IZGRADNJA DRUMSKOG MOSTA PREKO REKE SAVE KOD OSTRUŽNICE

CONSTRUCTION OF ROAD BRIDGE OVER THE SAVA RIVER NEAR OSTRUŽNICA

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1 UVOD

Postojeći drumski most preko reke Save kod Ostružnice lociran je u blizini Beograda, u Republici Srbiji. Izgrađen je u okviru prve faze jugozapadne obilaznice oko Beograda. Povećanje saobraćaja, posebno tranzitnog, rezultiralo je potrebom povećanja kapaciteta obilaznice oko Beograda, kako bi se rasteretilo saobraćajno opterećenje autoputa koji prolazi kroz centar grada.

1 INTRODUCTION

Present road bridge over the Sava river near Ostružnica is located near Belgrade, in the Republic of Serbia. It is constructed within the first phase of the south-western bypass around Belgrade. The increase of traffic, especially transit, resulted in the necessity of increasing the capacities of the bypass around Belgrade, to relieve the traffic load on the highway that runs through the city centre.

Slika 1. Lokacija mosta preko reke Save kod Ostružnice
Fig. 1. Location of the bridge over the Sava river near Ostružnica

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Izgradnja obilaznice započeta je 1991. godine, a prva faza je obuhvatala poluprofil (desnu traku) autoputa od Dobanovaca do Bujanj Potoka, predviđenu da se koristi za dvosmerni saobraćaj do završetka druge faze. Zbog poznatih okolnosti (sankcije međunarodne zajednice, hiperinflacija, ratna dejstva, NATO bombardovanje itd.) izgradnja prve faze je više puta prekidana, tako da je prva faza na delu od Dobanovaca do Resnika (sektori 1-5) završena u maju 2012. Trenutno su završene obe faze na delu od Dobanovaca do Ostružnice (sektori 1 i 2), radovi na drugoj fazi mosta preko reke Save kod Ostružnice (sektor 3) u završnoj su fazi, a planirano je da preostali radovi na obilaznici (sektori 4, 5 i 6) budu završeni do kraja 2021. godine.

Izgradnja postojećeg mosta preko reke Save (za desnu traku) započela je 1991. godine i trajala je, zbog navedenih okolnosti, sve do 1999. godine. Neposredno pre puštanja u saobraćaj, 28. aprila 1999. most je delimično srušen tokom NATO bombardovanja, da bi do 2004. godine bio potpuno obnovljen i pušten u saobraćaj. Novi most za drugu fazu obilaznice odnosno levu traku autoputa u konstruktivnom smislu potpuno je identičan postojećem, pošto su prvom fazom izgradnje bili obuhvaćeni zajednički rečni stubovi za obe mostovske konstrukcije. Izgradnja ove konstrukcije započeta je u julu 2016. godine.

2 KRATAK OPIS MOSTOVSKJE KONSTRUKCIJE

Ukupna dužina mosta je 1.963 m i sastoji se od četiri dela: prednapregnute betonske prilazne konstrukcije na levoj obali ($L = 592,30$ m) i desnoj obali reke ($L = 699,13$ m), armirano-betonske konstrukcije preko autoputa Beograd-Obrenovac ($L = 85,30$ m) i čelične konstrukcije preko reke Save ($L = 586,00$ m). Čelična konstrukcija preko reke Save je kontinualni čelični sandučasti nosač, s pet raspona, promenljive visine, od 3,8 m do 7,9 m i najdužim rasponom od 198 m. Ukupna težina čelične konstrukcije je 4250 tona.

Slika 2. Dispozicija čelične konstrukcije mosta
Fig. 2. Layout of the steel structure over the river

3 TEHNOLOGIJA MONTAŽE ČELIČNE KONSTRUKCIJE

Projektovanom tehnologijom montaže bio je predviđen konzolni način izgradnje uz korišćenje plovne dizalice i privremenih oslonaca - čeličnih šipova pobijelih u korito reke. Zbog toga je konstrukcija podeljena na 56 montažnih polja, dužine 7,5-11,0 m i teških 60-85 tona. Nakon pregleda rečnog korita magnetometrima visoke rezolucije, otkriveno je postojanje velikog broja nepoznatih čeličnih objekata koji bi po gabaritima mogli biti neeksplozivna ubojna sredstva (NUS). Zbog toga se projektovana tehnologija montaže pokazala visoko-

Construction of the bypass around Belgrade began in 1991, and the first phase included a semi-profile (right lane) of the highway from Dobanovci to Bujanj Potok, intended to be used for two-way traffic until the completion of the second phase. Due to known circumstances (international community sanctions, hyperinflation, warfare, NATO bombing, etc.), construction of the first phase was repeatedly interrupted, so that the first phase on the section from Dobanovci to Resnik (Sectors 1-5) was completed in May 2012. Currently, both phases are completed on the section from Dobanovci to Ostružnica (Sections 1 and 2), the works on the second phase of the bridge over the Sava River near Ostružnica (Sector 3) are in the final phase, and it is planned that the remaining works on the bypass (Sections 4, 5 and 6) will be completed by the end of 2021.

The construction of the existing (right lane) bridge had begun in 1991 and lasted until 1999 due to the above circumstances. Shortly before its opening for traffic, on April 28th, 1999, the bridge was partially demolished during the NATO bombing, and by 2004 it had been completely rebuilt and put into service. The left lane bridge, whose construction is in progress, is constructively identical to the existing one, since the first phase of construction included river piers for both bridge structures. Construction of this structure began in July 2016.

2 BRIEF DESCRIPTION OF BRIDGE STRUCTURE

Total length of the bridge is 1.963 m and it comprises 4 sections: prestressed concrete approach structures on the left riverside ($L=592,30$ m) and right riverside ($L=699,13$ m), reinforced concrete structure over Belgrade-Obrenovac highway ($L= 85,30$ m) and steel structure over the Sava river ($L=586,00$ m). Steel structure over the Sava River is 5-span continuous steel girder, with box cross section of variable height, from 3,8 m to 7,9 m and with the longest span of 198 m. The total weight of the steel structure is 4250 tons.

4 METHODOLOGY OF STEEL STRUCTURE INSTALLATION

The designed installation methodology envisaged a cantilevered construction using a floating crane and temporary supports - steel piles driven into the river bed. Therefore, the construction is divided into 56 mounting sections, 7.5 - 11.0 m long and weighing 60-85 tons. After the high-resolution magnetic survey of the riverbed, it was discovered that there were a large number of unknown steel objects that could have been unexploded ordnance (UXO). Therefore, the designed installation methodology turned out to be high risky since the

rizičnom pošto bi moguća NUS mogla biti aktivirana tokom pobijanja čeličnih šipova u rečno korito.

Kako bi se izbeglo postavljanje privremenih oslonaca u rečnom koritu, razmatrane su različite alternative uz uslov da se već izvedeni delovi konstrukcije iskoriste u najvećoj mogućoj meri. Kao optimalna u datim uslovima, usvojena je nova metodologija koja uključuje: (I) podužno prevlačenje sekcije mosta S4-S6 ukupne dužine 187 m uz korišćenje pomoćnog plutajućeg oslonca, (II) konzolnu montažu delova konstrukcije iznad rečnih stubova S1, S2, S3 i S4 i (III) podizanje tri sekcije konstrukcije L=77(68) m.

(I) Podužno prevlačenje

Segment mostovske konstrukcije između stubova S4 i S6 (L=187 m) ugrađen je podužnim prevlačenjem, pošto je presek konstantne visine. Ovaj segment mosta predmontira se na radnoj platformi smeštenoj na obali, a zatim se hidrauličnim presama podužno prevlači na projektovanu poziciju. Ova operacija je podeljena u četiri faze:

- Faza I: podužno prevlačenje 45 m dugačkog segmenta bez pomoćnog oslonca;

- Međufaza I/II: postavljanje pomoćnog oslonca kako bi se omogućio nastavak podužnog prevlačenja;

- Faza II: podužno prevlačenje 44 m dugačkog segmenta oslonjenog na pomoćni oslonac, do stuba S5;

- Faza III: podužno prevlačenje 44 m dugačkog segmenta bez pomoćnog oslonca;

possible UXO could be activated during the driving of steel piles into the river bed.

In order to avoid the placement of temporary supports in the riverbed, various alternatives were considered, subject to condition that the already executed parts of the structure are used as far as possible. After considering possible alternatives, new methodology that includes (I) incremental launching over floating pier of the bridge (section previously preassembled on the riverside L=187 m) and (II) lifting of 3 structure sections (L=77 m, G=550 tons) pre-assembled in the shipyard 10 km far from the bridge location, launched into river and transported to the site were selected as optimal in current conditions.

(I) Incremental launching

Bridge section between piers S4 and S6 (L=187 m) was installed by incremental launching since the cross-section is of constant height. This section of the bridge is preassembled on the launching platform located on the riverside and then pushed over the river by hydraulic jacks until reaching final position. This operation is divided in four phases:

- Phase I: launching of 45 m long segment as cantilever, without floating support;

- Intermediate phase I/II: installation of floating support, to enable continuation of launching;

- Phase II: launching of 43 m long segment supported by floating pier, until reaching pier S5;

- Phase III: launching of 44 m long segment as cantilever, without floating support;

- Međufaza III/IV: postavljanje pomoćnog oslonca kako bi se omogućio nastavak podužnog prevlačenja;
- Faza IV: podužno prevlačenje 55 m dugačkog segmenta oslonjenog na pomoćni oslonac, do stuba S4

- Intermediate phase III/IV: installation of floating support, to enable continuation of launching;
- Phase IV: launching of 55 m long segment supported by floating pier, until reaching pier S4

Slika 3. Prva faza podužnog prevlačenja segmenta S4–S6
Fig. 3. First phase of incremental launching of segment S4 - S6

Slika 4. Druga faza podužnog prevlačenja segmenta S4–S6
Fig. 4. Second phase of incremental launching of segment S4 - S6

Slika 5. Segment S4 - S6 nakon završetka podužnog prevlačenja
Fig. 5. Segment S4 - S6 after completed incremental launching

(II) Konzolna montaža delova konstrukcije iznad stubova S1, S2, S3 i S4

Da bi se omogućilo podizanje segmenata konstrukcije koji su predmontirani u brodogradilištu i transportovani na gradilište rekom, potrebno je formirati osnovu sa koje će se raditi podizanje. Zbog toga je izvršena slobodna konzolna montaža najpre baznih (osloničkih) segmenata iznad stubova S1, S2, S3 i S4, a nakon toga i susjednih segmenata.

(II) Cantilever assembly of structure segments over river piers S1, S2, S3 and S4

In order to allow the lifting of segments of structure that are pre-assembled in the shipyard and transported to the site by the river, it was necessary to form the basis from which the lifting is to be carried out. Therefore, free cantilever assembly of the base (support) segments above the piers S1, S2, S3 and S4, and subsequently of adjacent segments was performed.

Kako bi se obezbedila stabilnost elemenata čelične konstrukcije mosta u ovoj fazi montaže, bilo je neophodno konstruisati i montirati pomoćni alate - privremene oslonce iznad stubova S2, S3 i S4. Pored obezbeđenja stabilnosti, ovi privremeni oslonci preuzimaju deo uticaja u fazi dizanja i prenose ih na stubove.

In order to ensure the stability of the steel structure elements at this stage of assembly, it was necessary to construct and install auxiliary tools - temporary supports above the piers S2, S3 and S4. In addition to providing stability, these temporary supports take over some of the impacts during the lift phase and transfer them to the piers.

Slika 6. Dispozicija pomoćnog oslonca na stubu S2
Fig. 6. Layout of temporary support on pier S2

Slika 7. Stubovi S4 i S3 s montiranim pomoćnim osloncima, delovima čelične konstrukcije mosta i „Derrick” kranovima
Fig. 7. Piers S4 and S3 with installed temporary supports, steel structure segments and “Derrick” cranes

(III) Podizanje tri sekcije čelične konstrukcije

Ostatak čelične konstrukcije montiran je podizanjem tri sekcije ($L = 77/68$ m, $G = 550/450$ tona) prethodno montirane u brodogradilištu 10 km od lokacije mosta. Pre porinuća u reku, ugrađeni su dodatni elementi koji obezbeđuju vodonepropusnost i plovnost svake sekcije. Prevoz do mesta ugradnje obavljen je rečnim tegljačima, a podizanje je urađeno „Derrick” kranovima uz korišćenje četiri hidraulične prese kapaciteta 200 t.

– Faza I: podizanje sekcije MP2-MP8, $L=77$ m, $G=550$ t

(III) Lifting of 3 structure sections

The rest of the steel structure was installed by lifting of 3 structure sections ($L=77/68$ m, $G=550/450$ tons) previously assembled in the shipyard 10 km far from the bridge location. Additional elements for providing water tightness and navigability were installed before launching the segments into the river. Transport to the site was performed by tugboats and lifting was done by “Derrick” cranes and 4 hydraulic jacks, each capacity of 200 t.

– Phase I: lifting of section MP2-MP8, $L=77$ m, $G=550$ t

– Faza II: podizanje sekcije MP32-MP38, $L=77$ m, $G=550$ t

– Phase II: lifting of section MP32-MP38, $L=77$ m, $G=550$ t

– Faza III: konzolna montaža elemenata MP13-MP16 i MP24-MP27 plovnom dizalicom

– Phase III: cantilever installation of segments MP13-MP16 and MP24-MP27 by floating crane

– Faza IV: podizanje sekcije MP17–MP23, L=68 m, G~450 t

– Phase IV: lifting of section MP17-MP23, L=68 m, G~450 t

Slika 8. Predmontaža sekcija konstrukcije mosta u brodogradilištu
Fig. 8. Pre-assembly of steel structure sections in the shipyard

Slika 9. Rečni transport sekcija konstrukcije mosta
Fig. 9. River transport of structure sections

Slika 10. Podizanje segmenta S1–S2

Fig. 10. Lifting of segment S1 - S2

4 PODACI O PROJEKTU, INVESTITORU, PROJEKTANTU, IZVOĐAČU I STRUČNOM NADZORU

Pored izgradnje mostovskih konstrukcija, projekat obuhvata i deo saobraćajnice - leve trake autoputa dužine 955 m kao i sve prateće radove (sakupljanje i prečišćavanje atmosferskih voda, javnu rasvetu, saobraćajnu opremu i signalizaciju, uređenje putnog pojasa). Investitor radova je Javno preduzeće „Putevi Srbije“, a radovi se finansiraju iz kredita Evropske investicione banke. Projektnu dokumentaciju je izradio „Institut za puteve“ iz Beograda, a deo projektne dokumentacije koji se odnosi na mostove izradilo je preduzeće „Mostprojekt AD“ iz Beograda. Izvođač radova je konzorcijum „Strabag AG – Ed. Zublin AG – Dywidag Bau GmbH – Strabag d.o.o.“ Podizvođač radova na izradi elemenata i montaži čelične mostovske konstrukcije je preduzeće „Mostogradnja AD“ iz Beograda koje je ranije izgradilo i postojeći most za desnu traku obilaznice. Stručni nadzor nad izvođenjem radova poveren je konzorcijumu koji čine UTIBER Kozuti Beruhazo Kft. - Project Biro UTIBER d.o.o. - Institut IMS AD.

4 INFORMATION ABOUT PROJECT, EMPLOYER, DESIGNER, CONTRACTOR AND SUPERVISION

In addition to the construction of bridge structures, the scope of project also includes a road section - the left lane of the highway 955m long, as well as all supporting works (collection and purification of atmospheric waters, public lighting, traffic signs and road furniture, road reserve landscaping etc.) The employer is Public Enterprise "Roads of Serbia", and the works are funded by a loan from the European Investment Bank. The design documentation was prepared by the Belgrade "Highway Institute" and the part of the design related to bridges was made by the company "Mostprojekt AD" from Belgrade. The contractor is a consortium consisting of Strabag AG - Ed. Zublin AG - Dywidag Bau GmbH - PZP Zajecar A.D. (Strabag d.o.o.). The subcontractor for the production and installation of the steel bridge structure is company "Mostogradnja AD" from Belgrade, which also in the past built the existing right-line bridge. Supervision of the works was entrusted to the consortium comprising UTIBER Kozuti Beruhazo Kft. - Project Bureau UTIBER d.o.o. - Institute IMS AD.

REZIME

IZGRADNJA DRUMSKOG MOSTA PREKO REKE SAVE KOD OSTRUŽNICE

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Drumski most preko reke Save kod Ostružnice, ukupne dužine 1.963 m, sastoji se od armirano-betonskih prilaznih konstrukcija na levoj i desnoj obali reke, dok je srednja konstrukcija preko reke Save kontinualni čelični sandučasti nosač, s pet raspona, ukupne dužine od 586 m. Montaža čelične konstrukcije prvobitno je planirana konzolnom ugradnjom 56 sekcija-montažnih polja, korišćenjem plovne dizalice i privremenih oslonaca - čeličnih šipova pobijenih u korito reke. Nakon pregleda rečnog korita magnetometrima visoke rezolucije, ova se metodologija pokazala visokorizičnom zbog mogućeg postojanja neeksplozivnih ubojnih sredstava (NUS), preostalih nakon NATO bombardovanja, koja bi mogla biti aktivirana tokom pobijanja čeličnih šipova u korito reke. Da bi se izbeglo postavljanje privremenih oslonaca u rečnom koritu, projektovana metodologija montaže čelične konstrukcije morala je biti izmenjena. Nakon razmatranja mogućih alternativa uz uslov očuvanja već izvedenih radova, kao optimalna u datim uslovima, usvojena je nova metodologija koja uključuje: (I) podužno prevlačenje sekcije mosta S4-S6 ukupne dužine 187 m uz korišćenje pomoćnog plutajućeg oslonca, (II) konzolnu montažu delova konstrukcije iznad rečnih stubova S1, S2, S3 i S4 i (III) podizanje tri sekcije konstrukcije L=77(68) m.

Ključne reči: Ključne reči: drumski most, Ostružnica, armirano-betonske prilazne konstrukcije, kontinualni čelični sandučasti nosači, konzolna gradnja, prevlačenje/potiskivanje čelične konstrukcije.

ABSTRACT

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Road bridge over the Sava river near Ostružnica, with a total length of 1.963 m, consists of reinforced concrete approach structures on the left and right riverside, while the middle structure over the Sava River is 5-span continuous steel box girder, with a total length of 586 m. Construction of steel structure was originally planned by cantilever installation of 56 sections, using a floating crane and temporary supports - steel piles placed in the river bed. After the high-resolution magnetic survey of the riverbed, this methodology has proved to be highly risky due to the possible existence of unexploded ordnance (UXO) left after NATO bombing, that could be activated during the piling into the riverbed. To avoid installation of temporary supports in the riverbed, the original methodology for the assembly of the steel structure had to be revised. After considering possible alternatives and to preserve already executed works, new methodology that includes (I) incremental launching over floating support of the bridge section S4-S6 with a total length of 187 m, (II) cantilever assembly of structure segments over river piers S1, S2, S3 and S4 and (III) lifting of 3 structure sections L=77(68) m, was selected as optimal under the given conditions.

Key words: Key words: road bridge, Ostružnica, reinforced concrete approaching structures, continuous steel box main girders, cantilever bridge construction, launching of steel structure.