Buletinul Ştiinţific al Universităţii "POLITEHNICA" din Timişoara

Seria HIDROTEHNICA
TRANSACTIONS on HYDROTECHNICS

Tom 56(70), Fascicola 2, 2011

Bridge „King Carol I” at 116 years

Butisca Anamaria Ioana[1] **Rominu Silvia Mihaela** [2]

Abstract: The paper presents the events of bridge “King Carol I” during 116 years. And also pointing the way in which they took into account water pressure and pressure from ice floes at that time in 1895.

Keywords: bridge, Anghel Saligny-bridge, historical construction, deck:

Acknowledgment: This work was partially supported by the strategic grant POSDRU 107/1.5/S/77265, inside POSDRU Romania 2007-2013 co-financed by the European Social Fund – Investing in People

Fig. 1 Bridge King Carol I

1. INTRODUCTION

The project of bridge “King Carol” demonstrated the cleverness of Romanian engineers; this structure will make a new face to design of bridge structure in Romania.

Project was made after two project competition, in 1887 Ministry of Public works made engineer Anghel Saligny General Supervisor by the design and construction of the structure.

At this moment the construction has 116 years and his behaviour in time is excellent because it suffered only a few signifying consolidations, one after the bombardment in the first war and seconds in the late ’63 and in the 1981 a consolidation of deck and also one in 1994.

The main steps to develop my research are to pick the date for Anghel Saligny project and to redesign the structure of Eurocode and make a comparation of the old design and the new design of structure. And also to remark the big changes in structure analysis after the consolidation of the late of ’60.¶

The historical character of construction is done for the age and for the architectural elements of the bridge, the form, the method for construction. It can see in the figure (1) the form of construction, also the piers and greatness of the construction.

2. STRUCTURAL CHARACTERISTICS

Superstructure was made by steel it was the first bridge built in Romania from steel.

As to the choice of steel of the deck the Ministry of Public Works was consulted and received a positive answer from the Technical Commissions belonging to the Ministries of Public Works of France and Austria and also from professor E.Winkler, because in that time the principal material of bridges construction was iron.

The King Carol I bridge was designed at 30 m above the highest Danube water levels possible, because the highests vessels of Turkish can’t pass under the bridge.

The deck has 1668 m, it has 6 piers and 5 openings, and the angle for the branching is 13-36 °. Deck has only one way.

[1]Politehnica University of Timişoara, Civil Engineering Faculty, Timisoara, Ion Curea Str., No. 1, E-mail: anamaria.butisca@ct.upt.ro

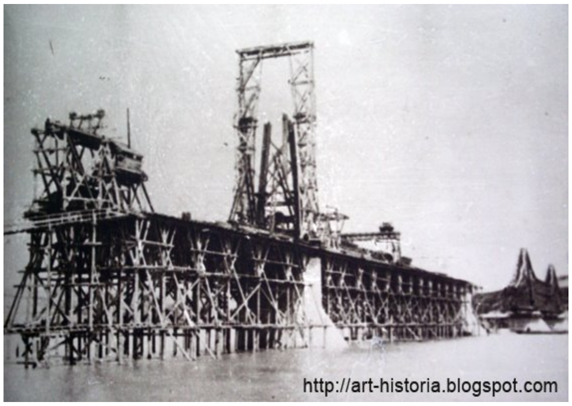


Fig. 2 Scaffold

When Saligny start the design of structure he made a documentation trip at bridge Firth of Forth in Scotland where the construction started in 1890 and at that moment Anghel Saligny could take same answer of this questions in this project.

Both bridges are cantilever-type and also both are de first steel cantilever bridge in Europe.

In the figure (2) and (3) it can see the scaffolding at the central parte to the superstructure.

Fig. 3 Scaffold

Foundations: Foundations are made of concrete and stone masonry, the foundations depth are 25-27 m under the low-water mark. It were executed on a compressed-air caisson.

The dimensions of caissons are 11.00 m width and 29.7 m length, walls of caissons were made with a steel plate of 8.0 mm thickness.

Substructures were of stone masonry with hydraulic mortar, dressed in an ashlar stone facing and there dimensions are 29.50x10.50m.

The substructures sizes were made on the following principles:

-to be only compression stresses in masonry;

-the maximum stresses do not exceed 12 kg/cm2;

-the maximum pressure on the foundation soil does not exceed 10 kg/cm2;

Deck: The structure was made in sections, cantilevers are 140 m, independents beams are 90m. The steel structures are made in Franta and in Bergia. Are two cantilever girders and three independent girders. The maximum height of the cantilever girders is 31.0 m.

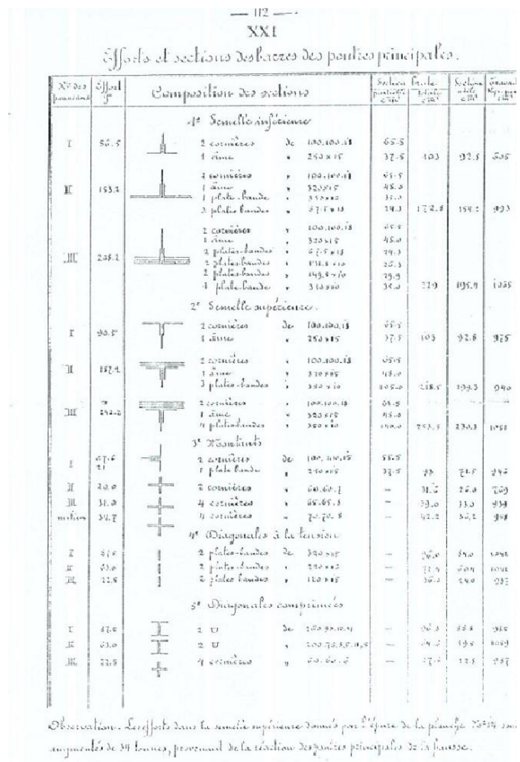
The height is of the cantilevers at the ends is the same as for the independent girders 7.50 m.

Geometry of elevation :

-the independent truss girders have a convex parabola

-the cantilever girders are a concave parabola all along the cantilevers and an elliptical concave form between the support sections. Material of cantilever and independent girders is S235.

Section of superstructure in 1895 was:



— 112 —

XXI

Efforts et sections des barres des poutres principales.

N° des panneaux	Effort T	Composition des sections			Section partielle	Section totale	Section utile	Travail
		1° Semelle inférieure						
I	56.5	2 cornières	de	100.100.13	65.5			
		1 âme	"	250 x 15	37.5	103	92.5	605
II	153.2	2 cornières	"	100.100.13	65.5			
		1 âme	"	320x15	48.0			
		1 plate-bande	"	350x10	35.0			
		2 plates-bandes	"	[illegible]	[illegible]	172.8	[illegible]	993
III	208.2	2 cornières	"	100.100.13	[illegible]			
		1 âme	"	320x15	45.0			
		2 plates-bandes	"	[illegible]	[illegible]			
		2 plates-bandes	"	[illegible]	[illegible]			
		2 plates-bandes	"	[illegible]	29.9			
		1 plate-bande	"	[illegible]	[illegible]	[illegible]	195.9	[illegible]
		2° Semelle supérieure						
I	93.5	2 cornières	de	100.100.13	[illegible]			
		1 âme	"	250x15	[illegible]	103	92.6	[illegible]
II	[illegible]	2 cornières	"	100.100.13	[illegible]			
		1 âme	"	[illegible]	[illegible]			
		3 plates-bandes	"	350x10	[illegible]	[illegible]	[illegible]	940
III	[illegible]	2 cornières	"	[illegible]	[illegible]			
		1 âme	"	[illegible]	[illegible]			
		4 plates-bandes	"	350x10	[illegible]	[illegible]	[illegible]	[illegible]
		3° Montants						
I	[illegible]	2 cornières	de	[illegible]	[illegible]			
		1 plate-bande	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
II	[illegible]	2 cornières	"	[illegible]	—	[illegible]	[illegible]	[illegible]
III	[illegible]	4 cornières	"	[illegible]	—	[illegible]	[illegible]	[illegible]
milieu	[illegible]	4 cornières	"	[illegible]	—	[illegible]	[illegible]	[illegible]
		4° Diagonales à la tension						
I	[illegible]	2 plates-bandes	de	[illegible]	—	[illegible]	[illegible]	[illegible]
II	[illegible]	2 plates-bandes	"	[illegible]	—	[illegible]	[illegible]	[illegible]
III	[illegible]	2 plates-bandes	"	[illegible]	—	[illegible]	[illegible]	[illegible]
		5° Diagonales comprimées						
I	[illegible]	2 U	de	[illegible]	—	[illegible]	[illegible]	[illegible]
II	[illegible]	2 U	"	[illegible]	—	[illegible]	[illegible]	[illegible]
III	[illegible]	4 cornières	"	[illegible]	—	[illegible]	[illegible]	[illegible]

Observation. – Les efforts dans la semelle supérieure donnés par l'épure de la planche [illegible] sont augmentés de 34 tonnes, provenant de la réaction des poutres principales de la fausse.

Fig. 3 Sections [Notes de calcul. Anghel Saligny 1895]

All the construction has 16823 t. At inauguration 16 trains pass by deck with 70 km/h, in this way the resistance of structure was confirmed.

3. LOADING FOR ANALYSIS

The structure was design for 13t/m locomotives and 3.5 t/m railway cars, the wind pressure was taken 270 kg/m2 and also ice pressure on piers was considered 23,3 tones.

The surface exposed to the wind was considered as a real lateral surface of the girder members multiplied by a coefficient of 1,5-2,0 in order to observe the influence of the second girder.

For the train it was considered a continuous rectangular surface with a height of 2.5 m and its lower part at 50 cm from the rail road.

The pressure of the wind for the train was calculated in the following way:

$$P= 1 \times 2.10 \times 0.180 \text{ t} = 0.370 \text{ t}$$

Where:
2.5-0.4=2.1
0.4-is the distance which is decreased from height 2.5

The live load was taken 3, 5 tone/m. For this load was admitted to carry the deck with 3 locomotives and wagons.

4. HYDRAULIC CALCULATIONS

Hydraulic pressure taken into account when designing the bridge in 1895 was determined by the formula:

$$P= \xi * \frac{v^2}{2g} F \gamma \qquad (1)$$

In the formula we have:
P- Total pressure of the water infrastructure elements
ξ- Form factor 0.57
γ-water charge 1000 kg
g- gravitational acceleration 9.81
F-surface
v- water velocity
Water velocity was determined by the formula:

$$v= \frac{23 + \frac{1}{n} + \frac{0.00155}{J}}{1 + (23 + \frac{0.00155}{J}) \frac{n}{\sqrt{R}}} \sqrt{RJ} \qquad (2)$$

F=73 m3
J=0.000435
n=0.025
R- depends on river profile, and it is 8.62
So that we obtained the velocity:
v=1.27 m/s
And the pressure is:
P=3420 kg
Pressure from the ice floes was taking after the values obtained from the experience in Russia and North America because at that time at us in Romania weren't measurements, so that its value has been 23.3 tons.

5. CONSOLIDATION OF STRUCTURE

The big consolidation was made in 63-67.
The most difficult strengthening requiring a special technology was realized for the cantilever beam.

For the upper polyhedral flange they have chosen the solution to use a third flange made up of bars placed along and in axis of the flanges, successively pretension.

The connection between the existing elements and the new flange was realized using rigid triangles.

The stretched diagonals were strengthened using additional prestressed elements and the low flange by foreseeing of a third exterior wall, in the central zone/area of the flange.

The cross bars were strengthened using also pre tensioning.

After all these strengthening works were done the King Carol I bridge were given into normal operation for the network, any restrictions or tonnage or speed limitations. It was used 4000 t of steel S235.

The railway lines were closed between 1 hour and half to 3 hours.

The works have lasted about 5 years. The King Carol I bridge strengthening has once more proved that using rightly chosen solution the life length of the bridge may be prolonged efficiently, under traffic conditions, in normal safety conditions, even after an intensely long usage period of exploitation.

Were a very difficult project and also a model project for the future consolidation on Romanian bridge.

The consolidation was made by ISPCF Bucuresti and at this consolidation worked the greats Romanian engineers of that moment.

After this consolidation in 1981 was replaced section of deck VD1 and in 1994 was strengthen SP2.

6. CONCLUSIONS

If this structure has been built in our time it would be designed and constructed in a different way. New building techniques, machines and materials would be used to build the bridge and far fewer labourers. However, this bridge stands as a testimony to what can be achieved by good design and a willing workforce. It has stood for one hundred and fifteen years carrying thousands of trains over the Danube, acting as an inspiration to engineers and designers of the world, and quite rightly remains one of the most famous bridges of the world. With the right maintenance, respect and care this bridge will still be standing in another hundred years, long after more recent buildings and bridges have collapsed or been replaced.

In 2011 the bridge is on conservation, in the next years it will be rehabilitated and if is possible it will become a historical monument.

7. REFERENCES

[1] Anghel Saligny „ Project du pont le Danube a Cernavoda. Note de calcul" Direction Generale des Chemins de fer Roumains. Service por la construction de la ligne Fetesti-Cernavoda.

[2] Băncilă R., Petzek E. "The History of the Romanian Danube Bridges" Interenational Congress Construction History , Cottbus ,Germaniy Vol. 1, p. 99-106, May 20-24 2009;

[3] Butisca Anamaria Ioana; Rominu Silvia Mihaela; Lucian Blaga; Gabor Ramona "STUDY OF BEHAVIOR IN TIMES OF THE BRIDGE KING CAROL I OVER THE DANUBE" ModTech 2011 International Conference- under publication

[4.] Popa.N., Bancila R.,Florea S.,Stanescu D. "Anghel Saligny-The Greatest Constructor of Bridges in Romania"International Conference Bridge On The Danube ,Vienna-Bratislava-Budapest p.77-83 1992;

[5]. Popa N., Băncilă R., Stanescu D. "King Carol I Bridge" Over The Danube at Cernavoda International Conference Bridge On The Danube, Vienna-Bratislava-Budapest p.85-93 1992;

[6]. Stanescu Dumitru "Structure Reinforcement of the "Bridge King Carol I" in Cernavoda", p.1-9

[7]. Stanescu Dumitru "Date privind construirea podului Anghel Saligny" Buletinul Stiintific al Institutului de Constructii Bucuresti, T.22, Nr.1-2,1979, p.41-56;

[8] Teodorescu D. "Le Complexe Ferroviare et Routier de Traversee du Danube dans la zone Fetesti –Cernavodâ, Roumanie" L'Institut de projects de chemins de fer Bucarest, p.1-9;

[9]. Stanescu D., Bondariuc V., Băncilă R., "Anghel Saligny-Activitatea si Opera lui 130 de ani de la nasterea sa" Buletinul Stiintific si Tehnic al Institutului Politehnic "Traian Vuia" Timisoara, Tom29 (43) Constructii 1984, p. 101-106;

[10]. Stanescu D., Andreescu G., Teodorescu D., "Strengthening and rehabilitation solutions for Danube Bridges for 100 years of operation" Poduri noi peste Dunare in zona Fetesti-Cernavoda, Bucuresti 1995, Editura Inedit.

[11.] Popa N., Teodorescu D., Florea S., "The centenary of the " King Carol I" bridge over the Danube in Cernavoda" Poduri noi peste Dunare in zona Fetesti-Cernavoda, Bucuresti 1995, Editura Inedit.

[12]. A D Magee, "A CRITICAL ANAYLSIS OF THE FORTH BRIDGE" Proceedings of Bridge Engineering 2 Conference 2007 27 April 2007, University of Bath, Bath, UK

[13]. Paxton, R., Shipway, J., Cox, W., Grant, D., Birse,R., 1990. 100 Years of the Forth Bridge, Thomas Telford.

[14]. Hammond, R., 1964. "The Forth Bridge and its

Builders", Eyre & Spottiswoode.

[15]. Ibell, T., 2007. "Bridge Engineering".

8. PICTURES REFERENCES

[1]. http://art-historia.blogspot.com

[2]. http://locuri-unice.ro/wp-content/uploads/2

[3]. http://cernavodablog