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THE FINAL DESIGN AND WORKS EXECUTION OF THE VIADUCT IN ˝BATAJNICA˝ INTERCHANGE, BELGRADE BYPASS, SECTOR A1

Summary: *This article presents the most important details from the Final Design of the viaducts in ˝Batajnica˝ interchange, part of the Belgrade bypass, on the E-75 highway Novi Sad - Niš. The whole construction contains two viaducts, each about 1400 m long, and four approaching ramps. Main viaduct structures are voided pre-tensioned concrete slabs, supported by 115 columns, and ramp main girders are reinforced voided concrete slabs. Viaduct span length is between 18 – 31 m, ramp main span length is 16 m and end-span 11 m. Bridge traffic profile is the highway profile. Bridge piers were founded on piles (piles are about 31 m long).*

Key words: *viaduct, concrete bridge, highway*

1. INTRODUCTION

˝Batajnica˝ interchange is part of the 70 km long Belgrade bypass, as the way of heavy traffic relocation from the urban city center. Interchange is located at the beginning of the sector A, Batajnica-Dobanovci, 10.1 km long, connecting highway E75 (Novi Sad-Belgrade) and E-70 (Belgrade-Zagreb).

Slika 1. Obilaznica Beograda - Petlja ˝Batajnica˝ (Belgrade bypass – ˝Batajnica˝ interchange)

2. STRUCTURE GENERAL INFORMATION

Viaducts' structures forming a part of the structure within Batajnica Interchange Project, extend from km 187+012.36 (right bridge), that is 187+005.08 (left bridge) with connection to Novosadski Road, to km 188+406.53 (right bridge), that is 188+400.20 ((left bridge) at the end towards Dobanovci.

The total length of both viaducts is 1396 + 1429 = 2825 m. The viaduct comprises entry – exit ramps which enable connection of motorway routs to the roads leading to Zemun and Batajnica. The total length of all four approach ramps is 681 m. Surface area of all structures is around 46000 m^2.

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1.1 Traffic cross sections of viaducts and ramps

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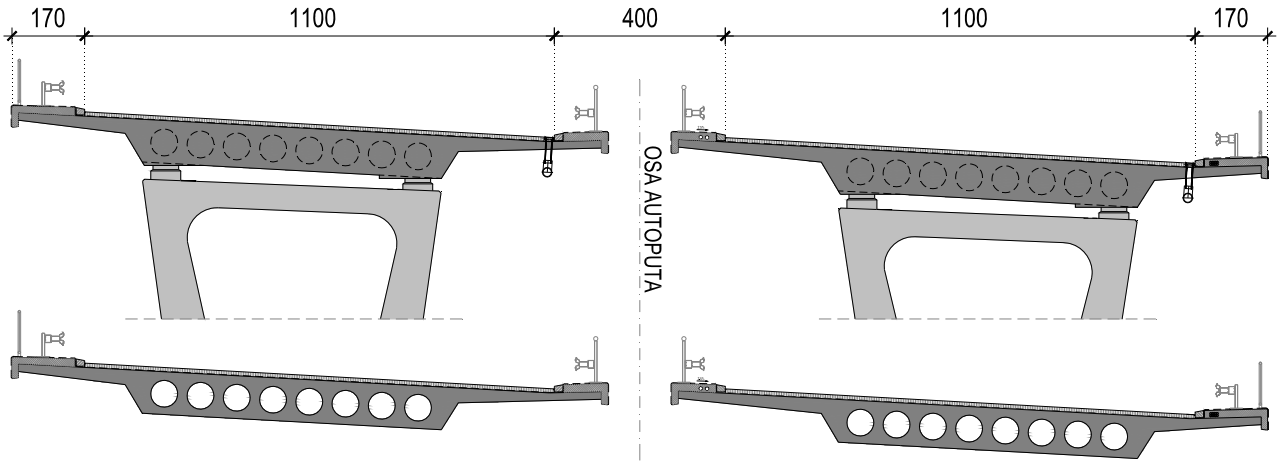
Traffic profile of the motorway viaducts is :

Traffic paths : 2.50 + 2 x 3.75 + 2 x 0.5 = 11.00 m (same as on Novosadski Motorway to which the viaducts are connected to), except on widenings at entry – exit ramps, where the pavement width is 11.85 m. Transition to motorway width of 11.50 m is to be performed after the viaducts end, i.e. in the zone of connection with Sector A2.

Steel guard rails with shoulders: 2x(0.5+0.5) = 2.00 m

Service path: 0.5 m



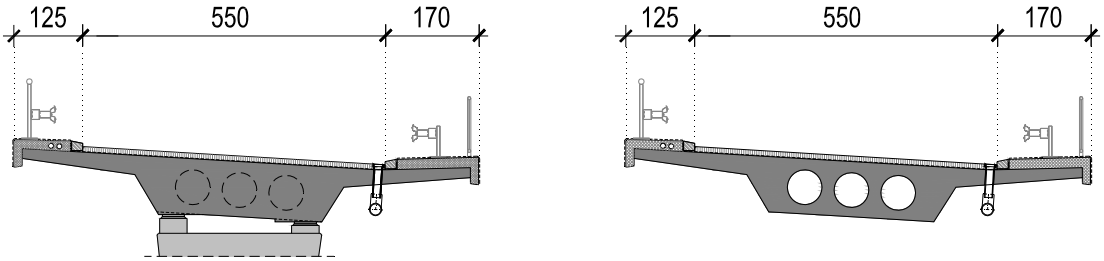
Slika 2. Tipski poprečni presek glavne konstrukcije vijadukta (Typical viaduct superstructure cross section)

Traffic profile on ramps is :

Traffic path : 5.5 m

Steel guard rails with shoulders: 2x(0.5+0.5) = 2.00 m

Service path: 0.5 m



Slika 3. Tipski poprečni presek rampi (Typical ramp superstructure cross section)

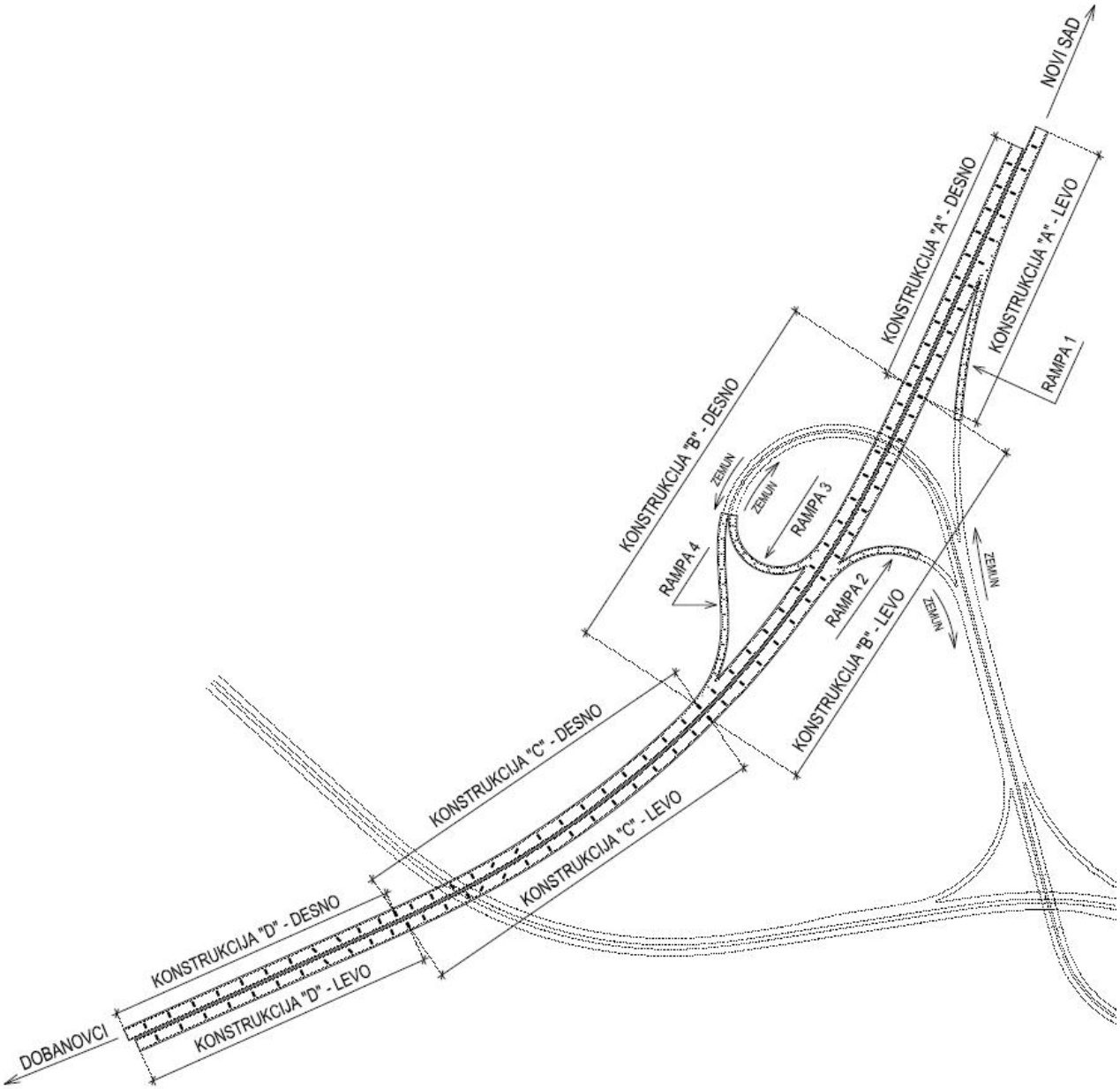
1.2 Viaduct structure

The position of the viaduct, in respect of both horizontal and vertical alignment, integrates into the Detailed Design of the given road. Terms of Reference, requirements of relevant public enterprises, revised Preliminary Design and Detailed Design of motorway route on the Batajnica – Dobanovci Section, sectors A1 / A2, form the basis for preparation of the structure's Detailed Design.

Structure of each viaduct consist of 4 separated structures (A, B, C i D), 350-400 m long, with spans of around 26 m – 31 m, structurally continuous, with expansion joint devices on both ends of each segment (see interchange ˝Batajnica˝ scheme).

Cross section of viaduct superstructure is prestressed, reinforced concrete voided slab, 1.0 m thick. The voiding is performed in order to reduce structure's self-weight, by installing polyethylene pipes with outer diameter of Φ630 mm and pipe wall thickness of 9 mm, with welded fronts to prevent any water ingress. The slab width in the area where it is supported by piers is 7.00 m, and inclination of sides is 40 cm. Cantilever overhangs along the shoulders are 330 cm, and on outer sides from 245 cm to 330 cm, depending on the width of the pavement structure (11.00 m or 11.85 m). The ramps have identical visual silhouette, whose 1 m thick "main girders", continually "flow into" the main structure. Cantilever overhangs on ramps are 300 cm, and 275 cm. All ramps are rigidly connected with the main structures – monolithic connection.

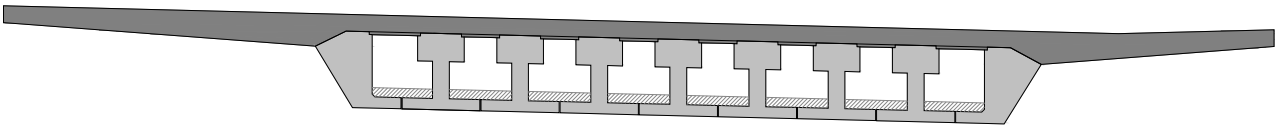
Ramp structures are reinforced concrete beams – slabs, 3.0 m wide at the bottom of the cross section, that is 3.6 m at the top, at the beginning of cantilever overhangs, and are hollowed with three PE pipes Φ630 mm; ramp span is around 11.0 m on the ends, that is 16.0 m in central spans. They are supported by piers – in the areas with less longitudinal movement (expansion) via reinforced concrete piers, and in the areas with greater longitudinal movement via elastomeric or sliding bearings.



Slika 4. Shema petlje ˝Batajnica˝ (Interchange ˝Batajnica˝ scheme)

Slika 5. Montažno polje preko pruge - segmentu D (Precast span over the railway - segment D)

Superstructure span over the railway, 28 m long (in segment D), because of technological requirements, is done as precast span, with external contours same as the contours of main slab (figure 6). Precast beams (edge and middle) are 12 m long and prestressed, 82 cm thick, and supported by scaffolding during the installation. Scaffolding towers are placed by existing tracks of railway Belgrade-Zagreb.



Slika 6. Poprečni presek montažnog polja (Precast span cross section)

Main structure piers are ˝V˝ shaped piers (450 cm wide at the bottom, 700 cm wide at the top, except special types), with ˝tie beam˝ on the top (60 or 80 cm thick). There are 111 piers, and they are categorized by types for easier calculation and execution. Piers height depends of their position in structure, and varies from 5.0 m to 9.5 m, and their thickness is 60, 70, or 80 cm, which depends of pier height and support conditions. Piers are doubled (twin piers) at the joints of two structures, and they are on 0.6 m distance, placed on the same foundation beam. Every inner pier are funded on two piles ø1200 mm, 28 to 31 m long, and foundation beams have dimensions 520x150 cm and height 120 cm.

Central groups of piers of each segment (their number varies from three to six) are rigidly connected to the superstructure via reinforced concrete joints, adjacent two-three piers, on both sides of this central group of piers are connected to the structure via elastomeric bearings, and a few of the first and last piers, including abutments, have movable “pot” bearings. Movable bearings are longitudinally directed (in the bridge axis direction) and they can take over transverse forces from the superstructure, together with piers with reinforced concrete joints.

Slika 7. Izgled konstrukcije i stubova vijadukta i rampi, zajednički stub dve konstrukcije (Viaducts superstructure and piers, ramp piers and twin pier between two constructions)

Piers supporting ramp structures are trapezoidal, 150 cm wide at the bottom, 300 cm wide at the top, and their thickness is 60 cm. They are supported by one pile Φ1200 mm, 24 to 28 m long, with pile caps 180x150 cm and 100 cm thick. Depending of the position on the ramp piers height varies. There are 42 piers. Also, depending of the height and their position on the ramp, their connection with the pile cap and superstructure is different.

Slika 8. Izgled konstrukcije i stubova vijadukata - 3D model (Viaducts superstructure and piers – 3D model)

Slika 9. Stubovi vijadukta (Viaduct piers)

End piers (abutments) of the main viaducts are to be constructed as piers with embankment, with cones in gradient 1:1.5. They are supported by 3 piles Φ1200 mm, and a pile cap with “angel” wings shall be constructed over them. Piles shall be constructed upon completion of embankment, in order to avoid adverse impact of negative friction on piles.

End piers of ramp structures, shall be, in principle, constructed in the same manner as on the main structure, that is by drilling the piles through the previously constructed and stabilized embankment.

Maximum dilation of main structure segments due to concrete shrinkage and creep, and due to temperature are 100 – 120 mm towards spans, and 50-60 mm towards adjacent segments. Expansion joints are “comb” type, watertight.

Atmospheric water from the pavement structures is, via gullies, collected in horizontal pipes and taken away to catch pits.

Slika 10. Specijalni stubovi vijadukta u zoni gasovoda (Special viaduct piers in gas-pipeline zone)

3. EXECUTION METHOD

Bored piles Φ1200 mm are constructed by applying a method which is common for that type of foundation. All are constructed in relation to the existing terrain level, except piles for end piers of main structures and ramps, which are constructed after completion of embankment, which is compacted and consolidated.

After concreting, bearing capacity of several piles is checked by load impact test and it was concluded that the ultimate bearing capacity is greater than 12.000 – 13.000 kN for around 30 m long piles. Please note that the service force of G + ∆G + P is around 4.500 – 5.000 kN.

All piers are constructed in two phases.

Bridge superstructure is to be constructed by a successive concreting and prestressing procedure, “span by span”. First span of individual segments of 20-22 m, and other spans (around 27 – 28 m) are spanned by a fixed scaffold, with one strong scaffold tower in mid span. After concreting of each of the phases (comprising one span + 3.8 m of culvert), “half” of the total number of 11 tendons in cross section is stressed (7 x 12Φ15,7 + 2 x 2k13Φ15.7) and anchored by using couplers in cross section – construction joint. Considering that in each construction joint 5-6 (≈ ½ of the total number of tendons) are coupled, there are two groups of tendons – one which is stressed in construction joint, and the other one, which only goes through that construction joint and is stressed at the next one. After relocation of the scaffold from the span

where one group of tendons has been stressed (leaving only the scaffold tower in the span's centre until stressing of the second group of tendons), next span is concreted to the next construction joint and the second group of tendons is prestressed. Central scaffold tower is removed after all the tendons in one span have been stressed. The procedure is continued in N identical phases. Prestressing of the slab is performed after strength of grade C25/30 concrete has been achieved (breaking of cylinder Φ150 mm at 25 MPa, and cube 200 mm at 30 MPa). Segments with smaller spans than span B have in their "edge girders" one 15Φ15.7 tendon, instead of two 13Φ15.7 tendons.

Due to considerable transverse tensile stress in the slab (both transversally and vertically) in concrete of the next phase of concreting (due to prevented shrinkage of "young" concrete next to the "old" concrete of the previous phase) in the area next to the construction joint, additional reinforcing of the slab is performed in the area immediately next to the construction joint.

Due to voids in cross section, concreting is performed in two phases – first phase to the PE pipes- clips preventing surfacing of PE pipes are anchored in that concrete, and second phase, usually the day after the first phase, alowing the first phase concrete to achieve min C12/15 and prevent surfacing of the pipes.

Slika 11. PE cevi za ošupljenje konstrukcije (PE voids)

Detailed plan of the prestressing phase with initial forces on press is provided on special drawings, for each segment separately.

In structure segment D, over the railway, precast beams are installed. Once they have been mounted on scaffold towers, steel 2U280 profiles are installed under the girders, at a distance of 3.0 m, which are anchored by reinforcement protruding from the edge girder. Those steel profiles 2U280 cover the entire width of the viaduct cross section (around 14 m) and their overhanged parts serve as support for formwork of the cross section's cantilever. Intermediate girders have, in their lower part, 50 mm diameter openings through

which reinforcement bars are inserted to accommodate transverse flexural moments and ensure that structure is “functioning” as a slab. This reinforcement is welded to identical reinforcement protruded from the edge girders as anchors. The area is then concreted in a 12 cm thick layer, leaving 50 mm diameter holes to drain water from that area. Between the precast girders, at their top, formwork sheets are placed for concreting of bridge deck, 18 cm thick.

Connection of precast girders and bridge deck is achieved through stirrups, in order to secure transfer of shear forces between the deck and the girders. The bridge deck is then concreted together with the cantilevers. Other areas of the span, left and right from the precast girders area to the piers are concreted on a standard scaffold. After the required strength has been achieved, continual tendons are inserted (two tendons 13Φ15.7 in edge and one tendon 13Φ15.7 in intermediate girders) and stressing is performed according to the usual order, coupling half the tendons in each construction joint. Scaffold towers are to be removed then.

Slika 12. Završeno montažno polje (Finished precast span)

4. MATERIALS

1. concrete:
- piles C25/30
- blanket courses and fills C12/15
- approach slabs, pile caps, cone claddings and foundation C25/30
- wing walls, bearing beams,parapets,all intermediate piers C30/37, V6, M100
- plinths, superstructure C30/37-C35/45, V6, M150, 0
- sidewalks, cornices C30/37, V6, M150, 0
2. reinforcement: B500-B (500/560), ili B500-C (500/580)
3. tendons: Y1860 (1670/1860)
4. bearings and expansion joints:
- elastomeric: natural and choloprene rubber (NR or CR), reinforced with S235 steel plates, vulcanized, low damping ($\zeta < 0,06$), CE conformity marked, acc. to EN 1337
- sliding : CE conformity marked, acc. EN 1337
- expansion joints :˝comb˝, watertight, acc. to ETA
5. steel elements: S235, zinc coated

6. waterproofing: polymer – bitumen sheets
7. asphalt: asphalt – concrete and SMA

5. SOIL DATA AND FOUNDATION

According to the data obtained by exploration works, as part of Soil-mechanics Analyses of the “Highway Institute”, it may be concluded that the terrain, to the depth of around 21.5 – 24.5 m, is composed of extremely to medium compressible loess deposits – 4 horizontal layers of loess, with four layers of ˝pz˝ soil between them. Under those layers are less compressible swamp sediments and less compressible sandy-clays, which on depths over 35 m are preceded by medium compressed to compressed lacustrine sand. Bearing this in mind, piles of the main structure (with maximum forces from 4200 kN – 5070 kN) are 28 – 31 m long, under the level of pile cap bottom.

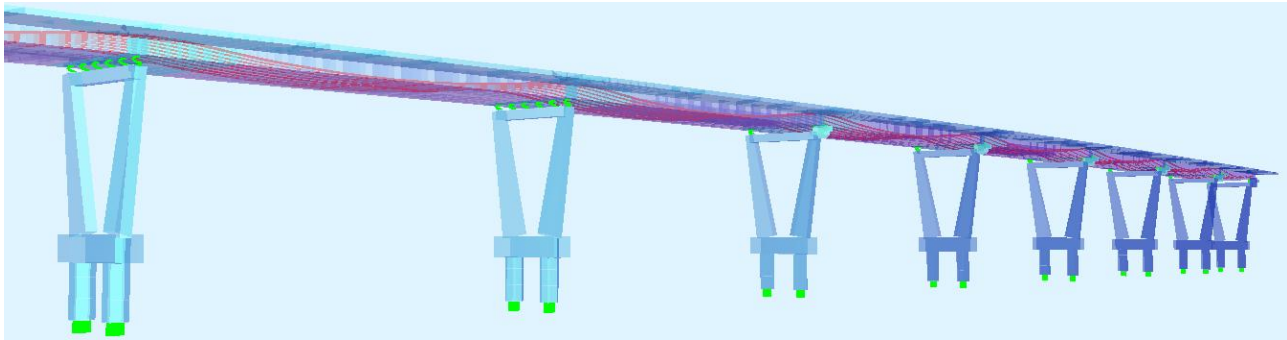
The underground water level has been detected at depths of 1.4 – 4.6 m from the terrain’s surface.

In terms of geophysics , this area should be treated as a grade VII seismic zone for return period of 100 to 200 years (geophysical investigations from 2005). Category of the structure is I, soil category II, seismic coefficient Ks = 0.028, and design soil acceleration 0.11g.

Allowable pile bearing capacity have been calculated on the basis of data from the existing Soil mechanics Analyses of the ˝Highway Institute˝, (as well as data of the additional testing of test piles by impact test) applying several methods – method taken form domestic Code of practice for structures foundation, Brinch – Hansen method, static penetration method, semi-empirical method based on the results of standard penetration, and of the formula for soil resistance mobilization.

6. STRUCTURAL ANALYSIS

Disposition and lengths of structurally independent segments A, B, C and D on the right bridge (that is A’, B’, C’ and D’ on the left bridge) have been constructed taking in consideration the positions of the approach ramps and their ˝connections˝ with the main structures: segments ˝B˝ and ˝B’ ˝ are so located that the exit ramps are approximately in their middle, i.e. in the area of zero temperature movement, in order to avoid discontinuity and to achieve rigid joint between the main structures and ramps. Those ramps have expansion joints on their ends only, along the contact with embankment, and they are relatively small – for movement ± (20 – 25) mm. Similarly, on structure ˝A’ ˝ with the entry ramp for traffic from Zemun to Novi Sad located very close to the segment center, use of expansion joint on the connection with the main structure has been avoided. In the same sense, the entry ramp for traffic from Zemun (Batajnica) towards Dobanovci is rigidly connected with the main structure ˝B˝ , but on three – four of its end piers, in the area next to the structure ˝B˝, sliding bearings are installed to accommodate the temperature movement of the structure. Expansion joint on that ramp, at the connection with embankment, has movements which depend on temperature at which continuation of segment ˝B˝ with that ramp will be constructed, and they range from ±15mm do ±40mm.

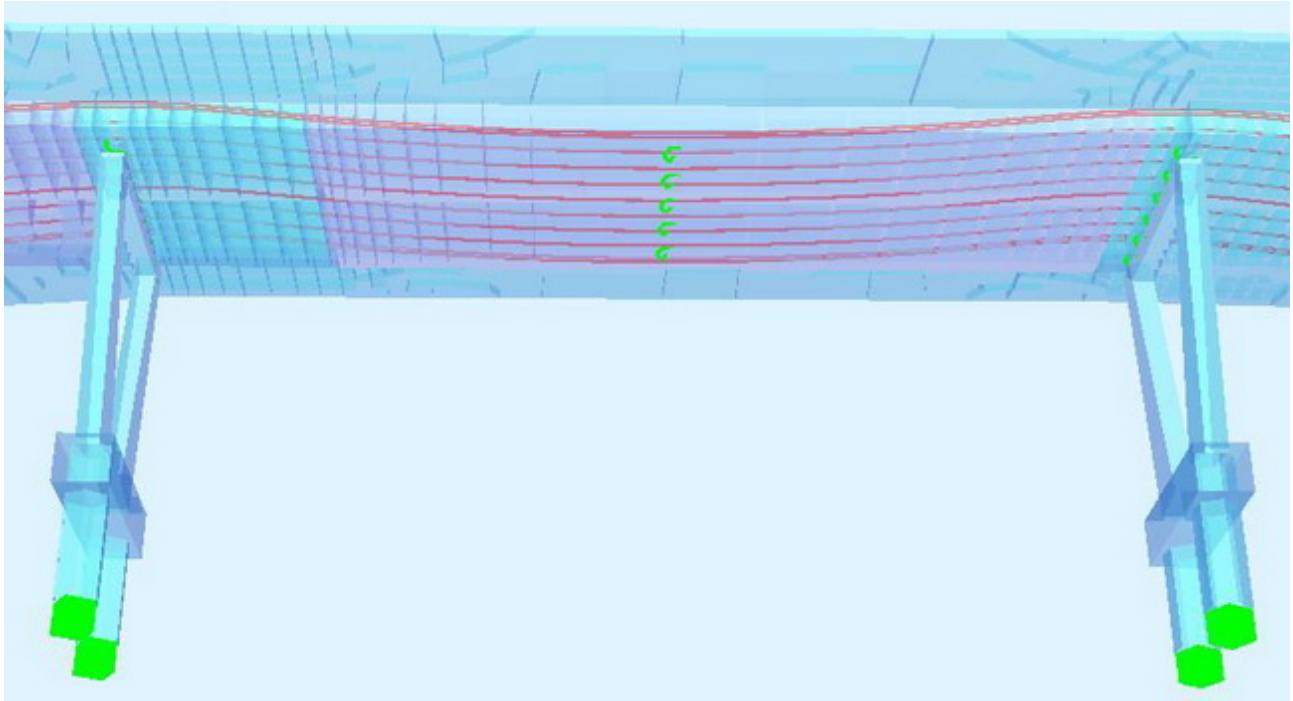


Slika 13. Model za statičku analizu SOFiSTiK (Structural analysis model SOFiSTiK)

Calculation of the effects in the viaduct structure, for gravitational loads and prestressing has been performed using ˝SOFiSTiK˝ software, while calculation for horizontal effects has been done as „Tower“ model. Superstructure has been modeled as a slab, with characteristic cross sections along the bridge. Considering that the structure is supported by piers, at those points, a rigid slab element has been modeled, with bearings, modeled by “springs”, on its ends, so that support areas may accept torsion. All the bearings, depending on whether they are elastomeric (as well as how thick they are) or sliding, get their “spring” characteristics Cx, Cy, Cz and Cm, establishing direct interaction between the functioning of the superstructure and substructure. The calculation of the “B” segment served as (as the most detailed calculation for both vertical and horizontal movements) the basis for dimensioning of all other segments of the structure.

Calculation of the effects has been performed according to the domestic “Code of practice for technical norms for determination of bridge loads ”, from 1991.

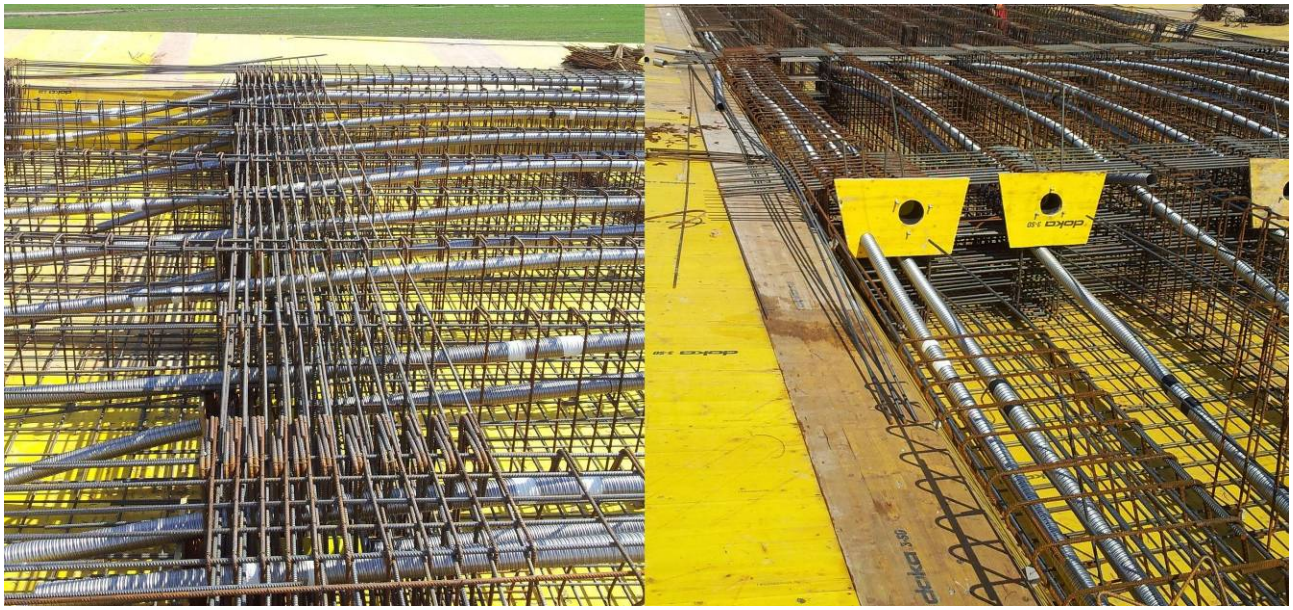
Tendons (7 x 1k 12Φ15,7 + 2 x 2k 13Φ15.7) have been inputted into the system by “Geos” module real-time solid geometry, and successively with construction procedure, modeled and activated in ˝Construction Stage Manager˝. Current losses of force in tendons (stressed to 0,8 βku) are automatically calculated by the software (wedging, friction, elastic shortening) , thus obtaining cross section stress state in all construction phases, due to continuous load and prestressing, as well as after completion of construction. Tendons 12Φ15.7 are placed in central areas of the slab (between the voids), and doubled tendons 2k13Φ15.7 in the slab’s edge areas. Successive anchorage of tendons for coupling (couplers) is performed in sections at 3.8 m from the pier, in areas of solid cross section of the slab.



Slika 14. Kablovi za prednaprezanje – model SOFiSTiK (Prestressing – model SOFiSTiK)

Other effects on the superstructure (moving load and temperature differences) have also been calculated and incorporated in the stress state T_o. The governing position of a vehicle SLW 600 + SLW 300, considering the viaduct curve, is along the outer kerb.

Stress state for all combinations in T_o meet the allowed levels of strain in materials.



Slika 15. Kablovi za prednaprezanje (Prestressing)

Losses of prestressing force due to concrete shrinkage and creep, as well as relaxation of tendon steel, have been calculated by applying the method proposed in EC2. In addition to changes in cross sections the moment state due to permanent load, caused by force decrease in tendons, redistribution of bending moments due to the very procedure of structure construction, has also been calculated by applying prof. Jörg Schlaich method. Stress state for normal stresses in T_∞ is also within allowed limits, with tensile stresses in some cross sections, caused by total (basic and additional) load, which are also within allowed limits. Strain stress "wedge" is "covered" by reinforcement in those zones also.

Evidence of structure load bearing capacity has been done for typical cross sections in span and over the pier (withe tensile stress in T_∞), showing that it has a satisfactory safety coefficient in relation to failure.

Principal tensile stresses have also been checked. These stresses are also within permitted levels, allowing reinforcing of structure with transverse reinforcement.

The cross section structure has been checked for transverse effect, that is bending normal to the direction of the bridge. According to the obtained effects, dimensioning of transverse reinforcement and control of stressing of these elements in SLS (Serviceability Limit State) state, has been performed. Deflections of cantilever ends (considering the given length) due to concrete creep caused by permanent load, has also been calculated, and for those values formwork of cantilever ends is to be initially raised, in relation to the existing layout.

All the details which are important for proper functioning of the structure have been thoroughly checked and constructed – reinforced concrete joints, cross section elements in the construction joint area have been secured against prevented shrinkage of "young" concrete of a new segment against "old" concrete of previous segment; particular care was taken to calculate the tension in the piers' "tie beam" considering the permanent tensile force resulting from permanent load, and all controls of the tension, cracks and deflections SLS' have been performed accordingly.

Particular care was taken to ensure replacement of bearings on the structures and ramps, during operation, by checking tension in main structure's piers, considering the position of presses in relation to the "tie beam" at the pier top.

Slika 16. Armiranje konstrukcije (Superstructure reinforcing)

Bearing in mind the construction procedure, as well as the considerable length of each of the 4 segments of one viaduct with only two expansion joints on the segment's ends, movements of the structure and bearings due to all the effects they are exposed to, have been calculated in detail. Each of the 15 construction phases of segment "B" and the resulting movements of the structure have been calculated, taking into account the percentage of completed and remaining shrinkage values. The appropriate longitudinal bending moments of the piers with elastomeric bearings and reinforced concrete joints, due to all the construction phases and pertaining shrinkage and tension related structure shortening, were thus obtained. It is implied that these moments are "relaxed", since they are the result of the superstructure effects which are affine with the process of pier's concrete creep, so they were calculated with adjusted effective modulus $Eb^* = Eb/(1 + X\Phi) \approx 0{,}3\ Eb$.

Regarding pier buckling, for majority the slederness is $75 < \lambda < 50$, except for the piers that are higher than 6.5 m which have sliding bearings on the top (slederness coefficient 2.0) where slenderness is greater than 75. For all the piers where slenderness is greater than 50 second order effects were applied to the increase of the bending moment due to the first order theory. For piers with slenderness greater than 75, second order moment calculation is performed by more accurate, nonlinear analyses. Regarding the slenderness coefficient, for the piers with sliding bearings this coefficient is 2.0. For piers which are connected to the structure via reinforced concrete joint, slenderness coefficient is 0.7. Limit condition for the

piers connected to the structure via elastomeric bearings is somewhat more complicated, but it has been resolved by adopting the slenderness coefficient 0.7, but using adjusted effective height of those piers (increased by 25% – 47%). This effective height was obtained by determining the horizontal movement of the actual pier top with actual elastomeric bearing due to the unit force. The pier of “fictitious” (greater) height, without bearings, under the effect of the same unit force at the top, must have the same movement.

Slika 17. Stub 9.5 m - najviši, 5.0 m – najniži (Pier 9.5 m – the tallest, 5.0 m – the shortest)

For detailed check of pier stability, an additional calculation has been performed in Tower model which included piers and pertaining piles, with “actual” characteristics of the soil around the piles. This model proved that the limit load compromising the stability of pier-pile system is far greater than the operational on.

In the model, the substructure and the superstructure are taken as a whole. In the first iteration of the substructure calculation for horizontal effects of temperature, shrinkage, braking..., the “full” rigid joint at the bottom of the piers which have a group of foundation piles has been assumed. Effects that are obtained in first iteration with fictive “full” rigid joint at pile caps, are imported as an input to software ˝Deep Foundation System Analysis Program˝ where piles have been modeled according to the actual soil layers. This software is not usually based on linear ˝p – y“ curves, but takes into account non-linear behavior of the soil depending on the level of load that piles, when moving, impose on it. Taking into account the said effects, DFSAP software calculates the constants Kix / Kiy / Kiz that are now used as “springs” for “softened rigid join” at the bottom of the piers supported by piles. In the second iteration, horizontal effects are given again for the whole model, and effects (this time the moments are lower) in the “rigid joint” are obtained again, and imported into DFSAP. After several iterations (max 3-4) the final level of rigid joint at the bottom of the piers supported by piles, where the whole group of piles is presented by “springs” simulating its characteristics – naturally, for different load levels. It is obvious that, taking into account the load level, these “springs” must be different for effects of „t° + Hk + shrinkage” and for the effects of earthquakes.

For calculation of effects and dimensioning of substructure elements, as well as for the control of load in ULS (Ultimate Limit State), relevant combinations of load have been composed. For each of them, control of stress in relevant sections of piers and piles has been conducted. Also, for each of them, control of section’s load bearing capacity (for piers by designing interaction diagrams N / M, for both orthogonal directions).

Seismic effects have been calculated on the basis of valid domestic “Code of practice for technical norms for construction of buildings in seismic areas” (last updated in 1990.) for VII degree on MCS scale (return period 100 to 200 years). The period of the first longitudinal oscillation mode (obtained by multimodal analysis) is 2,68 sec. The structure’s piers do not have plastic properties by any of the two calculations (spectral analysis method and equivalent static load method). All piers are properly transversally reinforced in areas of potential plastic joints, in a manner that ensures that concrete withholds considerable pressure

related movements, for levels even over 3.5‰.

By applying calculation in accordance with the domestic Code of practice, all piers, for both orthogonal directions of earthquake impact, remain in elastic domain.

For calculation of bearing capacity of particular elements of the structure (ULS) the properties of the materials according to the valid PBAB (Code of practice for Plane and Reinforced Concrete) were used, i.e. for concretes βB, for reinforcement σ_v = 500 MPa (curve on the border of creep). For calculation of limit curve (section failure) ultimate strain, in steel 50‰ (B class), and in concrete 3.5‰ if not "stressed" (unconfined), and εcu,c if "stressed" (confined). For calculation and control of SLS's the following allowable levels of stress were used:

Superstructure concrete – according to the allowable stress of pressure and tension in concrete, for stressing and operation phases, from 1971 Code of practice.

Concrete of other elements (conventionally reinforced) – given that the PBAB does not recognize the "allowable stress" category, for control of SLS, recommended stress levels given in EC2, i.e. 0.45fck for permanent and 0.6fck for temporary stress states.

Reinforcement – for permanent states (0.55 – 0.60)fyk,, and for temporary states (0.70 – 0.75)fyk, (EC2 allows, for typical combination of loads, 0.80fyk).

Tendons – initial state (0.75 – 0.80)fku, that is 0.70fku for permanent state.

Allowable widths of a crack in serviceability limit states of reinforced concrete elements 8and of prestressed in transverse direction) are 0.2 mm for permanent load effects, and 0.3mm for total loads effects. Thicknesses of protective concrete layer to the reinforcement are:

- for piles, to the reinforcement 10.0 cm
- for elements in the soil 5.0 cm
- for piers 4.0 cm
- for superstructure 3.5 cm, except for the upper surface of the bridge deck where it is 4.0 cm

7. FINISHING WORKS

For waterproofing of the upper surface of the structure section, polymer – bitumen sheets have been used, with required overlap, over the prepared surface, treated with primer. Surfacing layer is asphalt – concrete and SMA, constructed in two layers, total thickness 8 cm.

Slika 18. Završni radovi na vijaduktu –izolacija (Viaduct finishing works - insulation)

For protection of vehicles on carriageway steel guardrails are used, and safety of pedestrians on service path is ensured by a steel profile fence, treated by primer and triple PUR varnish coating. In the area of railway crossing, 2.2 m steel fence is installed (see figure 20.). Permanently elastic kit is used at the curb and asphalt joint. Sidewalk (service) is coated with triple waterproofing – abrasive coating, polyurethane based. Gullies and gratings on the bridge are made of cast iron, and they drain the water from the pavement into the horizontal system of pipes, and further to a catch basin under the bridge (included in a separate Drainage Design). Between the gullies, which collect water from the pavement, drain tubes 40 – 50 mm in diameter are placed, to drain water form waterproofing. These tubes are not connected with horizontal system of pipes.

Public lighting poles are installed on the bridge, powered by electricity via cables inserted through Φ 100 mm openings in sidewalks (included in separate Lighting Design).

Bearing in mind the size of the facility, it is necessary to take all safety measures during the works execution, paying special attention to the existing gas pipeline route, old Batajnicki Road, railway and existing rainwater drainage and sewerage utilities in the area of the route.

Slika 19. Završni radovi na vijaduktu (Viaduct finishing works)

Slika 20. Završni radovi na vijaduktu (Viaduct finishing works)

The Design has been prepared in line with all applicable Codes of practice, norms and standards, enclosed in technical documentation.

This Detailed Design is in compliance with the revised Preliminary Design, Detailed Design of the Road, Terms of Reference, requirements of the relevant public enterprises, and existing soil mechanics analysis.

Slika 21. Završen desni vijadukt (Finished right viaduct)