The History of the Romanian Danube Bridges

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ABSTRACT: The River Danube is an international waterway flowing 2857 km across EUROPE and is listed immediately after the river Volga, as the second biggest river in Europe. It flows from the heights of the Schwarzwald Massif down to its estuary in the Black Sea Delta. In its passage, the river crosses 22 geographical longitudes, joining 8 countries: Germany, Austria, Slovakia, Hungary, Serbia, Romania, Bulgaria and Ukraine. It is largely these factors, together with the importance of the management of its water resources, which historically encouraged civilisations and cultures to develop along the banks of the river. The Danube has in Romania a length of 1075 km; they are only five permanent crossings: the paper presents a short overview of the Romanian Danube Bridges and some perspectives for new bridges across the Danube.

INTRODUCTION

The Danube River (to investigate the origin of the name “DANUBE” we have to go back to the Celtic tribes who lived in the upper Danube basin. The word “Danu” is of Celtic origins and signifies “swift, rapid, violent, undisciplined”. Emperor Cesar in his work “De Bello Gallico” had named the stream Danubius. Phoenicians and Greeks had explored the river from the delta upstream but knew only the lower course, known as Istros or Istria. The name Danubius can be found in the work of Aristoteles, Ovid, Strabo, Plinius the Second. “Istros” is mentioned by Herodot and Virgil. Other nations migrating along the stream called the river Donau, Dunaj, Duna, Dunav, Dunarea, the name being transformed and modified according to the language of the country) flows through our country on around 1075 km, of which 225 km exclusively on Romanian territory. Among the riverain countries Romania has the longest access to the river, including the Danube Delta. Romania also put into operation since 1986 the Danube – Black Sea Channel (Cernavoda – Constanta). The Danube with the Main – Rhine channel forms Europe’s blue diagonal for river transports.

Few are the permanent crossings built on the lower Danube (Fig. 1). The paper presents a short overview of the Romanian Danube Bridges History.
During the Roman Empire public works had known a great development. Temples, arches, basilicas, baths, aqueducts are well known even in our days. As a first priority roads were constructed (via vita). A network of roads covered the entire surface of the Roman Empire. 90000 km of principals roads covered had been built. The construction of roads and bridges reached a very high level during the period of the roman emperor TRAIAN (98 – 117 A.D.) A main road starting from the north of Italy passed trough Vienna and continued along the Danube valley. During the Trajan’s rule the road reached the zone of Turnu – Severin, the border of the Roman Empire. On the other side of the Danube was Dacia. In 101, Emperor Trajan started the first war for conquering Dacia. The Roman army crossed the Danube near Drobeta on a pontoon bridge. After defeating Decebal’s army and the peace conclusions, the Romans realised that the domination and colonisation of the new province Dacia, could be not achieved without a fixed bridge across the Danube. The bridge was built between 103 – 105 A. D. (Fig. 2).

Figure 2: Trajan’s bridge over the Danube in Drobeta Turnu – Severin

Having a lengths of over 1200 m, Trajan’s bridge, astonished modern researchers for the enigma of ist technical building solution. The bridge was considered superior to all other bridges built by the Romans. Some hypothesis about the bridge construction and its service life can be presented. Unfortunately, the monography of the bridge, written by Apollodor from Damascus who was the architect and builder of the bridge, had been lost. The documents elaborated by the researchers of the bridge indicate that the more plausible assumption regarding the bridge site selection is the possibility of temporary deviation of a part of the Danube; therefore some of the piers could be built on land. In 1853, a great lowering of the Danube offered to a team of Austrian specialists and to a Romanian engineer, the possibility to make an inspection on site. Further information concerning the substructure of the bridge, was obtained in 1909 when the Romanian Hydraulic Service ordered the demolition of two ruined piers located close to the Romanian shore, because they obstructed the navigation along the river. On this occasion when divers worked in the Danube area, they discovered traces of wooden caissons used for the construction of the piers. The piers were erected by two methods:

- A part of the piers were constructed on the land subsequent to the Danube deviation along the southern channel;
- The other piers located in the Danube were constructed with open wooden caissons provided with two walls sustained by wooden piles, between which hydraulic concrete (mortar) was cast. The sediment inside of the caissons was removed out, the ground consolidated by broken stones (Fig. 3).

Figure 3: Bridge end with portal and foundation (restoration)
The superstructure was conceived by wooden arches (with a remarkable span of \( L = 51 \) m). The images shown on Trajan’s Columna in Rome, as well as ancient coins indicate the wooden structure. After the demolition of the piers the oak beams were preserved at the museum from Drobeta - Turnu Severin. In 1906 at the National Romanian Exhibition, the French engineer Edgar Duperex, tried to restore the bridge; he achieved a model scale 1:100, complete with the portals of the bridge (Fig.3). This model is nowadays in the museum from Drobeta - Turnu Severin).

At the end of these considerations, some hypotheses about the destruction of the bridge are presented; there are two theories:

- Subsequent to Trajan’s death in the year 118 the destruction of the superstructure was ordered by the emperor Hadrianus his successor. Probably this decision was taken when the barbarians got into Dacia
- The second view indicates that the bridge destruction was caused by the floods; we do not know the exact details.

As a conclusion, the bridge over the Danube in Drobeta - Turnu Severin was one of the most important constructions of the Roman Empire. It is sure that the bridge was not built only for a single military company; it was constructed for years on the purpose of strong connection with the territories over the Danube. Even in our days the ruins of one pier can be admired on the Romanian river side (Fig. 4).

**BRIDGE OVER THE HYDRO - POWER STATION PORTILE DE FIER I (IRON GATE I)**

The hydro-power station Iron Gate I was finished in 1972. The dam connects Romania and Yugoslavia. The superstructure (Fig. 5) of the bridge is made of prestressed concrete beams with following spans: \( L = 36 + 21 + 13 \times 26 \) m.

**THE DOUBLE DECK BRIDGE GIURGIU - RUSSE**

The need for a bridge to link Romania and Bulgaria was raised in the last century. Technical and economical conditions impeded its construction. Romania has a long frontier line with Bulgaria, over 400 km. Between the two World Wars this problem was again set on the table; the Germans supported this project. But only after the last War, when strategic interests in this area begun to take shape, was the need for the construction of a
bridge re-established. This emplacement was settled upstream of Giurgiu. In the 1950 signed agreement, it was decided that the Soviet Union would undertake the task of the design of the new bridge and coordination of the on site operations. The actual construction of the bridge fell under the obligation of the Romanian and Bulgarians. The final chosen solution was a combined – double deck – bridge with a simple railway track and two highway lanes. The bridge (Fig. 6), including the viaducts has 37 spans, with a total length of 2224 m. The main bridge has the following spans $L = 4 \times 80 + 2 \times 160 + 86 + 2 \times 160 + 2 \times 80$ m. The name of the structure is the “Friendship Bridge”. The central span of 86.4 m is mobile and can be lifted in order to ensure that in special cases of high waters, or large ships the vertical clearance, can be increased to 20 m. The well chosen technological procedures and the combined efforts of constructors, allowed the bridge to be finished in a very short time: 2 years and 3 months.

![Figure 6: Giurgiu – Russe Bridge; general view](image)

After 1990 the whole traffic movement South of Balkans was directed on this bridge. The traffic become heavier and denser than the assumed initial values. In the last years the bridge capacity was verified (structural capacity for EC 1 loads and the remaining fatigue life, according to the real time – stress history). The conclusion is, that the bridge behaves well for the present traffic conditions.

**CONSTRUCTION OF THE OLD DANUBE BRIDGES (1890 – 1895)**

The first contemporary permanent crossing was achieved in 1890 – 1895, when Anghel Saligny built the famous bridges over Borcea and Danube (Fig. 7).

![Figure 7: The Cernavodă Danube Bridge](image)

The bridge King Carol I across the Danube at Cernavoda is the most famous bridge in Romania. In second half of the last century a direct link between Bucharest and the Black Sea became a necessity. The railway tracks Cernavoda – Constanta and Bucharest – Fetesti had already been built. It remained only a difficult section of 15 km. The Danube in this zone is divided in two branches: Borcea and the Danube. Between them there was the Iezer marsh. Starting with these difficulties the Ministry of Public Works organised in 1883 a first contest. Eight famous companies from Austria, Switzerland, Germany, France and Belgium participated at the competition. The submitted projects were characterised by a great variety of solutions. After the analysis, all of the proposals were rejected. A second contest organised one year later, did not reveal any profitable result. Then, the Ro-
The Romanian Ministry of Public Works decided in November 1887 to found a special office headed by the 33 years old engineer Anghel Saligny. Saligny made a short documentation trip especially to Scotland where the famous Firth of Forth Bridge was under construction. The information acquired during this discussions with the engineers John Fowler and Benjamin Baker, influenced undoubtedly the final solution. The main characteristics of the project are:

- Adoption of the cantilever trusses, known as the Gerber system (Fig.8) with economical and aesthetics advantages;
- The slope of 1:10 of the main girders had a favourable consequence over the wind action and stability of the structure. Saligny considered a wind pressure of 180 daN/m², in contradiction with the English standard which prescribed 270 daN/m². The time proved that Saligny assumptions were adequate.
- Adoption of a substructure made entirely of masonry elements, with a foundations depth of – 27 m under the river;

It was the first large span steel bridge built in the continental Europe of converted (mild) steel.

The central cantilever girder was erected by means of wooden scaffold and brought in the final position with the help of hydraulic presses and under building of the 63 m height piles. The most risky operation was the erection of the central independent span. Saligny built a wooden scaffold which stood for one year in the middle of the Danube, at the final position of the bridge (Fig.9). The inauguration of the bridge took place in September 1895, in the presence of King Carol I. Fifteen steam engines passed over the bridge at a speed of 70 km / h. At this time it was the longest bridge in continental Europe (central span L = 190 m). The history of the bridge is very eventful. During the First World War, the bridge was mined; nevertheless the structure did not collapse and was repaired by the German army during the war. In the Second World War the bridge was bombed and seriously damaged; the circulation was entirely interrupted for 4 months. In the '60 when the traffic grew enormously and the stresses in many elements were near to the yield point (every eight minutes a train passed the bridge), the structure was reinforced whilst still in use. This was compared to an open heart operation.
The traffic of passengers and goods on the main line Bucharest - Constanta increased continuously between 1965 and 1974 as a result of the economical development. In 1968 - 1970 the line was doubled. Considering also, the perspective of a direct motorway connection to the Black Sea, the solution of a combined bridge in the vicinity of the existing bridge complex, was chosen. The Borcea Bridge consists of a viaduct having 11 spans of 50 m each and a main bridge with 3 x 140 m spans (Fig. 10). The Cernavoda bridge consists in a viaduct having 18 spans of 60 (70) m each and a central bridge with 3 spans: 140 + 190 + 140 m (Fig. 11).

The superstructure of the main bridge is - in both cases - a continuous steel Warren truss of three spans designed to carry a double track railway line and a four lane motorway; the highway is supported on cantilevers at both sides of the main girders (Fig. 12). After many studies, it was finally decided that the steel deck would be carried out from OL 52 - 4K (similar to St 52 - 4); besides the usual requirements the content of sulphur was limited at maximum 0.02 % (compared to 0.45 % in the standard) and the equivalent carbon 0.44 %; every delivered sheet with a thickness of 15 - 50 mm was ultrasonic checked. The structure was calculated according to the Romanian standards (very similar to the German ones); a space analysis of the structure was performed.

The main truss girders with parallel chords are conceived in a triangular system with posts, while panels are 10,0 - 12,0 m long. The constructive solution of the deck beams took into account the direct fixing system of the railway trucks on the deck stringers as well as the connection and continuity of highway cantilevers in the nodes. The erection of the main bridge was done by cantilever method proceeding from both ends at the same time and closing in the middle of the central span. At the side spans a counterweight was necessary. The simultaneous execution of the erection from both ends of the bridge required a correct and very accurate determination of the longitudinal deck axis and of the end points. During the whole period of erection they
were performed measurements regarding the geometry of the structure and the stresses in the principal elements of the bridge (approximately 3500 determinations). The final part of the measurement programme was the in situ test loading of the whole structure. The aim of the tests was the verification of the calculus hypothesis and the determination of maximal values of stresses and deflections. The measurements were performed for the most unfavourable load hypothesis in static and dynamic regime. For the Cernavoda Bridge they were considered 11 loading schemes composed of Diesel locomotives and loaded trucks. The analysis of the obtained data confirms the initial theoretical hypothesis reflecting the adequate behaviour of the bridge. Generally the determined values were smaller than the calculated ones. The results represent also a useful guide in clarifying the difficulties of spatial analysis of complex bridge structures.

As a concluding remark, the new Danubian bridges built in the zone Fetesti - Cernavoda are open for traffic since 1987. After more than 30 years of operation the structures do not raise any special problems.

THE HIGHWAY BRIDGE GIURGENI VADUL OII

The last bridge over the Danube in Romania is the Giurgeni - Vadul Oii four lanes highway bridge (situated on the E 60 European highway). The bridge was built in the period 1966 – 1970. The main structure is composed of a continuous steel plate girder with five spans, variable height and orthotropic deck: \( L = 120 \text{ m} + 3 \times 160 \text{ m} + 120 \text{ m} \) (Fig. 14). Till the erection of the new bridge complex in Fetesti – Cernavoda it was the only highway link to the Black Sea. It was the entirely welded bridge in Romania. The superstructure of the bridge is made by steel St 52.

FUTURE DANUBE CROSSINGS

Several possibilities for new Danube crossings were analysed in the last years:
- A link between Romania and Bulgaria; the bridge now in construction situated in the zone Calafat – Vidin will probably be finished in 2009.
- The Romanian towns on the lower Danube are developed only on the one side of the river; e.g. Braila and Galati. Two bridges in this area would assure an economical growth of the Eastern part of Romania.
- Another analysed opportunity for Danube crossings is two bridges at the beginning of the Danube Delta; this territory is at present totally isolated without any connection to the railway or highway network.
CONCLUSIONS

This paper presents a short overview of the Romanian Danube bridges. On a length of 1075 km, they are only 6 crossings in Romania (besides the ones above, permanent crossings were created over the Iron Gates I dam). Large perspectives are opened for the Romanian bridge builders.

REFERENCES