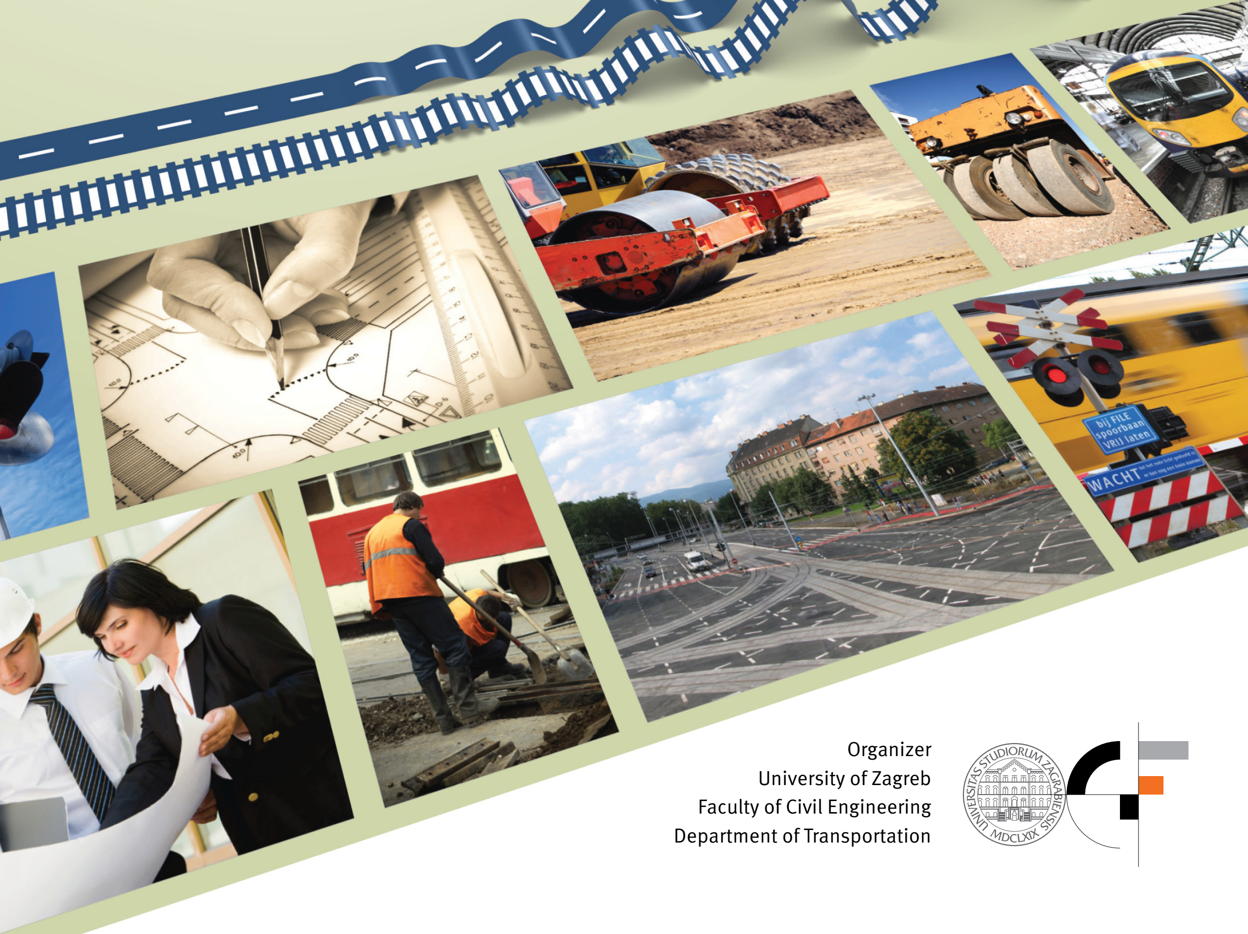
CETRA 2012

2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

Stjepan Lakušić – EDITOR



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Road and Rail Infrastructure II

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VIADUCT DESIGNS ON THE SECTION OF THE PAN–EUROPEAN CORRIDOR X IN SOUTH SERBIA

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Abstract

On the planned section of the motorway E–75, a viaduct design has been developed to connect the deep valley and Koznicka River. The right and the left lane of the motorway divert in the viaduct area, because the motorway leads into two separate tunnel tubes, right after the bridges.
According to the layout solution, a design has been prepared for a 6 feild viaduct, bridged over by previously prestressed precast girders with a span L = 25.40 m and which have continuity over intermediate piers. Within the scope of a cross section, four precast girders with 'I' cross–section, with height of h = 1.70 m and mutual spacing λ = 3.00 m, have been anticipated. Reinforced concrete pavement slab is cast over the girders. Reinforced concrete cross girders above intermediate piers are being cast together with a slab, thus providing continuity. The impact calculation within the load girders, caused by their own weight, fresh concrete mass of cross girders and the pavement slab, has been carried out within the first phase. For this loading phase calculation and impact control have been carried out within the bearing beams and intermediate piers for cases of symmetrical and asymmetrical load disposition.
After the executed continuation of the span structure and formation of a continuous panel structure with intermediate piers, calculations have been carried out for the impact of primary and additional constant load, traffic volume, additional effects and exceptional effects, using the SOFISTIK software package.

Keywords: viaduct, prestressed girders, continuous structure, static impact

1 General data

On the E–75 motorway, which passes through Serbia from Horgos to Presevo, a 26.4 km long south section that passes through the gorge Grdelica, , is the most complicated section design wise and the most expensive section for construction. This gorge represents a natural transport corridor, which connects Aegean Sea and Asia. A preserved Roman and medieval 'Imperial Road' is located there. The old Belgrade–Nis–Solun railroad also passes through there, as well as the modern main road. In this morphologically narrowed gorge profile there are several settlements, networks of electric feeders (of high and low voltage), international coaxial telephone cables, as well as the local water supply system. Under such complex morphological, geologic–geotechnical and other field conditions and restrictions, geometrical elements of the motorway route are adjusted to present conditions, providing various engineering solutions and structures. The left and right motorway carriageways are separated in the area of viaducts, because immediately after the bridges the motorway enters two separated tunnels.

2 Data for design documents preparation

- Preliminary design
- According to the Preliminary design, the viaducts are planned to be constructed over the river Koznička reka.
- The adopted solution includes a continuous frame structure as well as a span structure made of prestressed prefabricated girders. Founding of viaducts has been accomplished directly, via footings in an open foundation pit.
- The Employer's Terms of Reference.
- The motorway Final Design in the area of the viaduct,
- A geological – geotechnical survey,
- A hydrological – hydraulic survey of river regulation (the River Koznička reka) with calculation of the bridge span.

3 Motorway elements in the viaduct area

Left and right motorway carriageways are separated in the viaduct, because immediately after the bridges the motorway enters two separate tunnels. The finished level of the motorway is in vertical convex curve, Rv=50.000m. Cross–falls of the pavement on the both motorway carriageways vary throughout the entire length of bridges. On the left motorway carriageway, the cross–fall is single–sided towards the left pavement edge and amounts: i pop=3.69% – 4.50% – 3.51%. On the right motorway carriageway, cross–fall of the pavement is warping, from i pop=2.50 % at the beginning of the bridge (towards the right pavement edge) to i pop =1.60 % at the end of the bridge (towards the left pavement edge). Both carriageways are in transition curves of various parameters.
The viaduct width is aligned with the width of the motorway pavement and amounts to:

- Pavement width: Bк=10.05m
- Width of space between inner brackets of viaducts is variable
- Thickness of prefabricated cornice on outer edges of brackets, each: d=8cm
- Total width of every viaduct on the motorway amounts to: B = 1.95×2+10.05+0.08×2=14.11 m

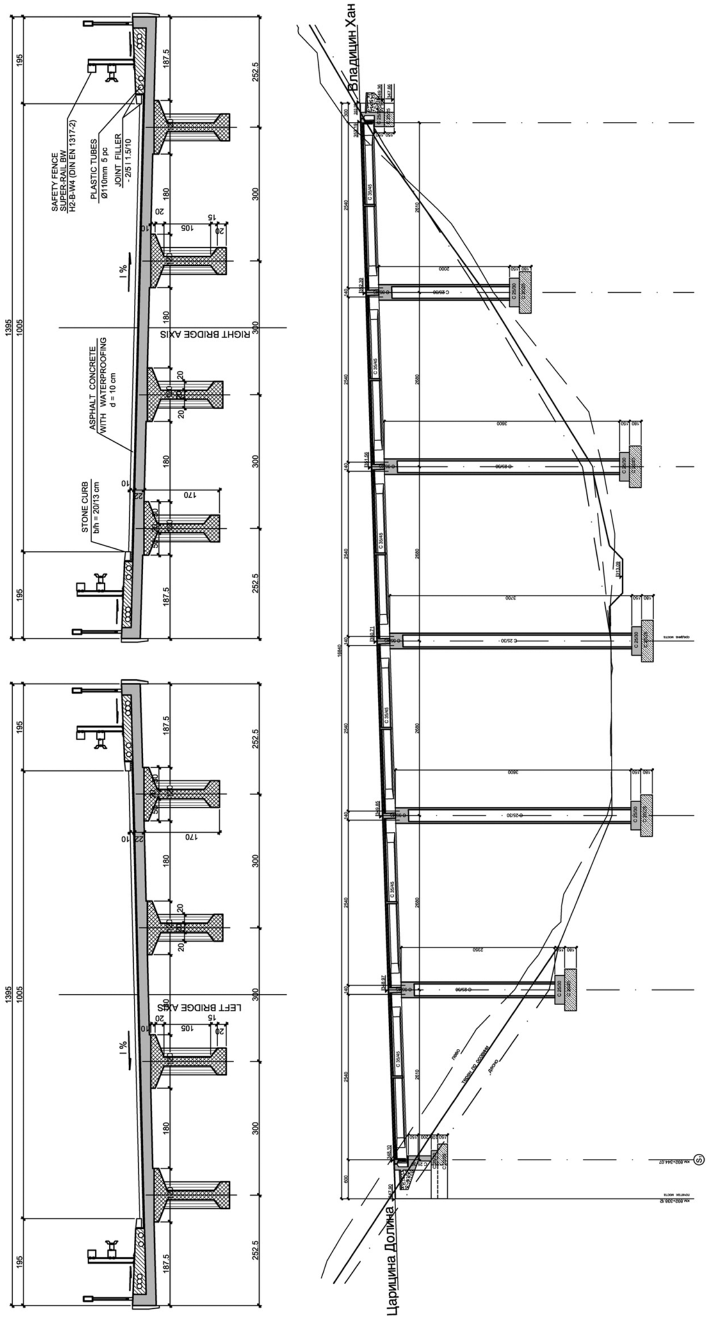

Figure 1 Cross section and longitudinal section of the bridge

4 Structural solution for viaducts

4.1 Superstructure

Viaducts have been designed according to the dispositional solution, with 6 spans each, bridged by prestressed prefabricated girders, with static span L=25.40m, which have continuity above intermediate piers, which results in a semi–integral structure. In cross–section there are four prefabricated girders at a distance of λ=3.00m. A reinforced concrete pavement slab is cast over girders, with thickness of d=22cm. Reinforced concrete cross girders are cast together with a slab above intermediate piers, which makes a continuation, and together with the pier a continuous frame structure is formed.
Within this system, impacts of moving load are received, additional permanent and exceptional impacts.
Prefabricated girders have 'I'cross–section, height h=1.70m, width of the upper flange b_1= 1.20 m, lower flange b_2=0.60m and ribs b_r=0.20m. In the middle of the main girders, cross girders are planned, width b=0.30m, which are concreted subsequently. Longitudinal, main and cross girders form a normal crib. Longitudinal crib axis follows a tangent curve on the part of the transition curve on every span. The carriageway curvature on viaducts is achieved with a concrete pavement slab.
Girders are being prestressed by three cables 12 ø 15.2 mm, rated strength fpk = 1.860 N/mm². Starting force, per each cable is Fp=0.72×Fpk=2.250kN, and the final force in the middle of girder span is: F∞=1.744kN.
Cross girders above bearings on the abutments C1 and C7 are prestressed with 3 cables 7 ø 15.2mm, rated strength fpk=1.860N/mm².
Starting force, per cable is Fp=0.80×1.062 kN=850 kN, and final force, with 15% of loss, is: F∞= 722.2kN. Tightening of girders secures the impact that will occur during the replacement of bearings in the operational phase of the bridge. During the replacement of bearings the use of hydraulic presses is planned, and those should be placed below the middle area of tail cross girders.
Cross girders in the middle areas of main girders are prestressed with 3 cables 7 ø 15.2 mm. Starting force, per one rope, is Fp=0.70×1.062 kN=743.4 kN, and final force within the rope, with 15% of loss, amountsto F∞=(1-0.15)×743.4=632.0 kN.
The connection between the abutments and span structure is achieved via transflex expansion devices with carpeting of reinforced rubber, type T – 100 with expanding ability ΔL=± 50 mm. During concrete works on the pavement slab and tail cross girder, it is necessary to take into account the assembly of expansion devices. Support of span structure on the abutments is accomplished by reinforced elastomer bearings NAL ø 400, d=76 mm.

4.2 Substructure

Each viaduct substructure is made of two abutments and five intermediate piers with foundations. Choosing the position of piers is determined by land contour, finished levels of the motorway carriageways and geotechnical field data in the area of viaducts.
Intermediate bridge piers are made of reinforced concrete with a box, rectangular cross–section, dimensions 2.40×6.00 m, each having two cells and vertical walls with thickness d=30cm. Inside the head of every intermediate pier, there are reinforced concrete pile helmets, monolithically connected to the pier body. Dimensions of the pile helmet are b/d=2.40/6.00m with double–sided brackets with spans of 2.65m. Total length of the pile helmet is 11.30m. The height of the pile helmet at fixed end, at the intersection with the pier wall, is 2.00m, while at the end of the bracket the height is 1.00m.
Contact area of main girders and pile helmet of intermediate piers varies due to the motorway route curvature and it is provided in the design documents.

Pier heights sre determined on the basis of land contour and geotechnical profile of each pier location. In intermediate viaduct piers, the stem height on both motorway carriageways (not including the height of pile helmet) varies from 16.00m to 38.00m.
The design engineer has determined the depth, manner of founding and environment, based on recommendations from the geological – geotechnical survey. Founding of intermediate piers is performed directly on reinforced concrete pads of thickness d_J=150cm below which is the oversite non–reinforced concrete, thick d_S=180cm.
The solution for abutments is conditioned by distinctive features stemming from their position, land contour and depth on which the solid rock mass is located. All structural elements of the abutments are made of reinforced concrete.
Abutments, C1 – of the right carriageway and C7 – of the left carriageway, are composed of head walls, point–bearing wing walls, counterforts for stiffening of head carcass, pile helmets for bridge span structure support and parapet beam with crossing slabs. The footings are adjusted to the field in cascades.
Thickness of head walls carcass is d=60cm, while the thickness of carcass of each, the wing walls and the counterforts, are d=40cm.
The abutments structure, C1 – of the left carriageway and C7 – right carriageway of the motorway are different because of the land contour.
Gravel wedges will be positioned behind head walls of the piers. Reinforced concrete crossing slabs d=0.20m thick and 3.00m long, are anticipated for the connection between the viaduct and the motorway road base, above gravel wedges, and they will rely on parapet beams.
Reinforced concrete pile helmet is horizontal and of constant height. In order to achieve necessary design cross fall, bearings are placed on horizontal reinforced concrete ashlars of variable height. Bearing ashlar structure and altitude of cross–girders provide for, if necessary, a simple replacement of bearings or some other intervention during their maintenance.
Parapet beams are monolithically connected to pile helmets. The length of beam covers the entire width of the head carcass of the abutment; beam thickness is d=0.50m; height of parapet beam is variable and depends on the pavement cross fall. The beam structure has provided the approach to the area between the parapet beam and the tail cross girder of the viaduct for easier access to bearings and expansion devices during check–ups and possible interventions. The shape of the parapet beam top is adapted to the requirements of proper assembly of expansion devices.
The total length of the viaduct on the right motorway carriageway is L=168.06m.
The total length of the viaduct on the left motorway carriageway is L=169.50m.

4.3 Static analysis of the structure

Viaducts belong to the first category – 'bridges on motorways'. Computational pattern for traffic volume V 600 + V 300 has been used during impact calculation.
Impact calculation has been carried out for two stages of loading. The first stage refers to the assembly of the main girder. Impact calculation in girders for their own weight loading has been carried out with green concrete mass of cross girders and a bridge deck. Calculation and control of impact has been carried out, for this stage of loading, in pile helmets and intermediate piers for symmetrical and asymmetrical loading positions.
The second stage of loading refers to a phase after performed continuation of the span structure and formation of the frame structure, with intermediate piers. Calculation of impacts in continuous frame structure of the viaduct due to basic and additional loading, traffic loading, additional impacts (changes in temperature, wind force and stopping of vehicles) and exceptional effects (earthquake force) has been conducted on a model using the software package SOFISTIK.
The theoretical model for determining impacts on the construction is three–dimensional and based on the finite element method. The bridge structure is modelled by a certain number

of smaller size areas of finite dimensions using bar and plate elements, which represent the finite elements, interconnected in a finite number of knot points.
This knot cluster represents the finite element network for the entire bridge. Calculation of impacts on the intermediate piers with pile helmets, as well as on the abutments, was performed on special models of the software package SOFISTIK.

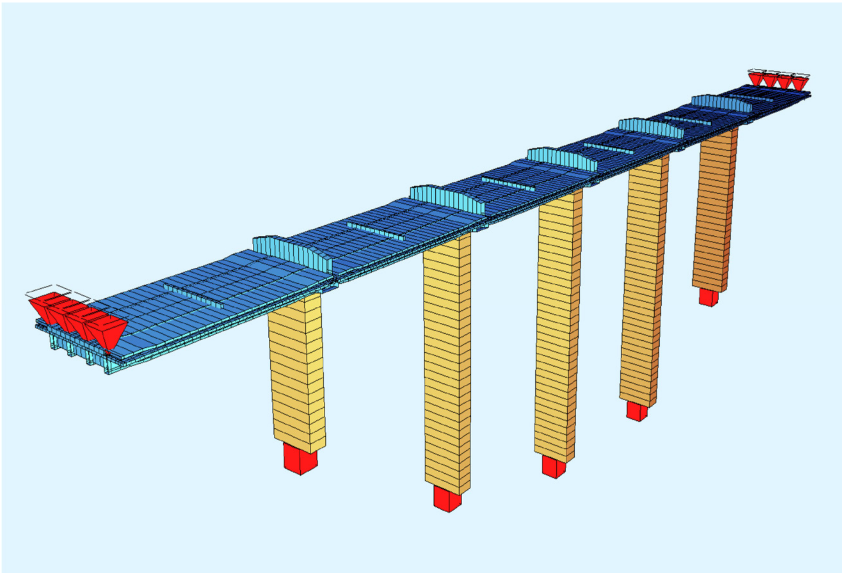

Figure 2 3D model of the bridge, from the software package SOFISTIK

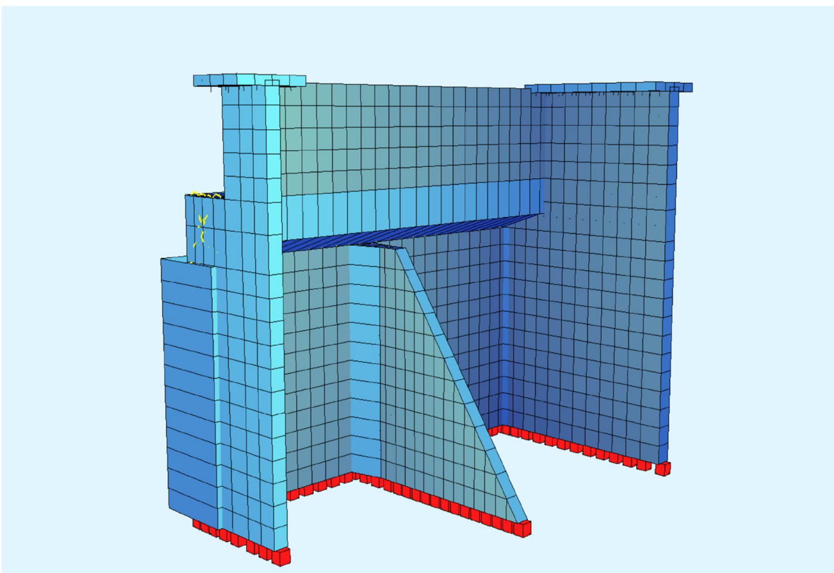

Figure 3 3D model of the bridge abutment

5 Building structures

A waterproof system with polymer–bitumen membranes for welding and embedding of polymer–bitumen membranes in a single layer is planned for reinforced concrete overpass bridge deck waterproofing.
Asphalt pavement shall be constructed on the structure in two layers, with total thickness d=10cm with a waterproofing layer.
Pavement is lined with stone curbs, with dimensions 20/13cm, which are elevated by 7cm from the pavement surface. The position of curbs is defined by the width of the motorway carriageway in the area of viaducts.
In order to secure car traffic, steel guard rails SUPER–RAIL BW H2 – B – W4 (DIN EN 1317–2) shall be installed on viaducts.
Public lighting piers shall be spaced on the inner side of the viaducts (towards the green area).

6 Conclusion

The viaducts have been designed as semi–integral structures, without expansions and bearings on intermediate supports, thus eliminating potentially weak spots and reducing costs of construction and maintenance during the operational phase, and making a safer traffic.
Concreting of bridge deck above precast girders provides a joint interaction in the cross–section, as well as the possibility of application at bridges in a curve and neutralizing geometric errors during construction.
The use of modern computer equipment and programmes based on the finite element theory provides a rapid and exact analysis of these bridges, on a physical 3D model.

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