968 |
| 105 | Peter Venetianer | 1964 | CE | | Switzerland | 1968 |
| 106 | Ivan Miroslav Viest | 1946 | CE | Private Practice/Consulting Engineer | USA | 1947 |
| 107 | Juraj Višný | 1962 | AR | | Switzerland | |
| 108 | Josef Karl Vlček | 1956 | CE | C & V Engineering/Principal | Canada | 1969 |
| 109 | Josef Anton Vlček | 1950 | CE | Private Expert/Construction Logistics | Switzerland | 1969 |
| 110 | Marián Weber | 1968 | AR | | Switzerland | 1968 |
| 111 | Joseph Yeast (Kvasnica) | 1966 | AR | | Great Britain | 1968 |
| 112 | Ján Zavesky | 1959 | CE | Road & Traffic Authority NSW/Head, Bridge Design | Australia | 1968 |
| 113 | Aristíd Zelenay | 1953 | CE | | Switzerland | |

**Table 2 The list of civil engineers (CE), architects (AR) and surveyors (SU) – the graduates of STU (SVŠT) in Bratislava who emigrated from 1948-1989, where all the data are not known**

| No | **Name Surname** | **Graduation at STU** | **Field of study** | **Occupation (institution/ position)** | **Workplace (country)** | **Year of emigration** |
|---|---|---|---|---|---|---|
| 1 | Jozef Andraško | 1967 | CE | Private Practice | Hamburg, Germany | 1968 |
| 2 | Ivan Bolcek | | AR | | USA | |
| 3 | Igor Čelko | | AR | | Switzerland | |
| 4 | Viera Držmíšková | | CE | | Switzerland | 1968 |
| 5 | Jakub Hluchý | | AR | | Switzerland | |
| 6 | Bern Pavol Karamann | | AR | | Switzerland | 1968 |
| 7 | Jaroslav Kevický | | AR | | Canada | 1968 |
| 8 | Mária Kianičková | | CE | | Switzerland | |
| 9 | Ivan Klinovský | | CE | | Canada | 1968 |
| 10 | Anna Kohler | | CE | Private Practice | Australia | 1969 |
| 11 | Lucia Korbelová | | AR | | | |
| 12 | Peter Korda | | SU | Government | Switzerland | 1965 |
| 13 | Dušan Lamoš | | CE | Fondexcan | Canada | |
| 14 | Amer Massarani | 1977 | CE | | Canada | |
| 15 | Pavol Minárik | | AR | | | |
| 16 | Milan Miske | | AR | | USA | 1968 |
| 17 | Jevoslav Opial | 1966 | CE | | Switzerland | |
| 18 | Marcela Pauer | | CE | | Germany | 1969 |
| 19 | Paul Putora | | AR | Lanny Investment, Inc. | USA & Switzerland | 1968 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 20 | Boris Rajek | | CE | | USA | 1968 |
| 21 | Pavol Rázgha | | CE | | USA | |
| 22 | Rastislav Schrenk | | AR | | Germany | |
| 23 | Vojtech Šebesta | | CE | Private Practice | USA | 1968 |
| 24 | Šebestová | | CE | Private Practice | USA | |
| 25 | Fero Šimko | | AR | Schultze Simko/Partner | Germany | |
| 26 | Stanislav Stančík | | AR | | Switzerland | 1968 |
| 27 | Paul Štefka | | CE | | Great Britain | 1968 |
| 28 | Otto Švec | | CE | National Research Council/Building Research | Canada | |
| 29 | Náco Vacval | | CE | | Canada | |
| 30 | Ada Weberová | | AR | | Switzerland | 1969 |

## 4. Statistical evaluation

The list of data about 249 persons is divided into two parts in the book. In the first part there are 172 names whose year of graduation from the STU and field of study are known. In the second part the data are not complete. The structure of the graduates of STU (SVŠT) who are listed as emigrants in the first part can be seen in Table 1. The percentage that depended on the period of emigration is illustrated in Table 2. The graduates of STU (SVŠT) emigrants on Dr. Viest's list of names settled in more than 12 countries. The table shows the percentage ratio depending on the country they emigrated to. Their application in practice is shown in the next table.

**Table 3 The percentage ratio of graduates of STU – the emigrants in the first part of the list**

| Civil engineers | Architects | Electrical engineers | Electrical engineers | Chemical Engineers |
|---|---|---|---|---|
| 43 % | 23 % | 14 % | 14 % | 5 % |

**Table 4 The percentage ratio of graduates depending on the period of emigration in the first part of the list**

| Before 1968 | in 1968 | in 1969 | After 1969 |
|---|---|---|---|
| 6 % | 70 % | 16 % | 8 % |

**Table 5 The percentage ratio in depending on the country the persons from the first part of the list emigrated to**

| USA | Canada | Switzerland | Germany | Australia | Other countries (Austria, Great Britain, Greece, the Netherlands, Peru, South Africa, Sweden) |
|---|---|---|---|---|---|
| 1/3 | 1/4 | 1/5 | 1/10 | 1/20 | 1/15 |

**Table 6 Application in practice of the graduates of the STU emigrants from the first part of the list (most of them are employed in the private sector)**

| Design and consultations | Industry | State organizations, universities, etc. |
|---|---|---|
| 1/2 | 1/4 | 1/4 |

Dr. Viest quotes from an article by J. Vlček in his book Czechoslovak Engineers and Architects (1990): "The knowledge of graduates of Czechoslovak technical universities

enabled them to be highly respected and to become successful. The quality of Czechoslovak universities meets the requirements of universities abroad. Dr. Viest gives examples of the unique structures, the emigrant graduates of STU (SVŠT) participated in.

They are, e.g., high-rise office buildings, banks, and hospitals in cities such as New York, Boston, Montreal, Paris, Singapore, the Opera House in Sydney, prestressed bridges in Australia, the Verrazano Narrows suspension bridge in New York, the Kohlbrandbrücke cable-stayed bridge in Hamburg, etc.

The shortened version of the first and second part of the list of graduates of STU (SVŠT) which was developed by Dr. Viest can be found in the above tables. Some parts of both lists concerning only the graduates related to the Faculty of Civil Engineering: civil engineers, architects and surveyors have been used with his permission [11].

The first author has several letters from Dr. Viest, including his own biography with very interesting details not given in this paper. The biography was submitted by the first author to authors of encyclopedia Beliana.

Interesting is the following taken from one of his letter: „I have a computer, I am writing this letter on it. I was first introduced to computers during the 1947/48 school year at the Georgia Institute of Technology. I started programming myself in the late 1950s. I bought my first personal computer in the early 1980s. I am not connected to the Internet, as I have decided to prevent anyone else from accessing my computer". The letter was written in perfect Slovak on January 11, 2009.

**Conclusion**

The five Slovak prominent designers: Kozák, J., Bustin, J., Behul, V., Martinček, M. and Bezák, I. and their structures are described in [13]. As Magnificent No.6 can be considered Poštulka, J. [14]. Dr. Ivan Viest is therefore considered as Magnificent No.7. All these great men were exceptionally modest.

The guiding principles of Dr. Viest:

1. Learn to like your everyday work and embrace it fully;
2. Steer your work toward the future but also endeavour to learn from history;
3. Maintain good relationships with your co-workers, as well as with a wide circle of friends and acquaintances; and
4. Do not forget the need for relaxation in a variety of forms such as sports (he has climbed several peaks, he enjoyed skiing and playing tennis and he is fond of playing golf), reading books and magazines, travel, participation in cultural events, etc.

Memorial Tribute to Dr. Viest was written: a) by GT Georgia Tech, School of Civil and Environmental Engineering, College of Engineering [5] and b) by famous John W. Fisher (1931), who visited Bratislava in 1994 with group of several American professors [6] on web side National Academy of Engineering [7]. Dr. Viest wrote Memorial Tributes to three famous Americans: a) Anton Tedesko (1903-1994) [8], b) Eivind Hognestad (1921-2000) [9] and c) Jackson Leland Durkee (1922–2007) [10], who thanks to Dr. Viest sent to the first author his collection of bridges with world record spans. Durkee obtained collection from LaBelle, both worked at Bethlehem Steel Corporation.

Information about three Slovak emigrants may be found in [12].

**Acknowledgement**

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# КРАТКА ИСТОРИЯ НА МОСТА НА ДЖЕЙМС БЮКАНЪН ИЙДС, НАД РЕКА МИСИСИПИ В ПЕРИОДА 1867-1874

ст. преп. Антоанета Димитрова Димитрова[1]

[1] ВСУ „Любен Каравелов“

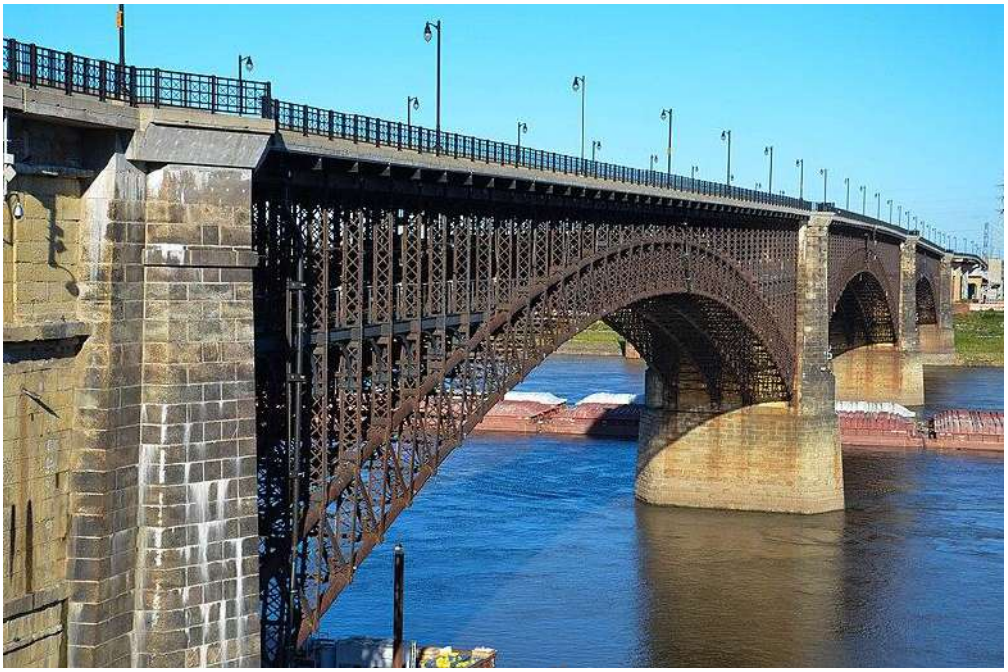
***Резюме**: Изследването прави кратък обзор на **Мостът Ийдс**, проектиран и построен от известния самоук инженер Джеймс Бюканън Ийдс в периода 1867-74 г., знаен като най-старият мост покрил обемното корито на река Мисисипи, при Сейнт Луис, явяващо се най-мащабното мостово съоръжение за времето си, както и първият комбиниран автомобилен и железопътен **мост**, изграден изцяло от стоманена конструкция. **Мостът Ийдс** е съоръжение, което инженерите биха нарекли „свръх застроен/о“, но Джеймс Бюканън Ийдс развива дързък иновативен подход в проектирането на мостовото съоръжение от такъв мащаб. **Мостът Ийдс** е първият, изграден с помощта на тръбни елементи и първият, който разчита изцяло на конзолна конструкция за изграждане на мостовата конструкция. В конструктивен аспект, мостът е погледнал и назад във времето, използвайки **римската арка**, като конструктивен елемент;пневматични кесони са били използвани при изграждането на опорите на моста, вкопани до недръзваната до тогава дълбочина от над 100 фута, до достигане на твърдо дъно.*

***Ключови думи:** мост, Мостът Ийдс, стомана, стоманена дъга, оребрена арка, конзолна конструкция, пневматични кесони*

## 1. Въведение

***Мостът Ийдс*** носи името на Джеймс Бюканън Ийдс, самоук инженер, проектирал и построил несравнимото съоръжение през 2-та половина на XIX век. ***Мостът Ийдс*** е първият мост през Мисисипи на юг от река Мисури. По-ранни мостове е имало на север от Мисури, където реката Мисисипи е по-тясна. Нито един от по-ранните мостове не е оцелял, което предопределя ***Ийдс*** като най-старият мост, премостващ реката. ***Мостът*** представлява комбинирана конструкция, която поема автомобилен трафик и обезпечава железопътен превоз над река Мисисипи, свързвайки градовете Сейнт Луис, Мисури, и Източен Сейнт Луис на щата Илинойс. Градежът на моста започва през 1867 г. Завършен е през 1874 (Фиг.1).

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**Фиг.1**. Мостът Ийдс, от Сейнт Луис до Източен Сейнт Луис, Илинойс, над р. Мисисипи (https://en.wikipedia.org/wiki/Eads_Bridge)

## 2. Основни параметри на моста

Основните параметри на моста са посочени в таблица 1.

Таблица 1.

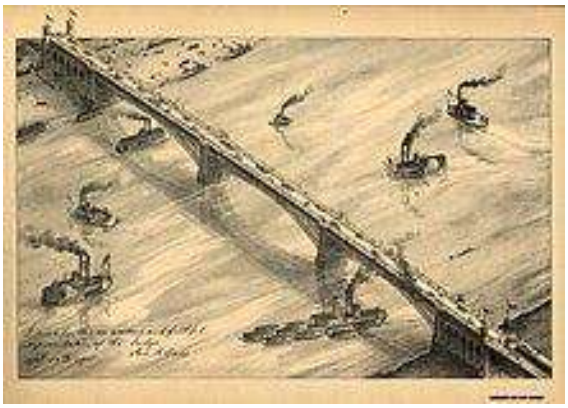
| | |
|---|---|
| **Координати** | 38°37′41″N 90°10′17″W |
| **Тип** | Арковиден мост |
| **Обща дължина** | 6,442 ft (1,964 m) |
| **Широчина** | 46 ft (14 m) |
| **Най-дълgo премостване** | 520 ft (158 m) |

За да поеме огромния воден обем и обуздае мощта на река Мисисипи, мостът ***Ийдс*** изисква поредица от инженерни подвизи, като широкото използване на **стомана** като строителен материал, **която** измества кованото желязо като основен материал за мащабни конструкции тогава. Основите на ***Ийдс***, вкопани на дълбочина от над 100 фута под вода, се явяват най-дълбоките подводни конструкции по онова време. Инсталирани са с помощта на пневматични кесони, безспорно, абсолютно иновативно приложение на кесонна технология в Съединените щати в онези дни. Те се явяват най-големите кесонни ботуши, изграждани някога. **Централният отвор на моста бил изпълнен с дъгова прътова стоманена конструкция,** с дължина на премостване от 520 фута, което представлява е най-дългият масивен участък, построяван по онова време. Арковидните дъги са били строени като конструкции, висящи от временно изграждани дървени кули, споменавани дори като използването за първи път на "конзолен принцип" за мащабно мостово съоръжение от такъв вид. Тези инженерни принципи са използвани в последствие за изграждането на по-късни мостове, например Бруклинският мост, през 1870 г. Мостът е вписан в Националния регистър на историческите места като национална историческа забележителност(фиг.2-8) (https://en.wikipedia.org/wiki/Eads_Bridge).



**Фиг.2.** Плакат от около 1874 г., илюстриращ конструкцията на моста





**Фиг.3.** Мостът Ийдс в процес на изграждане около 1874 г.
**Фиг.4.** Рисунка на моста Ийдс от 1875 г., от Камил Н. Драй





**Фиг.5.** Пункт за събиране на пътни такси
**Фиг.6.** Мостът Ийдс - поглед от станция East Riverfront St. Louis MetroLink





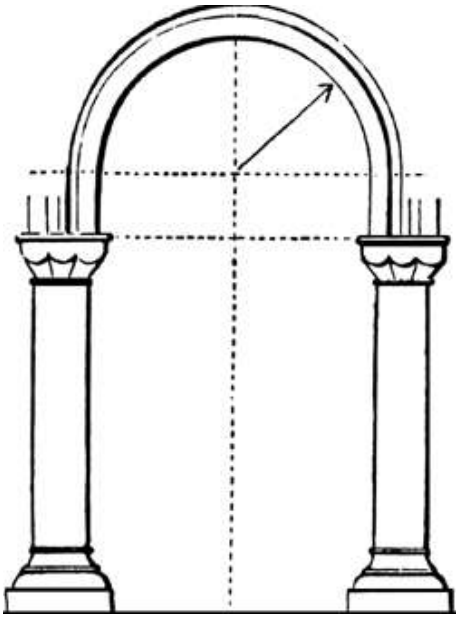
**Фиг.7.** Мостът Ийдс, показващ движението на MetroLink влак на долен пътен дек. Видими са светлинните стълбове на горната автомобилна платформа.
**Фиг.8.** Преминаващ влак на MetroLink по моста Ийдс

### 3. Приложение на съоръжението

**Разрастването на железопътните линии** след Гражданската война потиска значително равитието на речното корабоплаване. По този начин Чикаго се утвърждава като център на търговията на Запад. Мостът е бил предвиден да възстанови величието на Сейнт Луис като център на търговията, чрез свързване на железопътния и автомобилния транспорт през реката. Джеймс Ийдс е бил избран за главен инженер по изграждане на съоръжението. Мостът е построен от компанията за мостови съоръжения ***„Илинойс и Сейнт Луис“***. Подизпълнител е ***„Кийстоун Бридж Къмпани“***, основана през 1865 г. от Андрю Карнеги, ***които*** изграждат стоманената конструкция на моста. **В опит да подсигурят бъдеще на плавателните си съдове**, както и в защита на интересите си, параходните компании лобират за поставяне на ограничения в строителството на мостове, поставяйки непосилни стандарти за разстояния и височини, нечувани преди. Това е наложено, за да се подсигури необходимо експлоатационно пространство за плавателните съдове под основата на мостовете, по онова време. Заинтересованите страни на параходните компании са планирали да предотвратят изграждането на каквито и да е съоръжения или конструкции, с цел да си осигурят продължително надмощие в речния трафик, както и за поддържане на търговията в региона, а и да държат в зависимост друг вид транспортни превозвачи. Скрита цел е било да се изисква изграждането на мост, толкова грандиозен и висок, че да е **не**възможно да се издигне, следвайки общоприети/установени строителни техники. Такъв мост би изискал радикално инженерно решение в процеса на проектиране. Силното течение на река Мисисипи е било почти 3.8 метра в секунда, а през зимата строителите е трябвало да преодоляват и ледени пластове.

### 4. Аналогия на моста с три-отворна дъгова конструкция

**Оребрената арка** е добре известна строителна техника от векове. Конструкцията на тръбна метална арка с три участъка се поддържа от зауствания в двата края, т.е. в двата бряга, както и от носещи колони или опори в средата на реката. За този мост, четири чифта арки на участък (горна и долна) са били предвидени - на разстояние от осем фута (2,4 м) една от друга, поддържайки дек или пътно платно за автомобилен трафик на горно ниво, и железопътна платформа на долно ниво. **Конструкцията** включва разнообразни, но и озадачаващи проектантски решения, адресирайки различни напрежения. Тогава, щатските и федерални регулации не позволяват висящи или подемни мостове, или дървени конструкции. Има ограничения за дължината на отсечката на премостване и за височината над линията на водното ниво/платно. Освен това, местоположението изисква съгласуване на разликите във височините - от ниската заливна низина на Илинойс на източния бряг на реката до високата скала на Мисури на западния бряг. Видовете натиск, сили на въздействие и напрежения води до проектирането на мост, разпознат и признат като иновативен по отношение на прецизност и точност на конструкцията, както и по контрол на качеството. В този случай, това е първото използване на легирана стомана, като строителен материал в/за **мащабна строителна конструкция**, чрез използване на компоненти от лята хромирана стомана – въпреки че, както показват лабораторни изпитвания от 1988 г., количеството хром е било твърде ниско, за да има даде ефект на якост и здравина. Завършеният мост също използва значителни, но неизвестни количества ковано желязо. Идс твърди, че голямата устойчивост на сила на натиск на стоманата е много подходяща за използването й при дизайн на **издигната** (на височина) **арка или римска арка**, или например: Stilted Arch (Фиг.9).



**Фиг.9.** Схема на римска арка (https://encyclopedia2.thefreedictionary.com/stilted+arch)

**Решението** му е резултат от странна комбинация от случайност и необходимост, предимно поради недостатъчно добри **съпромат свойства** на **алтернативни материали**.

## 5. Технология на фундиране на моста

**Скалната основа** е можело да бъде достигната само чрез дълбоко сондиране, бидейки 125 фута (38 м) под нивото на водата от страната на Илинойс и 85 фута (26 м) в дълбочина от страната на Мисури. **Специфични** физически трудности на обекта стимулират интересни строителни решения. Дълбоките кесони, използвани за изграждане на подпорните колони и носещи опори, отбелязват нова глава в гражданското строителство. Носещите стълбове са изл**е**ти на почти 30 м. под повърхността на нивото на реката. Бидейки възпрепятствани да изградят временна подпорна скелетно-рамкова конструкция за изграждането на арковидните дъги, което би попречило на плаването по реката, инженерите на Ийдс изобретяват конзолна такелажна система. **Зидани стълбове** са издигнати на височина от почти 37 метра - приблизително височината на 10-етажна сграда. Около 24 метра от този участък е изкопан през пясъчното корито на реката, до достигането на скално дъно. Идс прилага строителен метод, който е наблюдавал в Европа, при който зидарията се поставя/изгражда върху метална камера, пълна със сгъстен въздух. В камерата се добавя камък, което води до потъването на кесона. Работници се гмуркат в кесона, за да нахвърлят пясъка в помпа, която го изстрелва във въздуха, за да може зидарията да бъде изпълнена и така вложена в коритото на реката.

## 6. Значимост на моста в онази епоха и отношението на обществото при неговото откриване

**Мостът Ийдс** е бил признат за безспорно иновативно и вълнуващо постижение. През целия си живот, Ийдс придобива 47 патента, много от които са били получени за части от конструкцията на моста и устройствата за неговото изграждане. На 14 юни 1874 г. Джон Робинсън повежда "пробен слон" тест-разходка по новия мост Ийдс, за да докаже, че е безопасно. Огромна тълпа аплодира, докато слон се тътри тромаво към Илинойс. Общоприето вярване гласи, че слоновете имат инстинкти, които биха ги накарали да **не** да стъпват върху опасни конструкции. Ийдс организира движението на 14 локомотива, които преминават едновременно през моста, в двете посоки. Президентът Улисис С. Грант освещава моста на 4 юли 1874 г. Генерал Уилям Т. Шърман забива златната пика, отбелязвайки края на изграждането на съоръжението. Честването в деня на откриването на 4 юли 1874 г. включва парад, който се простира на 24 км по улиците на Сейнт Луис. **През 1949 г.** здравината на моста е изпитана с електромагнитни тензодатчици. Установено е, че първоначалната оценка на Eads за допустимо натоварване от 3000 паунда на фут (4500 кг/м) може да бъде увеличена до 5000 паунда на фут (7400 кг/м). Според Карол Феринг Шепли, професионален писател, който е написал биография на дизайнера на моста, мостът Ийдс все още се счита за един от най-мащабните мостове, строени някога.

## 7. Търсене на аналогия между три-отворна каменна дъгова конструкция и три-отворна стоманена конструкция

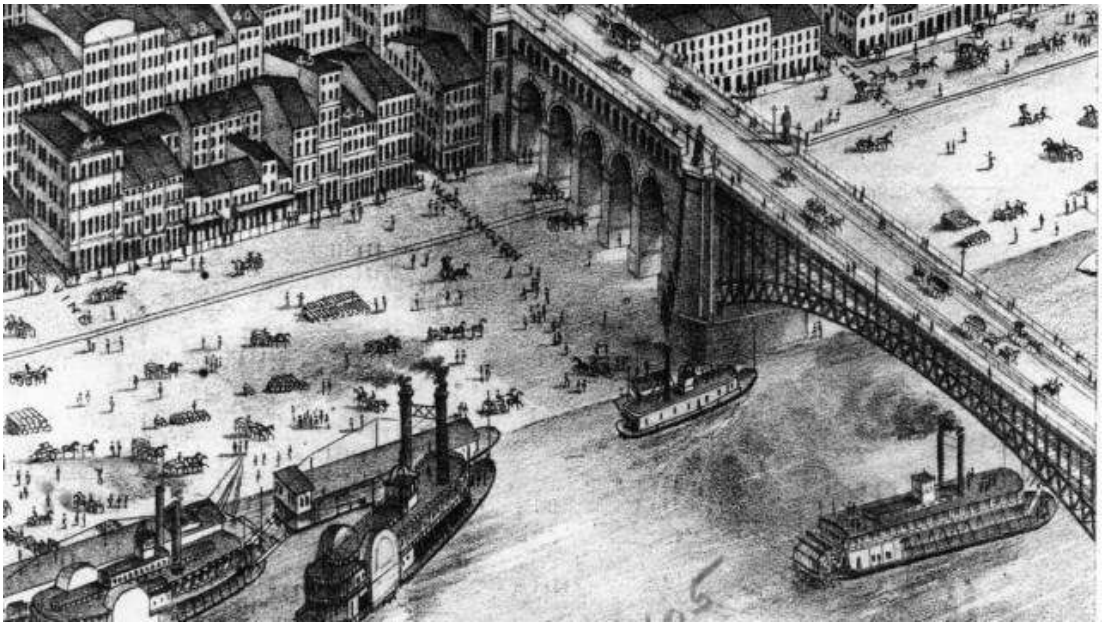
**Джеймс Ийдс** никога не бил строил мостове. В онези времена Ийдс се залавя да спасява и възстановява разбити параходи по реките Мисисипи и Мисури. Знаен е като самоук инженер. За да бъде възможно да се премости реката при Сейнт Луис, Ийдс е изискал направата или изработването на стомана по-здрава от желязо. Произведена за първи път от Бесемер през 1854 г., това е била стомана, която никога преди не е била използвана в строителството на мостове! Повечето мостове по онова време са били с фермови конструкции или висящи мостове, но Ийдс е искал да съчетае новия стоманен материал с древна форма, а именно, така познатата римска арка (фиг.10.) (https://www.freepik.com/premium-ai-image/symbolic-ancient-roman-aqueduct-arch-transparent-background_149318143.htm).



**Фиг.10.** Каменен три-отворен мост

**Трите значително дълги и високи арки** са позволили на множество речни плавателни съдове с високи височини да плават и преминават под мостовото съоръжение. За да осъществи дръзкото си инженерно решение, Ийдс е трябвало да преодолее Андрю Карнеги относно използването на високо-качествената стомана на Бесемер и Сименс-Мартин (Bessemer и Siemens-Martin) за новото мостово съоръжение. Карнеги не е вярвал, че използването на иновативно-разработената стомана, а и като нов строителен материал за целите на мостовата конструкция, ще бъде безопасно. През 1872 г., след като каменните носещи стълбове на моста стъпват на твърдо дъно и са фиксирани стабилно в земната основа, и след като цялостно опорните кули са изградени и завършени, се започва работа по стоманененото премостване. Радикалният дизайн на Ийдс изисква влагането на огромно количество метал – използват се близо 2400 тона стомана и над 3100 тона ковано желязо. **Компанията Steel дала възможност за това дръзко решение.**

**Подобно на арката Гейтуей днес, мостът Ийдс е символ на града по онова време.** Мостът Ийдс, завършен в Сейнт Луис през 1874 г., е първият в света мост с обособена конструкция на **стоманена дъга**. Той се явява и първата в света значима **стоманена конструкция** от какъвто и да е вид, което е довело до повратен момент в строителството на мостове и сгради. Ийдс успява да премости (да прехвърли) широката река Мисисипи в отсечка, където малцина смятали, че това би било възможно. Дори още преди да бъде завършен, **Мостът Ийдс** се превръща в символ на Сейнт Луис (фиг.11).



**Фиг.11.** Изглед на моста (https://www.waterwaysjournal.net/2024/07/01/eads-bridge-remains-an-engineering-marvel/ )

**Сам по себе си, Мостът Ийдс остава инженерно чудо. Явява се единствената структура**, която съперничи на **Арката Гейтуей (The Gateway Arch)** като символ на Сейнт Луис! „Това наистина е ненадминатата структура на съвършенството и красотата, и никога не ми омръзва", пише поетът Уолт Уитман през 1882г., **осем** години след отварянето на моста за движение (фиг.12).



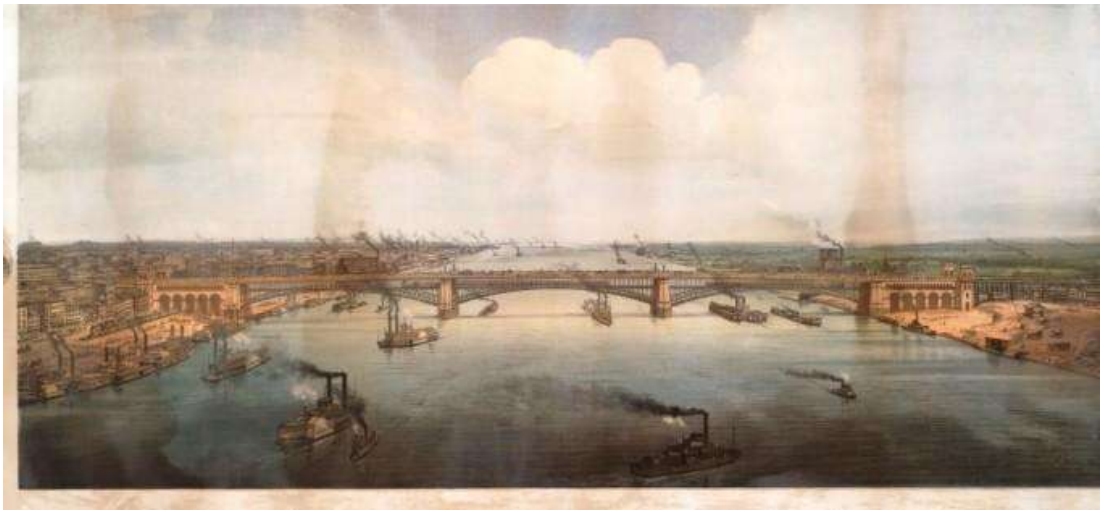

**Фиг.12.** Изглед на моста

## 8. Рехабилитация на моста през 2012 год.

**През 2012 г**. Двустранната държавна Агенцията за Развитие/Метро стартира проекта за рехабилитация на моста Ийдс, за да удължи експлоатационния му цикъл поне до 2091 година. Възстановяванията включват подмяна на 1,2 милиона паунда

подпори, скоби и друга опорна стомана, датираща от 1880 г.; премахване на цялата боя и корозия от надстройката; пребоядисване на надстройката с антикорозионно покритие; ремонт на повредена конструкция; възстановяване на бетонни опори; възстановяване на тухлени арки; и надграждане на релсите на компанията МетроЛинк (MetroLink). Общата стойност възлиза на 48 милиона щатски долара, като 27 милиона долара се обезпечават на база Американският закон за възстановяване и реинвестиране, от 2009 г. Въпреки, че се очаква да започне през 2009г., работата започва чак през 2012 г. поради трудови спорове и по-високи от очакваните оценки на разходите. Изпълнителите завършват проекта през 2016 г. (фиг.13).

На основание горе-изложеното дотук, може да се каже, че Джеймс Бюканън Ийдс е имал абсолютната идея за визия на мащабно стоманено съоръжение, т.е. направата на **мост от стомана**, макар и това да е предопределяло изпълнението и изграждането на многократно, статически неопределима ставно прътова **фермова конструкция.**



**Фиг.13. Изглед на моста през 2016 год. (** https://www.archpark.org/visit/points-of-interest/museum-at-the-gateway-arch/new-frontiers/eads-bridge )

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