

## ARCH BRIDGES IN UKRAINE

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### SUMMARY

Present article deals with the Ukrainian arch bridges. It is supplied with the information about most significant and historically valuable arch bridges, which have been built at different times. A number of such bridges have been built over the largest river of the country – Dnipro River and in mountainous areas during the latter half of the nineteenth and the first half of the twentieth century. In the article is described the current state of some functional and designed arch bridges.

**Keywords:** *Arch bridges, bridge crossings, history, Dnipro River, Ukraine.*

### 1. INTRODUCTION

Ukraine is the largest European country by territory. It directly borders by land on seven countries and has an outlet to the Black Sea. Bridge engineering in Ukraine has eventful centuries-long history by virtue of the geographical location of country, diversity of terrain and dense hydrographic nets. In the end of the tenth century were the first mentions in chronicles about bridges.

The country has in possession the developed transportation network, which consists of 22.3 thousand km of railroads, 172 thousand km of automobile roads, nearly 3 thousand km of inland waterways, 19 sea and 10 river ports, 36 airports. There are 7 434 railway bridges with the total length of 230 km in operation of the State Railways. There are 16 172 bridges and overpasses with the total length of 382 km on the automobile roads.

The largest rivers are Dnipro, Southern Bug, Dniester, Severski Donets, Desna. Among them, Dnipro is the largest and the longest river of Ukraine, which crosses the country from the North to the South and flows into the Black Sea. The length of the river in its natural state on the territory of Ukraine is 981 km. The other region that demands a great amount of bridge objects is the mountain territory of the Ukrainian Carpathians. A lot of bridges including the arched, have been constructed over Dnipro and in Carpathians Mountains in the second half of the 19th and the beginning of the 20th century. But during the First, and then and Second World War, span structures of most of bridges had been partially or completely destroyed. The considerable amount of objects of bridge construction, which have been constructed during the post-war period are in operation until today.

The capital of Ukraine is Kiev, one of the largest and oldest cities of Europe. The city located in the north part of Ukraine on both banks of Dnipro River. Nowadays the capital is the largest transport hub of Ukraine, where bridges over Dnipro play the key role. The

first major bridge over Dnipro has been built in 1853 year – it is so-called Chain Bridge, which was one of the largest architectural achievements of the time with suspension structure. In 1870 year in Kiev took place the opening of the longest at that time in Europe Railway Bridge over the river Dnipro with the length of 1068 m. Today the banks of Dnipro within Kiev are connected by eight bridges, four from them are automobile, two are railroad ones, one is combined for railway with automobile and one is pedestrian. The Podilsko-Voskresenskyi Bridge Crossing with the main arch span of 344 m is under construction.

## 2. HISTORICAL ARCH BRIDGES

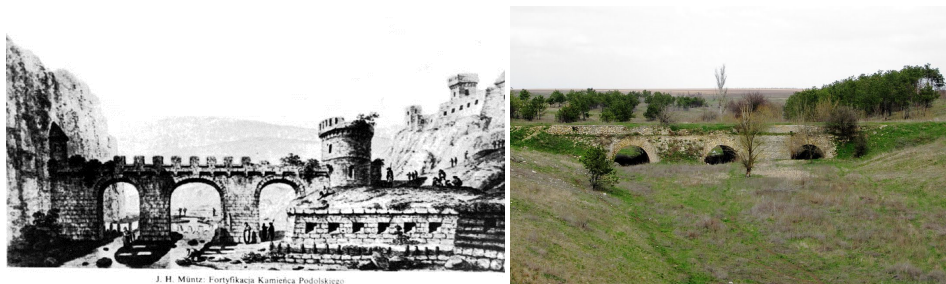
### 2.1. The oldest. Historical monuments

One of the oldest on the territory of modern Ukraine is considered *the Castle Bridge in Kamianets-Podilskyi*, which connects the «Old City», located on the peninsula at the Smotrich River loop, with the fortress on the promontory (Fig. 1). In archival sources the first mention of the bridge is dated by 1494 year. According to hypothesis of Eugenia and Olga Plamenitskaya and Janusz Rymsha - Romans built the bridge at the beginning of the II-nd century with the wooden span constructions [1]. The bridge also called Turkish Bridge, since in 1672-1699 years Turks owned Kamianets and carried out the reconstruction of the bridge. Also in 1369-1772 years Kamianets belonged to Poland, and the Polish fortifiers also performed restoration work. The authentic sites of this construction have not remained until today and now it has an appearance of powerful stone wall. Visually it looks like the dam. The bridge has the following sizes: length of the main part is 39 m, the average size of the span between axes is 7.8 meters, and the thickness of pillars is 2.1 m.

The other historically valuable is the stone three *arch bridge over the Burgundian gully* (Kherson region, near the village Burgunka). It was built in 1787 year (Fig. 1). It is known that it has been constructed for ensuring the visit of Catherine II to the Crimea.

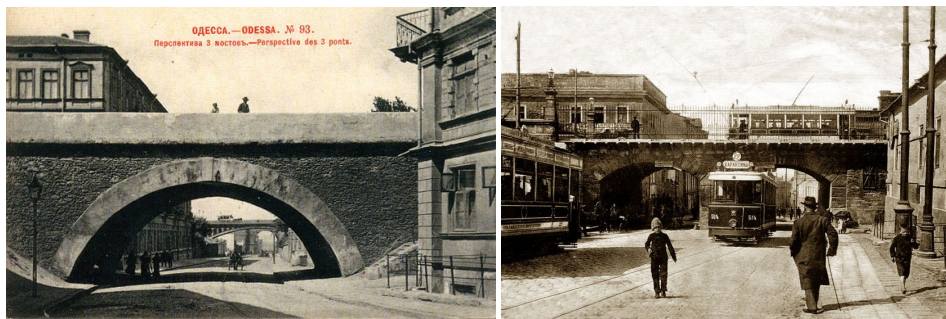
The significant progress in bridges construction has taken place during the 19th century. At this period many bridges, which were the top of engineering art of that time, have been built and became the symbols of the future. Among these bridges should be noted following. The first major bridge over Dnipro in Kiev – the Chain Bridge, with the length of 776 m long and width of 16 m, which existed in 1853-1920 years. The first capital all-metal railway bridge over Dnipro in Kiev, which became the longest (1067.6 m) in Europe for that time – Struve (Darnytskyi) Railroad Bridge. It was opened in 1870 year and was finally destroyed in 1943.

Many ancient bridge objects are still preserved in the city of Odessa (on the south of Ukraine). Among them, the attention is drawn to *Novikov's bridges, Stroganovsky and Kotzebue bridge*. They are constructed over Devolanivs'kyi descent. The arched single-span stone Novikov Bridge (Fig. 2) built in 1882-1824 years by the project of the engineer Z. V. Gayui and architect A. P. Digby. Stroganovsky bridge (Fig. 2) has been constructed during 1853-1863 years. Actually, it consists of two consecutive stone bridges, including three-span construction over the Polish Descent and two- span over Levashovsky Descent with the total length of 120 m and the height of 13 m. Soon after construction, it has been equipped with the high metal fencing for the purpose of the suicides prevention. This grid was kept on the bridge after its reorganization in 1970-th years.

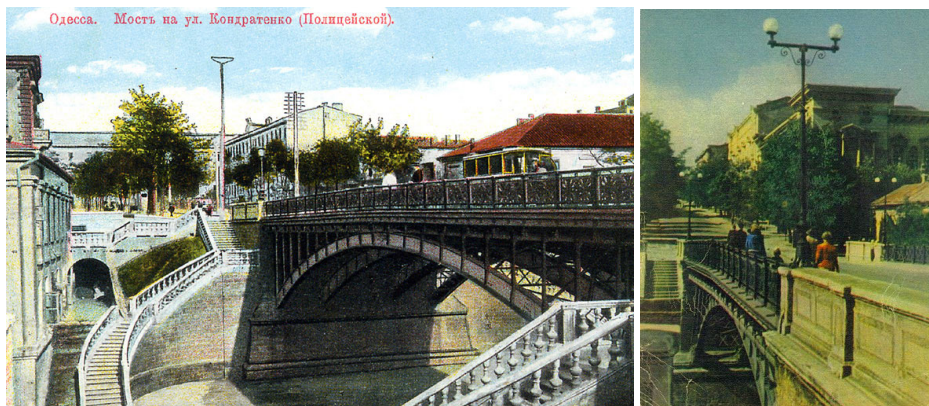


J. H. Müntz: Fortyfikacja Kamienica Podolskiego

*Fig. 1. Castle Bridge in Kamianets-Podilskyi to the left [2] and Burgundian bridge to the right [3].*



*Fig. 2. Novikov (to the left) and Stroganovsky (to the right) bridges in Odessa [4].*



*Fig. 3. Kotzebue Bridge [4].*

Kotzebue bridge (other name is Police bridge) has been built by the architect Landesman in 1889-1892 years (Fig. 3). Metal constructions of the bridge have been manufactured in Gustave Eýfel's workshop. On the wrought lattice in the middle of the bridge the old emblem of Odessa casted in iron has remained, the same, as on the staircase of the Opera theatre, but with the Maltese cross of the emperor Pavel I. The length of the bridge is 47.7 m, the width of the carriageway is 6.4 m, and the sidewalks are 2x1.2 m. As of February 2016 year, this bridge is closed to the traffic, it is planned the carrying out of capital repairs.

In 1894 year (according to another data in 1892 year), *the reinforced concrete arch footbridge in the yard of today's Lviv Polytechnic National University* (at that time – the Lviv Polytechnic School) has been constructed (Fig. 4). This bridge structure has been built to demonstrate the opportunities of reinforced concrete as an exhibit item of the international exhibition, which took place in Lviv at that time. It is one of the first reinforced concrete bridge structures in Europe. The author of the project is prof. Maxymilian Thullie (1853 – 1939), the Head of the department of bridges construction (1889-1925) of the Lviv Polytechnic. He has made a great contribution into development of theoretic framework of reinforced concrete and calculation of bridges. The span of the footbridge in light is 11.05 m, the width is 2.5 m, the plate thickness in the key of an arch is 10 cm, and at abutments is 12.5 cm and 14 cm. The bridge is reinforced along the bottom and the top areas by the knitted grid. The metal reinforcing bars with the diameter of 12 mm are located through the length and breadth of the span with the step of 110 and 130 mm. The thickness of protective layer of concrete fluctuates within 12-25 mm. At the beginning of the 21st century, the repair of the Thullie Bridge has been executed and today it is one of the symbols of the Lviv Polytechnic National University.



**Fig. 4.** *The modern view of Thullie Bridge in the yard of the University and M. Thullie [5, 6].*

The project of the Transcarpathian railroad line was developed in details in 1870 year. Its purpose was to connect Vienna and Budapest with the Eastern Carpathians. The railroad had to pass along the mountain rivers Tysa and Prut. During 1893-1895 years in the Prut valley the several big stony bridges and three tunnels (one of which reached 1221 m) have been built. The majority of bridges has been destroyed during the First World War and has been partially restored in the early twenties.

The vaulted bridge over the Lyubizhnya River near Delyatin became the first large bridge. It consisted of six arches, each with the length of 15 m, one – of 22 m and two –

each of 15 m. The bridge, with the total length of 275 m, reached 32 m over the encroachment line of the river. In 1917 year it was blasted.

The largest was the *bridge over the Prut River in Yaremche* with the total length of 190 m. It had 8 arched spans, main of which in the light was 65 m, and that made it the largest stone arch bridge in Europe for that time. The width of the bridge was 6.5 m at abutments and 4.5 m in the key. In 1917 year the Russian troops blew up the bridge and the main arch was destroyed. The bridge in Yamna was slightly smaller: it had 122 m of total length and the span of the arch of 48 m.

The other great stony viaduct has been constructed in Vorokhta (Fig. 5), today its Ivano-Frankivsk region of Ukraine. It had 12 spans, the biggest of which was 34.8 m. The main bridge span has been destroyed during First World War, and then it has been rebuilt during the Second Polish Republic and has remained until today. Since 2000th year, the the movement of trains was stopped and the bridge became the national landmark.

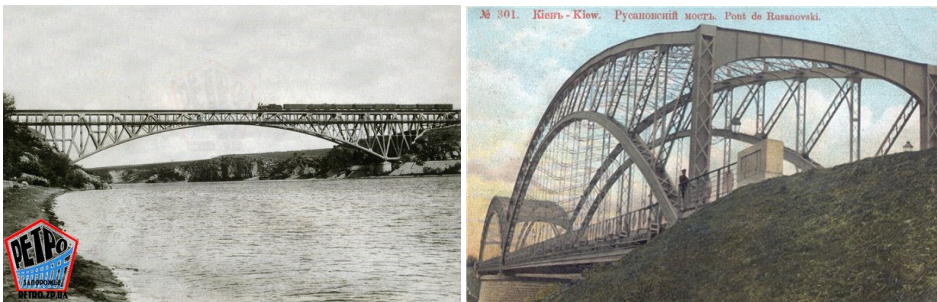


Fig. 5. Viaduct in Vorokhta. Photo by Sergey Lagoda.

## 2.2. Bridges of the 20th century

The necessity to connect the regions Donbass and Krivorizhzhya by the railroad line has led to construction of the bridge over Dnipro near today's Zaporizhia city. The construction of *Kichkasky bridge* (Fig. 6) has begun in the 1900th year. At the end of June 1902 year the only big arch bridge in the Russian Empire over Dnipro has been assembled and tested. The famous engineer L.D. Proskuryakov developed the project. The engineer F. V. Lat. conducted the construction. The bridge was double deck, one arched, metal, with the riveted structure. The distance between arch abutments was 190 m. The total length of the bridge was equal to 336 m. The distance from the top point of an arch and to the line of abutments – is 20 m. On the top floor has been laid the double-track railroad line, on bottom – from the left and from the right sides of the bridge – are pedestrian sidewalks. At the middle between sidewalks there passed the main bearing bridge constructions. The bridge was opened in 1902 only for the pedestrian movement. The railroad traffic on the bridge has been open in 1908. As Kichkasky bridge was of strategic importance, it has been partially blown up and damaged many times. In 1931 year it has been finally dismantled.

*Rusanivsky bridge* – is the bridge over Dnipro, that existed in 1906-1943 years in Kiev (Fig. 6). The project of the bridge was developed by engineers Beleyubskiy, Krivoshein and by the architect Apyshkov. The bridge was with two spans, with the length of each one equal to 101.35 m. As the unique characteristic became the accomplishment of constructions in the form of metal two-hinged arches with the height of 9.81 m over the abutment and 17.07 m over the middle of the span. Such method in the bridge construction in this region was applied for the first time. The road bed with the width of 8,08 m and two sidewalks with the width of 1,28 m each were made from the timber. The bridge has been secured by the metal handrails with the heights of 1,07 m. In July of 1908th year the fire has started on the bridge. In the 1912th year the tram has started running on the restored bridge. In 1920 year the bridge was blown up by Polish troops. Later it has been restored by the engineer Eugene Paton. Finally it has been destroyed in 1941 during the retreat of the Soviet troops from Kyiv. In its place, in 1965 year, the new bridge with the beam construction has been open, and it is in use today.



**Fig. 6.** Kichkasky Bridge (to the left) [7] and Rusanivsky Bridge (to the right) [8].



**Fig. 7.** Merefa- Kherson railroad bridge [9].

Dnipropetrovsk is one of the largest cities of Ukraine, also situated on the different banks of the Dnipro River. One of the symbols of the city and the architecture monument – is the *Merefa- Kherson railroad bridge* (Fig. 7) with the curvilinear trajectory. During the construction activities it was the biggest arch bridge in Europe. One branch of a railroad

is passing through the bridge. The two main arch spans are of 2x106 m, the others are of 55 m. The total length of the bridge crossing is 1610 m. The bridge has been built in 1932 year with the overlapping of the main span by metal trusses. And in 1948, during reconstruction of the bridge after the Second World War, new main reinforced concrete arches have been built. The bridge has obtained its modern view in 1951 year.

During various history, Merefa-Kherson bridge became the visually and historically valuable symbol and the show-place. It combines in itself the artistic expression and unique technical qualities. The reinforced concrete giant leaves the impression of light lace stretched over Dnipro. Its arched reinforced concrete spans, which are reflected in the water, have finished magnificent panorama and have made the bridge one of the symbols of Dnipropetrovsk and Ukraine. It is a monument of engineering architecture.

In 1952 year in Zaporizhia there were built the other two, so-called *Preobrazhenskoho bridges*. The first one is single-arched, double deck, over the old channel of Dnipro. Its length is 228 m. The second one is four-arched (by 140 m), double deck bridge, over the new corridor of Dnipro (Fig. 8). The total length is 560 m, the height is 54 m, the width of the carriageway is 8 m. The bottom deck is intended for vehicular and pedestrian traffic, and the top one is for two railroad lines.

Another one automobile arch bridge in Zaporizhia that connecting the right coast of the city with the Khortitsa Island, was built in 1970-1974. The length of the bridge is 320 m, the width is 20 m and the height is 40 m.



**Fig. 8.** *Preobrazhensky Bridge in Zaporizhia on the top [10] and Metro Bridge in Kiev below [11]*

*Metro Bridge* – is one of existing bridges over Dnipro in Kiev (Fig. 8). It was opened in 1965 year. The chief engineer of the bridge construction project is Fuchs George Borisovich. The double deck construction is intended for the movement of metro trains (at the center on the top deck) and automobile transport (at the sides on the bottom deck). *Metro Bridge* – is the first in the world arch construction with big spans, designed

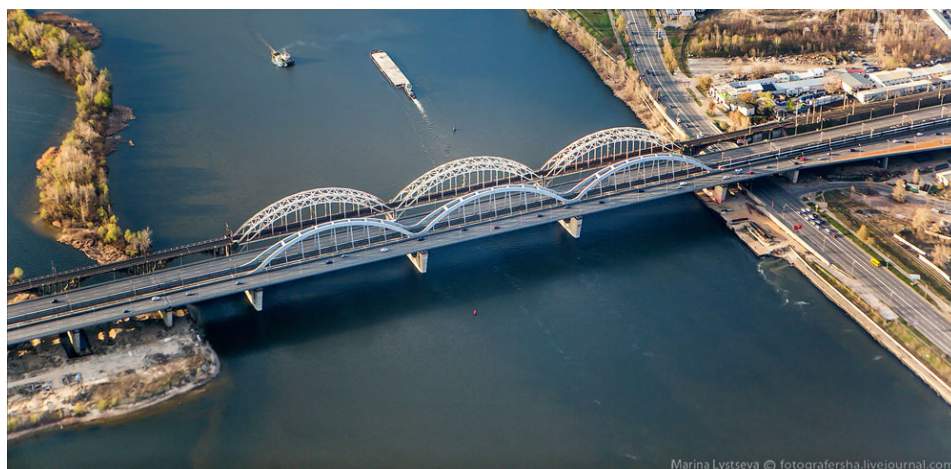
on the dry joints. The span between supports is 60 m. The total length of the bridge is about 700 m. The bridge has six spans of arched cantilever structure with the length of 117 and 87 m. The feature of the construction solution is the installation of blocks of semi-arches as cantilevers on raker piles and their combining on the spigots with the subsequent tension of transverse reinforcement of arches. The cantilevers are assembled from the separate reinforced concrete blocks connected by metal bolts.

*Darnitsky Bridge* is considered as the main railroad bridge, which connects the right and left banks of the capital of Ukraine – Kiev. With its help the regular railroad communication in eastern direction is carried out. Also through it is carried out the transit of many international trains. The first in this place was the Struve railroad bridge (the project of engineer Struve), opened in 1870 year, but twice blown up – in 1920 and 1941 years. It was finally destroyed in 1943rd year. The current bridge was built near the previous one. The chief project engineer is N. S. Rudenko. In 1946-1950 years there were built the bridge abutments (piers) on the precast reinforced concrete piles and intermediate abutments on caissons, which were made by the rapid-flow method and lowered by the hydro-mechanized way (a so-called "blind caisson"). The bridge for two railroad tracks is designed according to the symmetric scheme. Closer to the left bank there situated three large navigable spans of 106 m, covered by the arched metal trusses during the train traffic in the lower part (Fig. 9, on the background). The shallow right-bank part of the corridor is blocked by twelve smaller ones (of 53 m) by monolithic reinforced concrete arches with the driving on the top. All bridge abutments – are massive, monolithic, faced with granite.

### 3. NEW BRIDGES AND PROJECTS

#### 3.1. The railway and automobile bridge crossing over the Dnipro in Kiev

Near the Darnitsky railroad bridge in 2011 year the construction activities of the new railroad and automobile bridge crossing over the Dnipro were completed (Fig. 9).



**Fig. 9.** New combined railway and automobile bridge crossing in Kyiv on the background of Darnitsky Bridge (Photo by Marina Lystseva).



The bridge combines in itself two components: railroad one – two tracks, and automobile one – the road with six lanes (three at each direction). The length of the bridge – is 1066.2 m, the construction length of railroad tracks – is 32.71 km, the length of automobile approaches – is 15.08 km. The traffic capacity of the bridge is equal to 60 thousand cars and 120 couples of trains per day. The spans of the new bridge are located similar to the spans of the already existing bridge, as not to create obstacles for ships.

### 3.2. Podolsko-Voskresensky bridge crossing, Kiev

The Podolskiy bridge crossing – is the bridge crossing, which is constructed in Kiev across the river Dnipro and has to connect the Podol District with the left-bank regions of Voskresensk and the Rainbow District. It is the double deck construction consisting of the three bridges and trestle bridges that connect them. There planned six traffic lanes for automobile transport (3 for each side) at the top deck, and the line of subway at the bottom deck. The span of the main arch of the bridge is equal to 344 m, that when the construction is completed, may be the biggest arch bridge in Europe. The detailed information about this bridge provided in the article [12].



*Fig. 10. Visualization of the main arch of the Podolsko-Voskresensky bridge crossing in Kiev which is under construction [12].*

## 4. CONCLUSIONS

Arch bridges in Ukraine has a long rich history for ages. Due to the hydrographic network of the country and its conformation, the inhabitants built artificial structures to overcome the physical obstacles since olden times. Significant quantity of stony and metal arch bridges was constructed on the territory of Ukraine at 18-19-th century. Many of them were built in the mountain region of the Carpathians. The bridges across the river Dnipro, which crosses the country from the North to the South, are strategically important. During the First, and then the Second World War, superstructures of many bridge conduits were partially or completely destroyed. Some bridges have survived up to this day and are of historical, cultural and architectural values. Today in Ukraine there happening the construction activities of two big bridge crossings over the Dnipro – in Kiev and in Zaporizhia. The arch bridge in Kiev may become the largest arch bridge in Europe after building end.

## ACKNOWLEDGEMENTS

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