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# Knowledge FOR Resilient soCiEty

## DAMAGE AND DESTRUCTION OF BRIDGES OVER THE DANUBE IN NOVI SAD AND NEAR BEŠKA IN SPRING 1999

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CONSORTIUM MEETING + STUDY VISIT + TRAINING  
OHRID, July 2<sup>nd</sup> to 6<sup>th</sup>

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*"There can be little doubt that in many ways the story of bridge building is a story of civilization. By it we can readily measure an important part of people's progress."*

*Franklin D. Roosevelt (1931)*

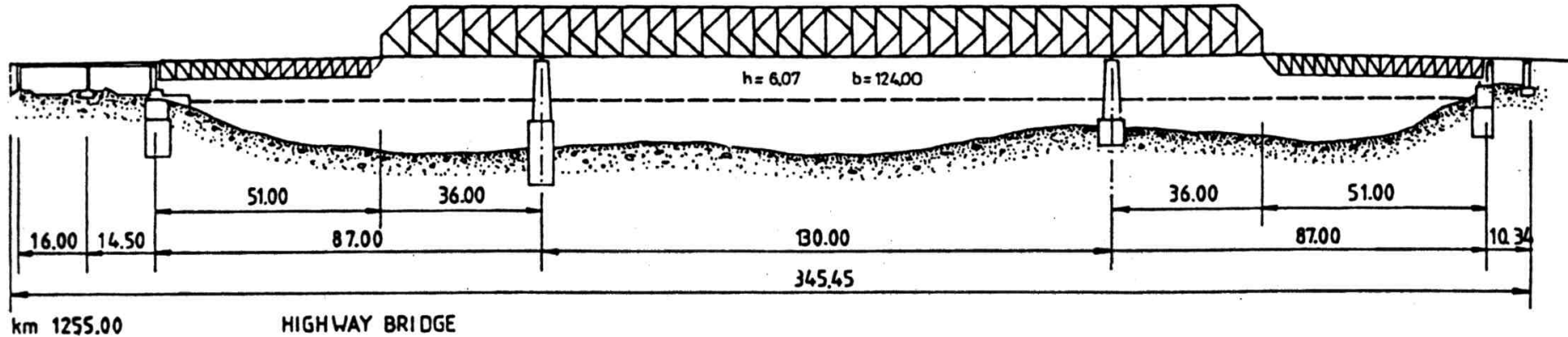


**The View of the Former Novi Sad Bridges  
(Žeželj's, Varadin and "Sloboda")**



**Varadin Bridge**

# VARADIN BRIDGE



## General Arrangement of Varadin Bridge

The total length of the bridge was 345 m, and the width of the deck was 5.5 m.

The truss is of Gerber's beam girder system (87m + 130m + 87m).

The base bearing structures are trusses with parallel chords and K-web, above the main span of 130m and two cantilevers of 36m.

The lower chord of the structure and the bank piers support two trusses (span - 51 m) with their upper chords.

## VARADIN BRIDGE

Varadin Bridge, one of 37 steel bridges with main truss girders over the Danube, connects the central part of Novi Sad with Petrovaradin.

It was erected on the well-preserved piers of Prince Tomislav's Bridge, from May 1945 to January 1946. It was mainly built of the remains of the old railway bridge.

Until 1962 it was used both for road and railway traffic, and afterwards only for roadway and pedestrian traffic.

The bridge lies on Dkm 1255.00.

**Early in the morning of 1<sup>st</sup> April 1999, with two missiles, Varadin Bridge was destroyed.**

# VARADIN BRIDGE



**Ruins of Varadin Bridge over the  
River Pier on Petrovaradin Side**

# VARADIN BRIDGE





# VARADIN BRIDGE



**Ruins of Varadin Bridge**

# VARADIN BRIDGE



**Ruins of the Inundation Structure of  
Varadin Bridge on Novi Sad Side**

# VARADIN BRIDGE

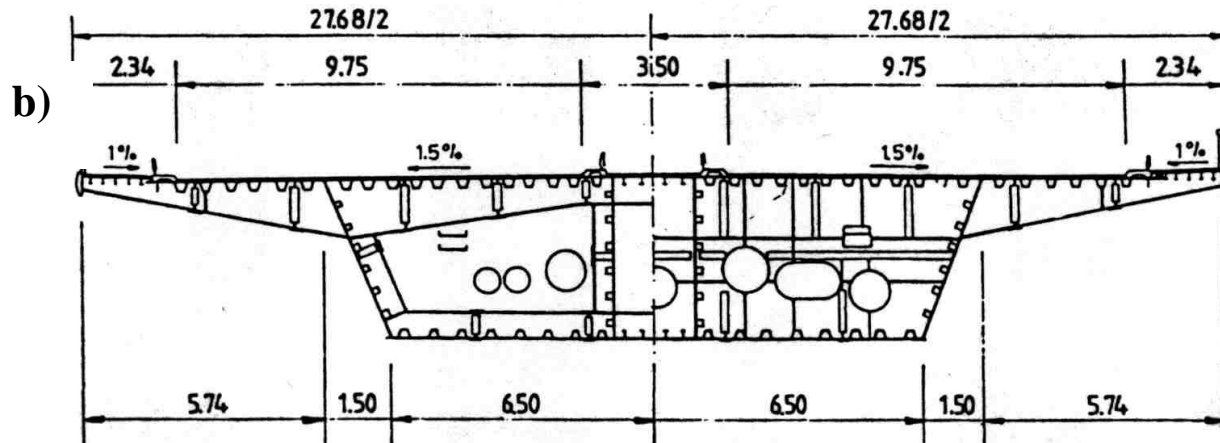
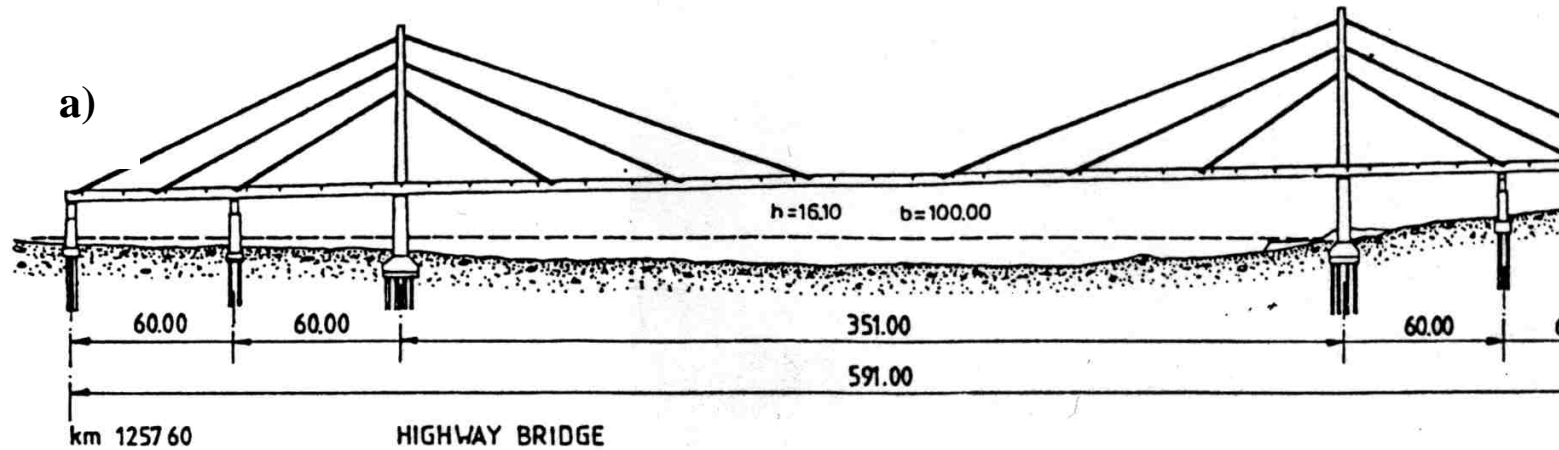


**Ruins of the Inundation Structure of  
Varadin Bridge on Novi Sad Side**



**"Sloboda" Bridge**

# BRIDGE "SLOBODA"



a) General Arrangement of the Main Structure

b) Cross Section

## BRIDGE "SLOBODA"

"Sloboda" Bridge, whose total length is 1312 m, is a cable-stayed bridge, built from 1976 to 1981. The width of the bridge is 27.68m and has six traffic lanes. On the right bank there is a double tunnel, which is 385m long. Water pipes, electric and TT cables are laid through the bridge.

There are 7 such bridges in total over the Danube built within this system. The main spans of all the cable-stayed bridges on the Danube range from 150 to 351 m, the largest of which is the main span of Novi Sad bridge.

The bridge is supported by 23 piers and consists of four structures:

- Inundation structure of prestressed concrete on the left bank, 301m in length;
- Approach composite structure on the left bank, 240m in length;
- Main steel structure, with the span  $2 \times 60 + 351 + 2 \times 60 = 591\text{m}$ ;
- Approach composite structure on the left bank, 180m in length.

The main designer of the project was the academician Nikola Hajdin, with designers G. Nenadic and P. Zelalic. The main contractor was "Mostogradnja", Belgrade; the steel structure was delivered by "G.Mavag" from Budapest, and the cables were delivered by "Stahlton" AG from Zurich.

## BRIDGE "SLOBODA"

**The Bridge was destroyed, with two missiles, in the evening of 3<sup>st</sup> April 1999 (19.55h).**



**Broken Main Span and Pylon**

# BRIDGE "SLOBODA"



**The Destruction of the Bridge Structure from the Left  
(Novi Sad) Side**



# BRIDGE "SLOBODA"



**The destruction of the Bridge Structure from the Right (Kamenica) Side**

# BRIDGE "SLOBODA"



**The Sight of the Destroyed Pylon**

# BRIDGE "SLOBODA"



**A Detail of the Broken Link Between the Pylon and Deck Structure**

## BRIDGE "SLOBODA"



**A detail of the Damaged Pylon Base on the Right Side of the Bridge**

# BRIDGE "SLOBODA"



**A Detail of the Broken and Damaged Cables**

# BRIDGE "SLOBODA"



## BRIDGE "SLOBODA"



**The Damaged Top of the Pier and its Inclination**

# BRIDGE "SLOBODA"





# BRIDGE "SLOBODA"



6/4/1999

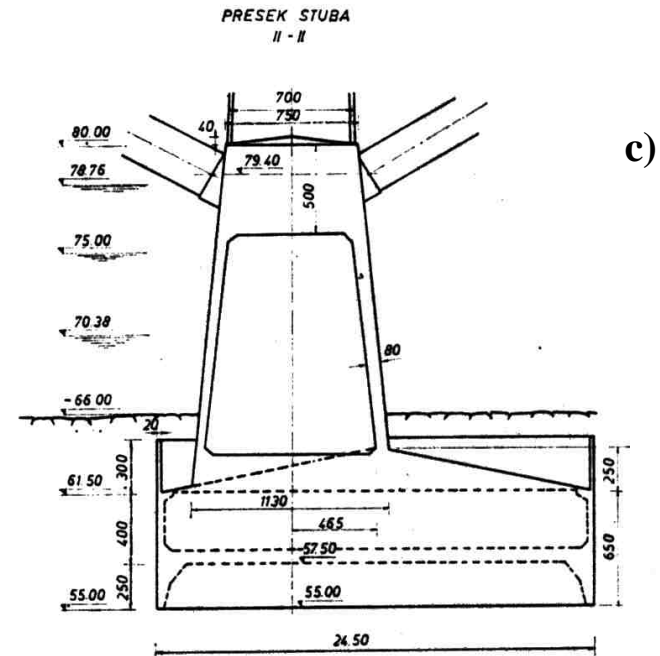
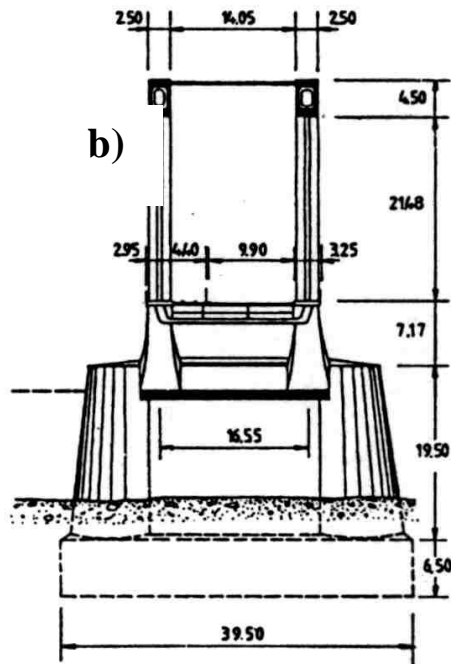
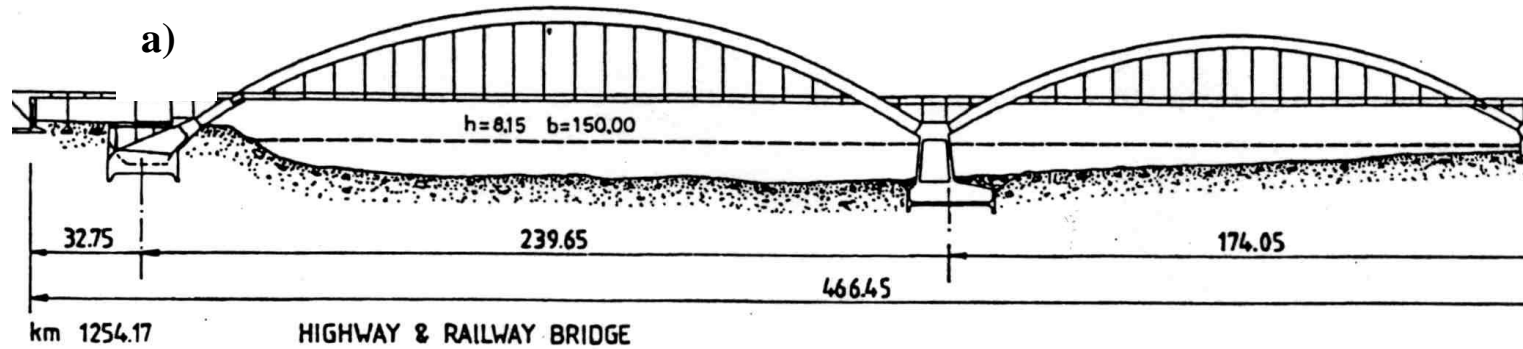
# BRIDGE "SLOBODA"





**Žeželj's Bridge**

# ŽEŽELJ'S BRIDGE



*a) longitudinal section, b) cross section through the top of the larger arch, c) cross section through the river pier and caisson*

## ŽEŽELJ'S BRIDGE

There are the total of 11 arch system bridges over the Danube, all of which are made of steel, except for Žeželj's Bridge in Novi Sad, made of concrete, and the one in Regensburg, made of stone. All of them are used for roadway traffic, except for the Novi Sad bridge, which was used both for rail and roadway traffic.

The span of the bridge is large compared to the standards of the system. The spans of the arches (with box cross section) are 211m and 165.75m.

The project was done by the “IMS-Belgrade”. The designer in charge of the structure of the bridge was B. Žeželj with associates I. Stojadinović, B. Petrović and D. Čertić (IMS Belgrade). The contractor was "Mostogradnja", Belgrade.

# ŽEŽELJ'S BRIDGE

**The Bridge was destroyed, in fifth attempt, in the night of 26<sup>st</sup> April 1999 (01.20h). It had been hit by 17 missiles.**



**Damaged Deck Structure After the First Attack**

# ŽEŽELJ'S BRIDGE



**The Sight of the Damaged Deck Structure from the Bottom Side**

# ŽEŽELJ'S BRIDGE



*Supports and Prompt Repair of the Damaged Structure*



# ŽEŽELJ'S BRIDGE



**Damaged Edged Longitudinal Beam and a Part of the Truss Structure for the Reparation after the First Attack**

# ŽEŽELJ'S BRIDGE



# ŽEŽELJ'S BRIDGE



# ŽEŽELJ'S BRIDGE



# ŽEŽELJ'S BRIDGE



# ŽEŽELJ'S BRIDGE



*The Ruins of the Bridge near Middle Pier*

# ŽEŽELJ'S BRIDGE

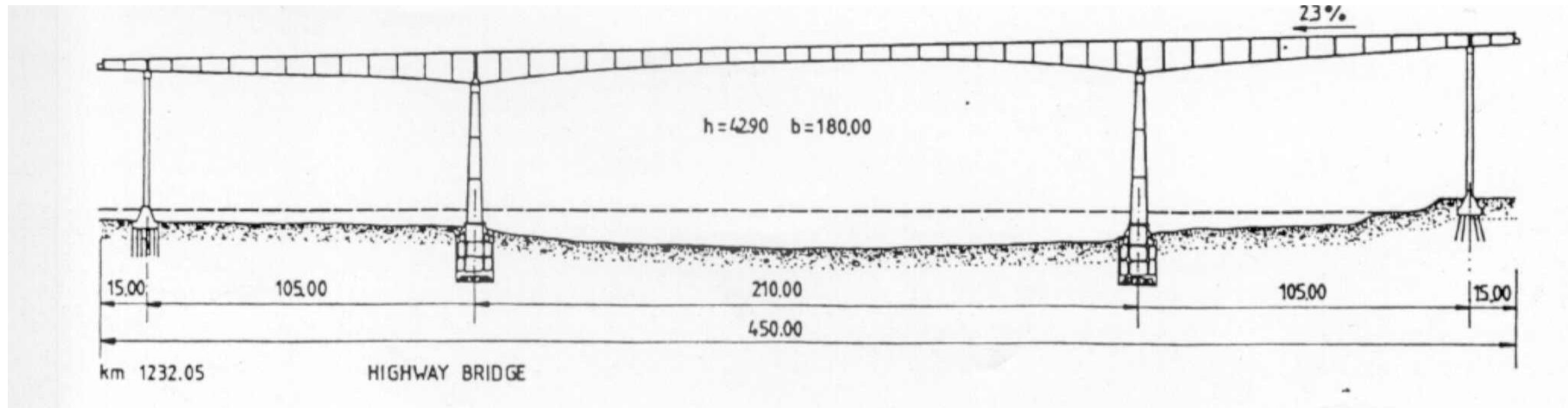


**The Ruins of the Bridge above the Abutment on the Left Bank**



**At the End of XX Century Novi Sad Without Bridges Again  
(Crossing by Ferries)**





## Disposition of Beska Bridge (longitudinal section)

The bridge was built from 1971 and 1975.

The total length of the bridge is 2250 m and the slant in the longitudinal direction is 2.3%. The length of the viaduct on Novi Sad side is 1575 m (35x45m) and 225m (5x45m) on Belgrade side. Its total width is 14.4 m, it has three traffic lanes of the total width of 11m and two pedestrian sidewalks of the width of 1.7 m each.

The section of the bridge over the water is a reinforced concrete continual beam with three spans  $105 + 210 + 105$  m and two cantilevers on both ends with the length of 15 m each. The bridge beam has a box cross-section of varying dimensions (the height of the beam above the middle river piers is 11m, and 6m in the middle of the central span).

The two middle river piers, of the height of 40m have box cross-sections.

The author of the structure was Prof. B. Žeželj, and the project designer Prof. Dr. M. Muravljov, IMS – Belgrade. The main construction company was "Mostogradnja" – Belgrade.

**The bridge was first hit on 31 March 1999 at 5.25.**



**The Damage of the Fence of the Bridge**

**The second strike was on 21 April 1999 at 3.00.p.m.**



**The Destroyed Part of the Approach Structure on Novi Sad Side  
(between Columns 6 and 7)**

# BEŠKA BRIDGE



# BEŠKA BRIDGE



# BARGE-SUPPORTED ROAD/PEDESTRIAN BRIDGE

The economically most acceptable and quickest solution was the construction of a barge-supported bridge. The bridge was designed and built within two months, from 14 July to 15 September 1999.



The Danube profile and the stability conditions required the disposition of 4 barges set transversally in relation to the river flow and two stabilizing barges at the ends, set in the direction of the river flow.

The total length of the bridge together with the transitional parts is 369.6m. The bridge is with two traffic lanes 3m wide and two pedestrian sidewalks 1.5m wide each. The total width of the bridge including the fences is 9.4m.

Piers of a former railway bridge "Franz Josef" were used as firm points for anchoring the barges. Barges 2 and 3 can be opened to let river traffic flow freely and because of potential piling of ice.

The amount of materials used for this structure is as follows:

-steel St 0361	711t
-mild reinforcement 240/360	22t
-ribbed reinforcement 400/500	48t
-concrete C 30	195m <sup>3</sup>
-concrete plates of C 30	3.334m <sup>2</sup>
-polymer mortar 2.5cm thick	965m <sup>2</sup>
-cement mortar and bitumen	1900m <sup>1</sup>
-steel cables Ø33, used for anchoring	3730m <sup>1</sup>
-steel cables Ø24	1400m <sup>1</sup>
-steel cables coated with zinc Ø26	980m <sup>1</sup>



# TEMPORARY ASSEMBLY-TYPE RAILWAY-ROAD BRIDGE



The river was bridged with four structures with the span of 72 m and one span of 102 m, and the inundation on Novi Sad side with a structure of the span of 36 m. The total length of the bridge is 433.5 m. The height of the trusses is 6.0 m and 12.0 m respectively, and their width is 5.3 m.

The roadway has two lanes which are 3 m wide each, and one pedestrian sidewalk 1.5 m. Approximately 50 trains and 8000 road vehicles a day cross the bridge.



The piers had urgently to be built while the level of the water was maximum (77.68). Therefore, the piers adopted consisted of the system of 6 piles fit into the river bottom and additional structures above the fitted-in piles which would support the structure of the bridge.

The bank piers were built as standard piers in formwork over drilled in piles.

The complete steel structures, including the carriageway were made out on a large working platform on the bank.



The specific feature of this steel structure is a very small number of different elements, which are relatively easy to combine and assemble.

By special carriages, steel structures were transported into the water.



Steel structures were taken by 4 special barges and placed on prepared piers.



The lifting and lowering of the steel structure was performed by means of steel yoke and hydraulic presses used for prestressing.



The amount of the materials used for this structure is:

-mounted steel structure	1565t
-bearings and dilatations	28.6t
-steel pipes for pile lining	217t
-steel profiles and tins	590t
-reinforcement	450t
-concrete of piles and piers	4692m <sup>3</sup>
-sand	5965m <sup>3</sup>
-pebbles and gravel	6810m <sup>3</sup>
-asphalt	5600t

The design, monitoring and testing of this bridge were carried out by the Traffic Institute CIP from Belgrade, whereas the foundation and steel structure mounting were performed by Mostogradnja from Belgrade.

This great construction success, achieved under exceptionally unfavorable hydrological conditions and by methodology used for the first time in our country, took only 100 days of work.

# "THE RAINBOW OF VARADIN" BRIDGE





# "THE RAINBOW OF VARADIN"

At the location of the destroyed Varadin bridge, the new bridge was built.

Its structure consists of three parts:

- the approach structure on the left bank (simple beam) with span=35.6m,
- the main bridge structure over the river, (continual girder) with span  $87.0+130.0+87.0=304.0\text{m}$ ,
- the approach structure on the right bank, (simple beam) with span=14.6 m.

The total length of the bridge structure is 357.20m. The total width of the bridge is 13.80 m and it includes two traffic lanes 3.5 m wide each, two safety lanes 0.5 m wide each, and two bicycle and pedestrian sidewalks whose total width is 2.9 m at both sides of the carriageway.

The bridge was completed in a record short period of time. The designing, building and assembling of the bridge took no longer than seven months. The bridge was open to the traffic on 13 October 2000.

# "THE RAINBOW OF VARADIN"

The amount of materials used for the bridge:

## upper structure

-steel structure 2028t

-cables for prestressing 2.3t

-reinforcement 40t

-concrete 316m<sup>3</sup>

## lower structure

-digging 750m<sup>3</sup>

-piles 150m<sup>1</sup>

-reinforcement 75t

-concrete 1108m<sup>3</sup>

In charge of the bridge structure design were Gojko Nenadic and Ljiljana Djukic. Financial and technical documentation for monitoring the bridge was made by the Traffic Institute CIP from Belgrade, and the works on the assembly of the structure were carried out by Mostogradnja from Belgrade.

# "THE RAINBOW OF VARADIN"



# "THE RAINBOW OF VARADIN"











**Faculty of Technical Sciences – Monitoring and Load Test TEAM**