REHABILITATION OF THE BRIDGE OVER THE RIVER RIBNICA

SANACIJA MOSTA PREKO REKE RIBNICE

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Summary: The paper presents a rehabilitation project of the bridge over the river Ribnica, based on on-site inspection and available technical documentation on the condition of the bridge. The existing bridge is a road, reinforced concrete with main steel girders IPE 180. The existing girder bridge has a span of 2 m x 6,5 m. Two variant solutions for the rehabilitation of the existing bridge are analyzed. The first solution included the removal of the existing reinforced concrete plate and the production of a new reinforced concrete plate, with the rehabilitation of the steel girders in accordance with the new load impacts. The second solution includes the removal of the existing reinforced concrete plate, the dismantling of the existing steel profiles and the production of a new reinforced concrete plate. The terms of reference required that the effects on the bridge be considered for the V300 vehicle. In addition to the road construction, two footpaths were designed. The static calculation was done in the Radimpex Tower 8.4 programme.

Keywords: bridge, reinforced concrete, steel profiles, rehabilitation, V300 vehicle

Rezime: U radu je prikazan projekat sanacije mosta preko reke Ribnice, na osnovu uvida na licu mesta i dostupne tehničke dokumentacije o stanju mosta. Postojeći most je drumski, armirano-betonski sa glavnim čeličnim nosačima IPE 180. Postojeći gredni most je raspona 2 m x 6,5 m. Analizirana su dva varijantna rešenja sanacije postojećeg mosta. Prvo rešenje obuhvata uklanjanje postojeće AB ploče i izradu nove, uz sanaciju postojećih čeličnih nosača u skladu sa novim uticajima od opterećenja. Drugo rešenje obuhvata uklanjanje postojeće AB ploče, demontažu postojećih čeličnih profila, uz izradu nove armirano-betonske ploče. Projektnim zadatkom je zahtevano da se uticaji na most uzimaju za vozilo V300. Statički proračun je urađen u programu Radimpex Tower 8.4.

Ključne reči: most, armirani-beton, čelični profili, sanacija, vozilo V300

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1. INTRODUCTION

Based on the in-situ inspection and the available technical documentation on the condition of the bridge, the bridge repairment was presented. The existing bridge over the river Ribnica is a girder, reinforced concrete bridge with the IPE 180 beams. It has two openings. The IPE 180 beams are a static system of two simply supported beams. They rely on the middle pillar in the river and the supporting pillars. The pavement structure is a solid reinforced concrete slab with a thickness of 20-25 cm. The existing length of the bridge is 13 m, while the width of the bridge is 3,20 m, without footpaths.

The need for rehabilitation arises due to the bad condition of the bridge and the compromised traffic safety, which is shown in Figure 1. Also, pedestrians are not safe, because no special space for pedestrians is provided.

1. UVOD

Na osnovu uvida na licu mesta i dostupne tehničke dokumentacije o stanju mosta, prikazan je projekat sanacije mosta. Postojeći most preko reke Ribnice je drumski, armirano-betonski sa glavnim čeličnim nosačima IPE 180. Čelični nosači su statičkog sistema dve proste grede. Oslanjaju se na srednji stub u reci i oporačke stubove. Kolovozna konstrukcija je puna armirano-betonska ploča debljine 20-25 cm. Postojeća dužina mosta iznosi 13 m, dok je širina mosta 3,20 m, bez pešačkih staza.

Potreba za sanacijom se javlja zbog lošeg stanja mosta i ugrožene bezbednosti saobraćaja, što je i prikazano na Slici 1. Takođe, pešaci nisu bezbedni, jer nije obezbeđen poseban prostor za pešake.

a) Pavement slab / Kolovozna ploča

b) Middle pillar and IPE beams/
Srednji stub i IPE nosači

c) Damage to the middle pillar/
Oštećenje srednjeg stuba

d) Coastal will / Obalni oporac

Figure 1 - Existing condition of the bridge/
Slika 1 - Postojeće stanje mosta

2. PLANNED REHABILITATION

In this paper, two variants of the solutions for the repairment of the existing bridge are analysed. The elements are dimensioned to be able to receive loads from traffic and footpaths The first solution included the removal of the existing reinforced concrete slab and the repairment of the steel beams (by adding 4 new IPE 180 beams) in accordance with the new loads impacts. A new reinforces concrete deck with a thickness of 25 cm was designed, which rests on 9 steel beams (existing and additional). Table 1 shows the characteristics of the applied steel standard section. Impacts from the load of vehicles and footpaths are transferred to the steel beams.

The planned width, for both analysed variant solutions, of the repaired bridge is 5,2 m, the roadway width 3,20 m and the pedestrian paths are 1 m wide. The pavement is raised 12 cm in relation to the road surface and a 12 cm x 15 cm curb is installed. In order to protect pedestrians, a 1 m high fence is provided on the footpaths.

2. PREDVIĐENE SANACIJE

U radu su analizirana dva varijantna rešenja sanacije postojećeg mosta. Elementi su dimenzionisani da mogu da prime opterećenja od saobraćaja i pešačkih staza.

Prvo rešenje obuhvatilo je uklanjanje postojeće AB ploče i sanaciju čeličnih nosača (dodavanjem 4 nova IPE 180 nosača) u skladu sa novim uticajima od opterećenja. Isprojektovana je nova AB ploča debljine 25 cm koja se oslanja na 9 čeličnih nosača (postojećih i dodatnih). U Tabeli 1 su prikazane karakteristike primenjenih čeličnih profila. Uticaji od opterećenja vozila i pešačkih staza se prenose na čelične nosače.

Planirana širina, za oba analizirana varijantna rešenja, saniranog mosta je 5,2 m, širina kolovoza 3,20 m i pešačke staze su širine po 1 m. Pešačka staza je izdignuta 12 cm u odnosu na kolovoz i postavljen je ivičnjak 12 cm x 15 cm. U cilju zaštite pešaka, na pešačkim stazama predviđena je ograda visine 1 m.

Table 1 - Basic characteristics of steel IPE 180 profile [1]
Tabela 1 - Osnovne karakteristike čeličnog IPE 180 profila [1]

Area for axis *x* / Površina za osu *x*	$A_x = 23{,}900\ \text{cm}^2$
Area for axis *y* / Površina za osu *y*	$A_y = 12{,}696\ \text{cm}^2$
Area for axis *z* / Površina za osu *z*	$A_z = 11{,}204\ \text{cm}^2$
Moment of area about *x-x* / Moment inercije za osu *x*	$I_x = 4{,}800\ \text{cm}^4$
Moment of area about *y-y* / Moment inercije za osu *y*	$I_y = 1320{,}00\ \text{cm}^4$
Moment of area about *z-z* / Moment inercije za osu *z*	$I_z = 101{,}00\ \text{cm}^4$
Section modulus about axis *x-x* / Otporni moment oko ose *x*	$W_x = 146{,}67\ \text{cm}^3$
Section modulus about axis *z-z* / Otporni moment oko ose *z*	$W_z = 22{,}198\ \text{cm}^3$
Plastic section modulus about axis *y-y* / Modul plastičnog preseka oko ose *y*	$W_{y,pl} = 165{,}30\ \text{cm}^3$
Plastic section modulus about axis *z-z* / Modul plastičnog preseka oko ose *z*	$W_{z,pl} = 33{,}124\ \text{cm}^3$

Partial factor for resistance of cross-sections whatever the class is / Parcijalni faktor otpora poprečnih preseka bilo koje klase	$\gamma_{M0} = 1{,}100$
Partial factor for resistance of members to instability assessed by member checks / Parcijalni faktor otpornosti delova na nestabilnost procenjen proverama delova	$\gamma_{M1} = 1{,}100$
Partial factor for resistance of cross-sections in tension to fracture / Parcijalni faktor za otpornost poprečnih preseka pri zatezanju na lom	$\gamma_{M2} = 1{,}250$

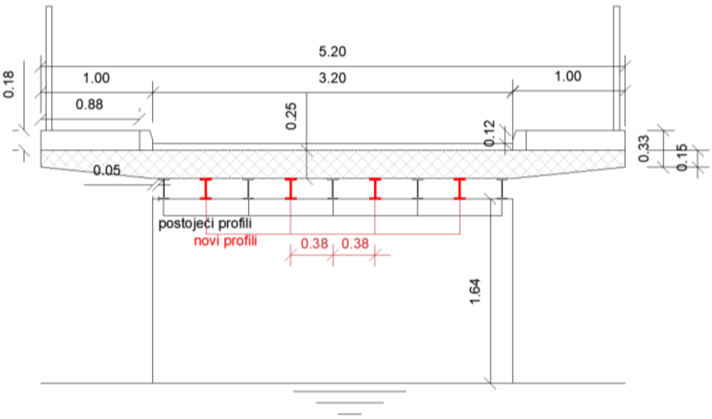

Figure 2 - Cross-section of the repaired bridge - the first alternative solution
Slika 2 - Poprečni presek saniranog mosta - prvo varijantno rešenje

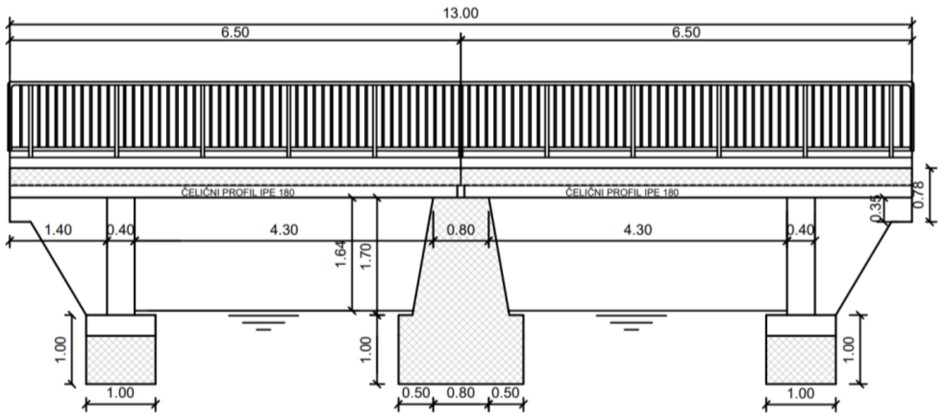

Figure 3 - Longitudinal section of the repaired bridge - the first alternative solution
Slika 3 - Podužni presek saniranog mosta - prvo varijantno rešenje

The second solution of the repairment includes the removal of the existing reinforced concrete slab and the dismantling of the existing IPE profiles, after which a new reinforces concrete slab with a thickness of 40 cm is constructed. Impacts from vehicle loads and footpaths are transferred to the concrete slab.

Drugo rešenje sanacije obuhvata uklanjanje postojeće AB ploče i demontažu postojećih IPE profila, nakon čega se izvodi nova AB ploča debljine 40 cm. Uticaji od opterećenja vozila i pešačkih staza se prenose na betonsku ploču.

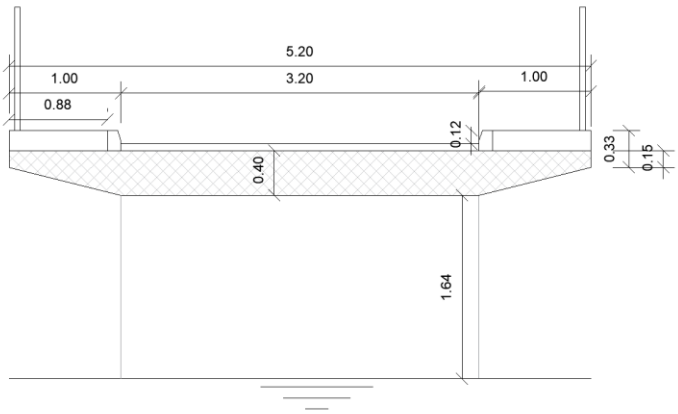

Figure 4 - Cross-section of the repaired bridge - the second alternative solution
Slika 4 - Poprečni presek saniranog mosta - drugo varijantno rešenje

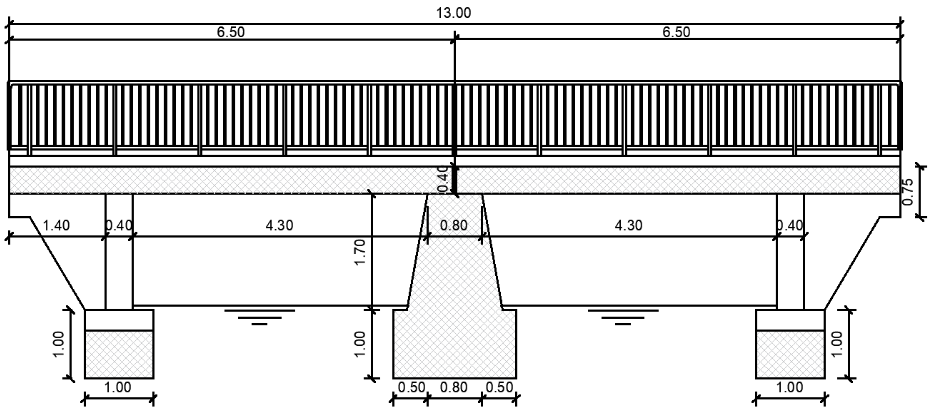

Figure 5 - Longitudinal section of the repaired bridge - the second alternative solution
Slika 5 - Podužni presek saniranog mosta - drugo varijantno rešenje

3. STATIC ANALYSIS OF THE BRIDGE

The static calculation of the bridge was performed by using the Radimpex Tower 8.4 programme, a static system of two simple beams. Materials are modelled as elastic and isotropic for all structural elements. Steel and hot-rolled profiles with Young's modulus of elasticity $E = 210\ \mathrm{GPa}$, Poisson's coefficient $v = 0{,}3$ and coefficient of lineal thermal expansion of the material at were used $\alpha_t = 10^{-5}\ 1/°\mathrm{C}$. The foundation, columns and reinforced concrete slab are made of concrete strength class C 25/30 with Young's modulus of elasticity $E = 31\ \mathrm{GPa}$ and Poisson's coefficient $v = 0{,}2$. The load analysis [1-3] included loads from: the structure's own weight, additional permanent load, axle traffic load from the LM1 model for the V300 vehicle, continuous traffic load from the LM1 model for the V300 vehicle, axle traffic load from the LM2 model for the V300 vehicle, vehicle starting and braking forces, loads on pavements, uniform temperature changes, linear temperature changes and vehicle impact on the kerb.

3. STATIČKI PRORAČUN MOSTA

Statički proračun mosta je izvršen primenom računarskog programa Radimpex Tower 8.4, statičkog sistema dve proste grede. Materijali su modelirani kao elastični i izotropni za sve konstruktivne elemente. Primenjeni su čelični IPE vruće valjani profili sa Jangovim modulom elastičnosti $E = 210\ \mathrm{GPa}$, Poasonovim koeficijentom $v = 0{,}3$ i koeficijentom linearne toplotne dilatacije materijala $\alpha_t = 10^{-5}\ 1/°\mathrm{C}$. Temelj, stubovi i AB ploča su izvedeni od klase čvrstoće betona C 25/30 sa Jangovim modulom elastičnosti $E = 31\ \mathrm{GPa}$ i Poasonovim koeficijentom $v = 0{,}2$. Analiza opterećenja [1-3] je obuhvatila opterećenja od: sopstvene težine konstrukcije, dodatnog stalnog opterećenja, osovinskog saobraćajnog opterećenja iz modela LM1 za vozilo V300, kontinualnog saobraćajnog opterećenja iz modela LM1 za vozilo V300, osovinskog saobraćajnog opterećenja iz modela LM2 za vozilo V300, sile pokretanja i kočenja vozila, opterećenja na pešačke staze, ravnomerne promene temperature, linearne promene temperature i udara vozila u ivičnjak.

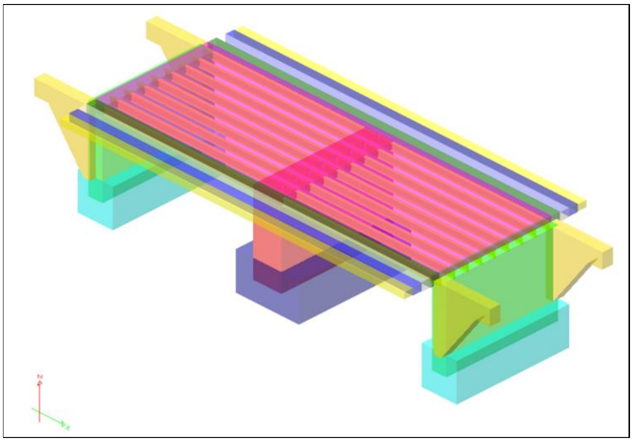

Figure 6 - 3D model of the first variant of the rehabilitation solution
Slika 6 - 3D model prvog varijantnog rešenja sanacije

The detailed calculation is not shown due to the large size, only the diagrams of the required reinforcement in the lower and upper zones of the planned bridges rehabilitation are shown.

Detaljni proračun nije prikazan zbog obimnosti, samo su prikazani dijagrami potrebne armature u donjoj i gornjoj zoni predviđenih sanacija mostova.

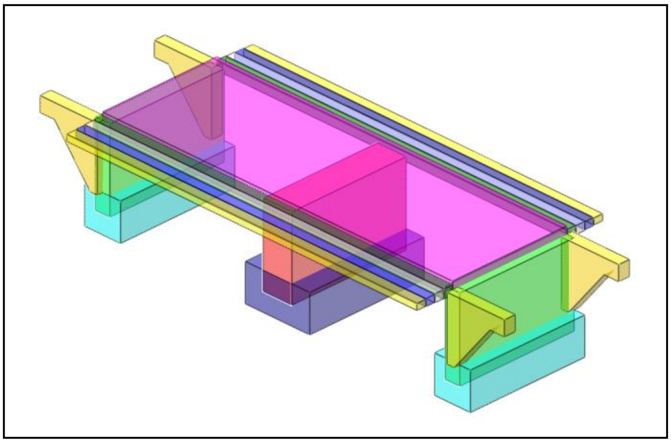

Figure 7 - 3D model of the second variant of the rehabilitation solution
Slika 7 - 3D model drugog varijantnog rešenja sanacije

4. RESULTS

Based on the conducted static analysis, the obtained results show that both variant solutions of rehabilitation meet the conditions for dimensioning. Figures 8 and 9 show the required reinforcement for the first case of repairment, and Figure 10 and 11 show the reinforcement for the second case of repairment. It can be noted that the isolines for the required reinforcement in the lower zone have a relatively similar appearance for both predicted variants, which is also shown by the required reinforcement. Also, it is the same for the upper zone, only for the first variant solution, a larger amount of reinforcement appears above the middle column, compared to the second variant solution.

4. REZULTATI

Na osnovu sprovedene statičke analize dobijeni rezultati pokazuju da oba varijantna rešenja sanacije zadovoljavaju uslove pri dimenzionisanju. Na Slikama 8 i 9 dat je prikaz potrebne armature za prvi slučaj sanacije, a na Slikama 10 i 11 prikaz armature za drugi slučaj sanacije. Može se primetiti da su izolinije za potrebnu armaturu u donjoj zoni relativno sličnog izgleda za obe predviđene varijante, što pokazuje i potrebna armatura. Takođe, isto je i za gornju zonu, samo se za prvo varijantno rešenje pojavljuje veća količina armature iznad srednjeg stuba, u odnosu na drugo varijantno rešenje.

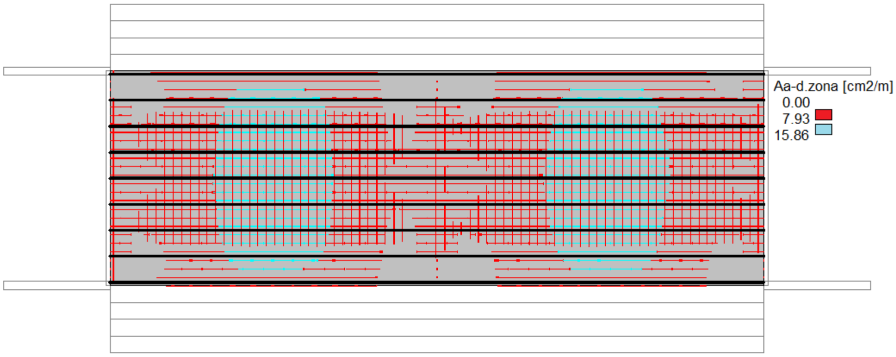

Figure 8 - Diagram of the required reinforcement in the lower zone of the reinforced concrete slab of the newly designed bridge - the first variant solution
Slika 8 - Dijagram potrebne armature u donjoj zoni AB ploče novoprojektovanog mosta - prvo varijantno rešenje

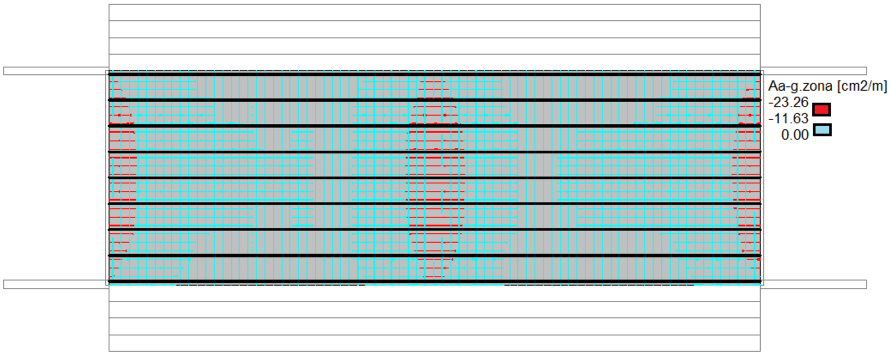

Figure 9 - Diagram of the required reinforcement in the upper zone of the reinforced concrete slab of the newly designed bridge - the first variant solution
Slika 9 - Dijagram potrebne armature u gornjoj zoni AB ploče novoprojektovanog mosta - prvo varijantno rešenje

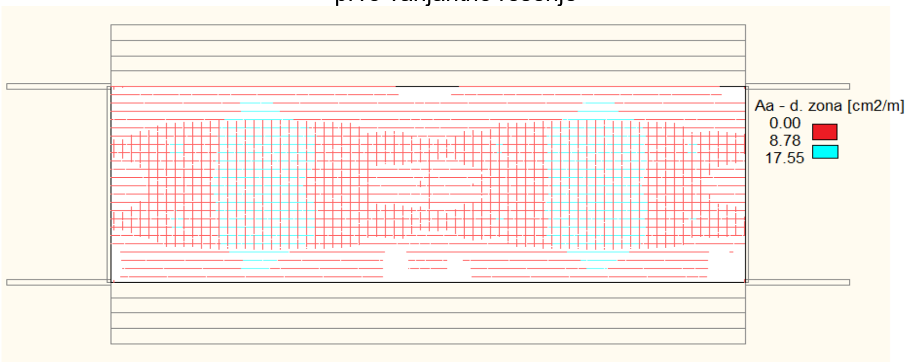

Figure 10 - Diagram of the required reinforcement in the lower zone of the reinforced concrete slab of the newly designed bridge - the second variant solution
Slika 10 - Dijagram potrebne armature u donjoj zoni AB ploče novoprojektovanog mosta - drugo varijantno rešenje

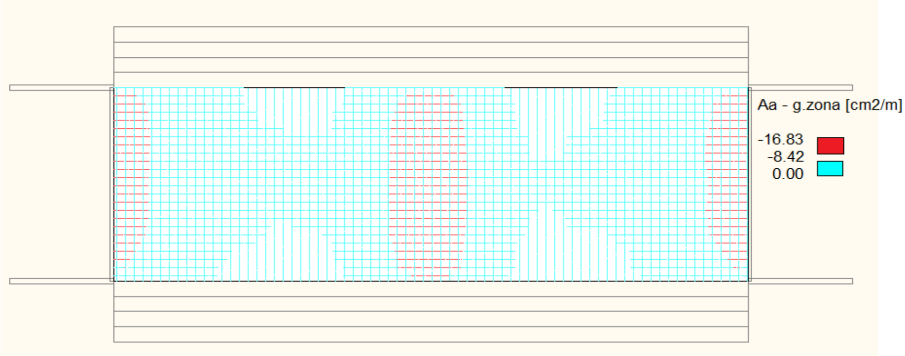

Figure 11 - Diagram of the required reinforcement in the lower zone of the reinforced concrete slab of the newly designed bridge - the second variant solution
Slika 11 - Dijagram potrebne armature u gornjoj zoni AB ploče novoprojektovanog mosta - drugo varijantno rešenje

5. CONCLUSION

The conducted static analysis determined that the shown variant repairment solutions meet the conditions for dimensioning. After that, the preliminary and estimate of the work for the presented variant solutions were prepared.
Based on the obtained impacts, an approximate amount of reinforcement is obtained, but the first variant solution retains the existing steel girders and the use of a smaller pavement slab thickness, while the second variant solution requires the removal of the existing steel girders and an increase in the pavement slab, which also increases the cost of the works. In the calculation, a price of 5300 RSD/m^3 was taken for concrete, for reinforcement 190 RSD/kg and steel supports 240 RSD/kg, but earthworks, the cost price of material transportation, disassembly/assembly of steel profiles were taken into account. According to the price analysis, the first variant solution requires 2.825.153,12 RSD, and the second variant solution 2.941.609,55 RSD, which determined that the first variant solution is more economical for the repairment of the bridge shown, but it is also simpler.

5. ZAKLJUČAK

Sprovedenom statičkom analizom je utvrđeno da prikazana varijantna rešenja sanacije zadovoljavaju uslove pri dimenzionisanju. Nakon toga urađen je predmer i predračun radova za prikazana varijantna rešenja.
Na osnovu dobijenih uticaja, dobija se približna količina armature, ali prvo varijantno rešenje zadržava postojeće čelične nosače i upotrebu manje debljine kolovozne ploče, dok drugo varijantno rešenje zahteva uklanjanje postojećih čeličnih nosača i povećanje kolovozne ploče, sto ujedno i povećava cenu koštanja radova. U proračunu je za beton uzeta cena od 5300 din/m^3, za armaturu 190 din/kg i čelične nosače 240 din/kg, ali uzeti su obzir zemljani radovi, cena koštanja transporta materijala i demontaže/montaže čeličnih profila. Prema analizi cena, za prvo varijantno rešenje je potrebno 2.825.153,12 RSD, a za drugo varijantno rešenje 2.941.609,55 RSD, čime je utvrđeno da je prvo varijantno rešenje ekonomičnije za sanaciju prikazanog mosta, ali je i jednostavnije.

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