EXAMPLES OF REHABILITATION OF RC BRIDGES OF SMALLER SPANS

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Summary: *The paper presents conducted rehabilitations on two bridges over the Paklešnice River, as well as the rehabilitation of the bridge over the Kravaričkog Brook at the Forestry House in Gornji Lajkovac Municipality of Mionica. Prior to the conducting control structural analysis of bridges and testing the quality of installed materials: concrete and reinforcement, detailed recording of all necessary dimensions of existing bridges was performed. On the basis of the performed measurements and conducted structural analysis of the obtained results for the relevant influences, the necessary remediation measures have been carried out.*

Keywords: *rehabilitation, RC bridges, smaller spans*

1. INTRODUCTION

In the floods of 2018, a large number of bridges were damaged in the territory of Mionica Municipality. In addition to damage to the deck slab due to flooding, the bridges also suffer the scour of foundation, which put their stability at risk, and the rehabilitation was necessary. Also, due to the lack of technical documentation, there was a need to determine the actual quality of the built-in materials, concrete and reinforcement, as well as the control structural analysis with actual load from the vehicle V300. The paper presents the rehabilitations carried out on two bridges over the Paklešnice River, on the cadastral plot no. 2339 and near Šujdović's house, as well as rehabilitation of the bridge over the Kravarički brook near the Forestry House, all in Gornji Lajkovac Municipality of Mionica.

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Bridge over PaklešniceRiver cadastral plot no. 2339 –BRIDGE 1

The existing bridge is constructed as a reinforced concrete bridge positioned at angle in relation to a water barrier, in one opening, a system of simply supported beam - slab with span of approximately l = 7.73 m (clear span between the abutments l = 7.32 m), Figure 1. The deck slab of the bridge at both ends is supported by the abutments of the bridge without specially designed transversal support beams. The deck slab is RC slab, thickness approx. d = 35,0 cm made on site. The existing width of the bridge perpendicular to the span is b = 4.20 m, without pedestrian paths.

Figure 1.Bridge over Paklešnice River cadastral plot no. 2339

Bridge over PaklešniceRiver near Šujdović's house– BRIDGE 2

The existing bridge is constructed as a reinforced concrete bridgepositioned at angle in relation to the water barrier, in two openings, with a supporting abutments, Fig. 2. The static system of the deck slab is two simply supported beams - slabs with spans approximately 2xl = 5.97m (an opening between middle pier and abutments l = 5.57 - 5.59m). The deck slab of the bridge is supported by the abutments and the middle pier, without specially designed transversal support beams. The deck slab is RC slab, thickness approx. d = 40,0cm made on site. The existing width of the bridge perpendicular to the span isb = 5.52m, without pedestrian paths.

Figure 2.Bridge over Paklešnice River near Šujdović's house

Bridge over theKravarički brook near the Forestry House – BRIDGE 3

The existing bridge is constructed as a reinforced concrete bridgepositioned at angle in relation to a water barrier, in one opening. The static system is simply supported beam-slab of a span approximately l = 5.56 m (clear opening between the abutmentsl = 5.17 m), Figure 3. The deck slab of the bridge at both ends is supported by the abutments of the bridge without specially designed transversal support beams. The deck slab is RC slab thickness approx. d= 36,0cm made on site. The existing width of the bridge perpendicular to the span is b = 4.62m, without pedestrian paths, with edge beams 18cm above the carriageway.

Figure 3.Bridge over the Kravarički brook near the Forestry House

2. PREVIOUS EXAMINATIONS

Before the conduction of the control structural analysis of the bridge and the testing the quality of the embedded material: concrete and reinforcement, detailed recording of all necessary dimensions of the existing bridge was carried out, as there are no archive samples of the tested bridges or details of the reinforcement, [1, 2, 3]. The testing of the quality of the embedded concrete was carried out with a sclerometer (presumed age of concrete over 20 years, unprotected surface, thickness of the protective layer 15-20 mm), Figure 4.

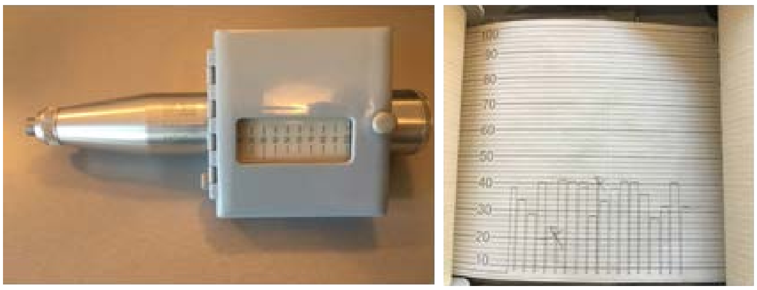

Figure 4.Used sclerometer

The estimated concrete strength of the pressure at testing for the lower zone of the deck slab and the abutments have been shown in Table 1, and the reinforcement in the lower zone of the deck slab and in the abutments have been determined in Table 2.

Table 1. The estimated concrete strength of the pressure

	BRIDGE 1	BRIDGE 2	BRIDGE 3
Constructive element	σ (MPa)	σ (MPa)	σ (MPa)
Lower zone of the deck slab	46(C-35/45)	40(C-35/45)	40(C-35/45)
Abutment	34(C-30/37)	36(C-30/37)	36(C-30/37)

Table 2. Determined reinforcement in the lower zone

Constructive element	BRIDGE 1	BRIDGE 2	BRIDGE 3
Lower zone of the deck slab			
• Main steel	Φ18/15	Φ18/15	Φ18/15
• On edge of deck slab	Φ18/30	Φ 18/7.5	Φ18/15
• Distribution steel	Φ6/20	Φ10/20	Φ10/20
Abutment			
• Main steel	Φ20/15	Φ18/15	/
• Distribution steel	Φ6/20	Φ8/20	/

3. PROJECT TASK OF REHABILITATION

The width of the rehabilitated deck slab of the bridges according to the terms of the project task is 4.00 m with pedestrian path 2x1.00 m. The pedestrians are protected at bridge by a 20 cm-wide curbs and 1.20 m high pedestrian fences.

Bridge over Paklešnice River cadastral plot no. 2339 - BRIDGE 1

The rehabilitation of the bridge is predicted in that way that the pedestrian paths are supported by new reinforced concrete girders with "G" cross-section, which are placed on the vertical abutments, that are supported by the expanded and reconditioned existing foundations, Figure 5. At the height of the supporting beams, reinforced concrete wing walls are designed to form the revetment of the embankment and connecting the pedestrian path to the existing embankment. Foundation is envisaged so that the existing foundations of the wing walls are underpinned and laterally expanded to accept new vertical reinforced concrete pillars (the supports for newly added laterally placed reinforced concrete beams-pedestrian paths) in all according to the conditions obtained from the geomechanical study.

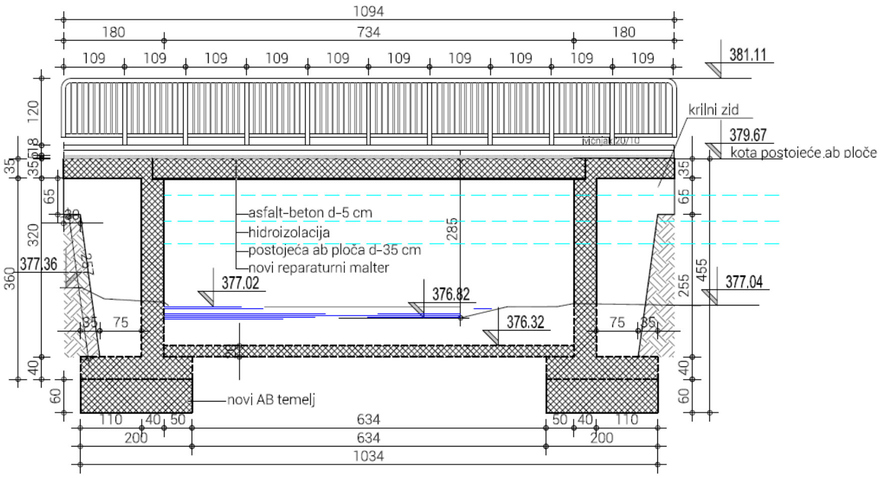

Figure 5.Projektnizadataksanacije – MOST 1

Bridge over Paklešnice River near Šujdović's house – BRIDGE 2

The rehabilitation of the bridge is foreseen so that the pedestrian paths are supported by new reinforced concrete girders with "G" cross-section, which are placed on the vertical edge abutments, that are supported by the expanded and reconditioned existing foundations, Figure 6. Due to the considerable visual damage of the upper surface of the deck slab a partially removal in a thickness of approx. 7.0 cm was predicted, as well as a part of the edge slab in the width of 20 cm. The removed part is cleaned under the pressure of the air in order to make connection between the old and the new concrete, which is performed in an additional thickness of 8 cm, therefore the rehabilitated part of the slab has a total thickness of approx. 15.0 cm. The appropriate reinforcement is installed in the upper zone of the rehabilitated slab. The connection of the old and new part of the slab is achieved by the installation of a certain number of anchors epoxied.
On both abutments at the hight of support beams, reinforced concrete wing walls are foreseen to form the revetment of the embankment and connect the pedestrian path to the existing embankment. Foundation is envisaged so that the existing foundations of the wing walls are underpinned and laterally expanded to accept new vertical reinforced concrete pillars in everything according to the conditions obtained from the geomechanical study.

Bridge over the Kravarički brook near the Forestry House – BRIDGE 3

The rehabilitation of the bridge is foreseen so that the pedestrian paths are supported by new reinforced concrete girders with "G" cross-section, which are placed on the vertical edge abutments, that are supported by the expanded and reconditioned existing foundations, Figure 7. At the height of the supporting beams, reinforced concrete wings are designed to form the revetment of the embankment and connecting the pedestrian path to the existing embankment. Foundation is envisaged so that the existing foundations of the wing walls are underpinned and laterally expanded to accept new vertical reinforced concrete pillars in all according to the conditions obtained from the geomechanical study.

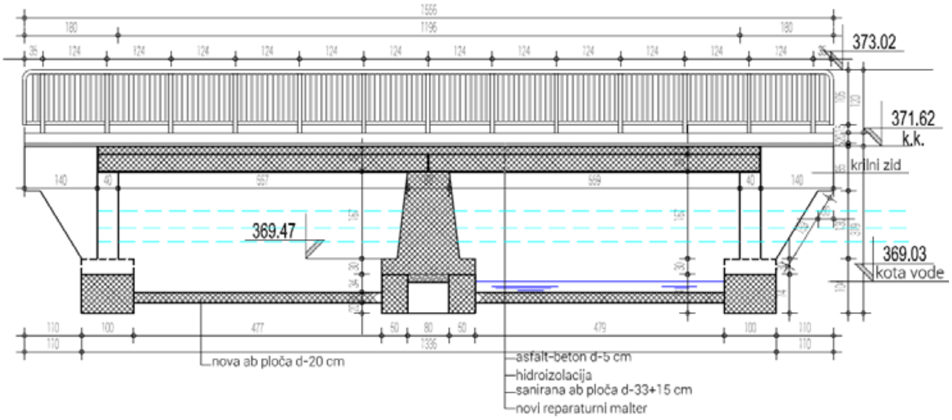

Figure 6. Project task of rehabilitation – BRIDGE 2

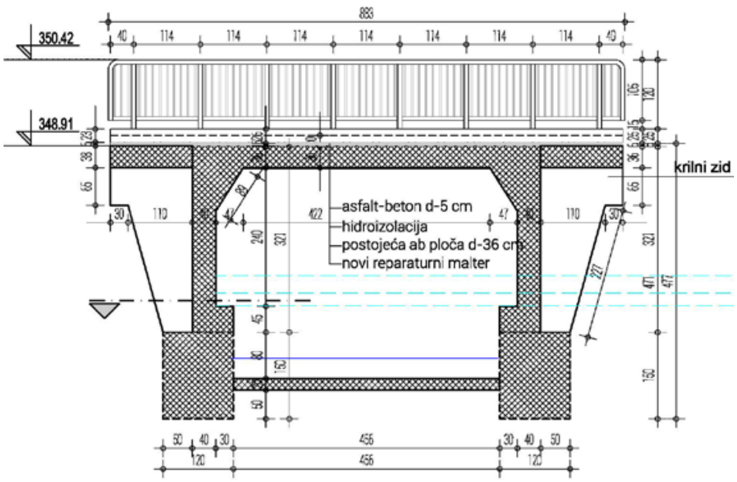

Figure 7. Project task of rehabilitation – BRIDGE 3

4. CONTROL STRUCTURAL ANALYSIS

During the analysis and dimensioning of the rehabilitated construction, the criteria for proof of stability and bearing capacity were applied in accordance with the applicable national regulations. The loads were approved according to the Regulations PBAB87 and The Rulebook on Technical Norms for Determining Loads of Bridges [4, 5, 6].
The project analyzes the following loads:

- Continuous load covering the weight of the main bearing elements, the constant load from the surface load (waterproofing, asphalt concrete, additional concrete on the console from pedestrian paths, ...), then line loadings from curbs, fence on pedestrian paths, installations,
- Traffic load, vehicle V300,
- Even change of temperature ±25°C,
- Uneven change of temperature-temp.variation ±10°C,
- Stop and start the vehicle,
- Snow,
- Wind,
- Seizmic load,
- Pressure of soil.

For the newly constructed structural elements of the rehabilitated bridges, the dimensioning was carried out using concrete, the quality of which is shown in Table 3.

Table 3. Quality of concrete of newly constructed structural elements

Constructive element	BRIDGE 1	BRIDGE 2	BRIDGE 3
New edge beams-supports of pedestrian paths	MB40	MB45	MB45
Vertical abutments	MB40	MB45	MB45
Foundations of rehabilitated abutments	MB30	MB40	MB40

Numerical model of the bridge structure and the loads presented in this paper were prepared in the ABAQUS software as given in the Figure 8. The model is based on 3D finite element modelling. In this way, a real picture of the stress states and deformations at all points, as well as the internal forces required for dimensioning of the elements of the bridge construction was obtained. The material is modeled as elastic and isotropic for all elements, that is, with the characteristics of the materials that correspond to the quality of RC given in Tables 1 and 3.

The bridges' models consist of a RC slab supported by the abutments that are rigidly connected to the foundations. Also, the connection between the vertical edge pillars and the abutments was achieved by a rigid connection. The supports are modeled as surface, with no movement in X, Y and Z direction.

With the aim of defining the geotechnical conditions for bridge rehabilitation, appropriate calculations of the permissible soil load were carried out. The calculations were made for data on the object adopted with the Bridge Rehabilitation Project, for the established geotechnical model of terrain.

The allowable load calculations were carried out using the Brinch-Hannsen formula. For the projected vertical disposition of the rehabilitated bridge, the foundation contact will be achieved in the layer of cracked sediments ($J_2^3Se^*$). Partial safety factors ($F_f = 1.5$ i $F_c = 2.5$) are included in the calculations. Based on the calculation of the relevant influences, the values of the permissible soil load have been shown in Table 4.

Table 4. Permissible soil load

	BRIDGE 1	BRIDGE 2	BRIDGE 3
Permissible soil load (kN/m^2)	210,74	207,07	183,83

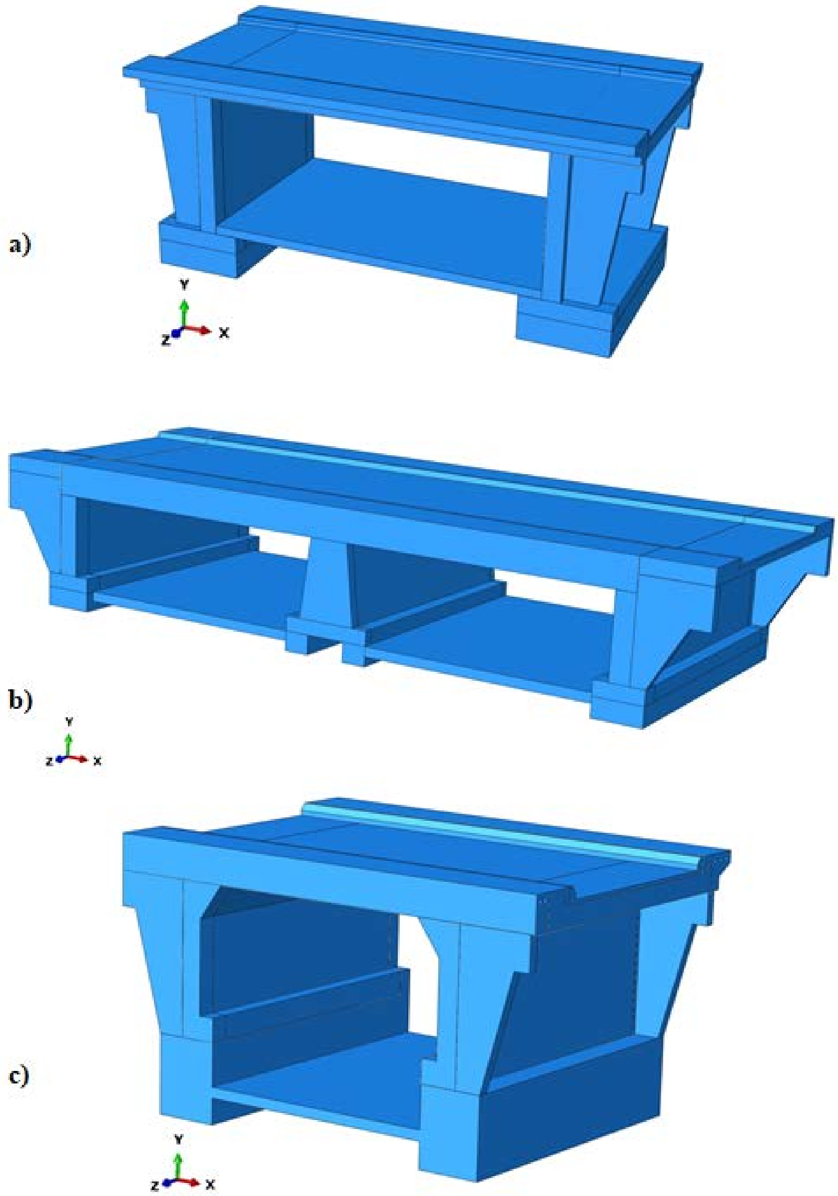

Figure 8. 3D numerical model for: a) BRIDGE 1; b) BRIDGE 2; c) BRIDGE 3

5. REHABILITATION MEASURES

Deck RC slab - Based on the results for the relevant influences obtained from the performed measurements and the performed structural analysis, for the existing deck slab, it is stated that:

BRIDGE 1 - existing main and distribution steel (Φ18 / 15/30; Φ6 / 20) do not meet the required calculated reinforcement, therefore it is necessary to repair the deck slab in both directions.
BRIDGE2 - the existing main steel (Φ18/15/7.5) meets the newprojected loads (A_{ax} = 17.04 cm^2, which is larger than the required reinforcement A_{ax} = 11.50 cm^2), therefore there is no need for rehabilitation in this direction. However, the existing distribution steel (Φ10/20) does not meet the required calculated value of the reinforcement (A_{ay} = 3.95 cm^2, and the new load A_{ay} = 5.62 cm^2 is required), therefore it is necessary to repair the deck slab in the y direction.
BRIDGE3 - the existing main steel (Φ18/15) meets the newprojected loads (A_{ax} = 17.04 cm^2, which is larger than the required reinforcement A_{ax} = 13.29 cm^2), therefore there is no need for rehabilitation in this direction. However, the existing distribution steel (Φ10/20) does not meet the required calculated value of the reinforcement (A_{ay} = 3.95 cm^2, and the new load A_{ay} = 10.23 cm^2 is required), therefore it is necessary to rehabilitate the deck slab in the y direction.
The rehabilitation will be done by adding carbon strips according to the dimensioning of the Sika CarbonDur S-type carbon tape (type S515, width 50 mm, 1.2 mm thick)
Foundations
Based on the hydraulic calculation, the angle of excavation of the existing trough of bridges is determined, therefore that the hundred-year-old water does not float the existing deck slab of the bridges (for BRIDGE 1 line of the HV level is 35 cm below the slab, 75 cm for BRIDGE 2 and 1.87 m for BRIDGE 3). Due to the scour of the existing foundations, the underpinning the existing foundations is designed and the installation of reinforced concrete slabs trough under the bridges.
Based on the obtained values of the permissible soil load, it can be concluded that the rehabilitated bridges, with the design method and the depth of the foundation, are secured from fracture in the ground and that the problems of permissible bearing capacity do not exist.
Installations on the bridge
In concrete of the pedestrian paths, two pipes Φ 110 are provided on both sides. On the upstream side of the bridges, a corridor for conducting installations is foreseen for needs of Telekom Srbija, and on the opposite side there is a corridor for the installations of Elektro Srbija.
Deck slab and pedestrian paths
Layers on the deck slab are asphalt concrete, thickness 6cm and waterproofing with thickness 1cm. Bridge deck is a width of 4.00 m and ends with a stone curb made of eruptive material. Pedestrian paths on bridges are 100 cm wide and extend between the sides of the wings on the opposite sides of the bridge. A concrete coating against the aggressive action of frost and salt is foreseen on the concrete pedestrian paths, which must be of adequate roughness to allow the safe movement of the pedestrians.
The works on the rehabilitation of bridges will be performed in stages: underpinning under

the foundations, construction of new pillars, construction of new beams of pedestrian paths and construction of wing walls.

6. CONCLUSIONS

The basic concept of performed rehabilitation of damaged RC bridges is based on reinforcement of their deck slabs by adding carbon strips, underpinning under the existing foundations, due to scour, and installation of RC slabs of trough under bridges. Based on the performed measurements and the structural analysis of the obtained results for relevant influences, it is concluded that the bridges rehabilitated in this manner can accept the entire load prescribed by the national regulations, and the implementation of the proposed rehabilitation measures has significant advantages in its simplicity and ease of manufacture.

REFERENCES

[1] Bešević, M.,Landović, A.,Prokić, A.: *Rehalibitation-underpinning of object due to removal (demolition) of ground floor columns*, Savremena dostignuća u građevinarstvu (5; Subotica; **2017**) ISSN: 978-86-80297-68-2, Gradjevinski fakultet Subotica Univerziteta u Novom Sadu, pp. 83-93.

[2] Tabaković, D.,Bešević, M.,Kozarić, LJ.: *Sanacija objekta u Tabovačkoj ulici u Beogradu*, Zbornik radova građevinskog fakulteta Subotica, Vol.29, pp. 25-34, **2016**.

[3] Bešević, M., Vlajić, Lj.: *Sanacija adaptacija i dogradnja objekta u Nemanjinoj ulici br.9 u Beogradu*, DGKS -13. KONGRES, Zlatibor -Čigota, ZBORNIK RADOVA, pp. 445-452, **2010**.

[4] Pravilnikotehničkimnormativimazabetoniarmiranibeton, Sl. list SFRJ br. 11/87, **1987**.

[5] Pravilnik o tehničkim normativama za određivanje veličina opterećenja mostova, Sl. list SFRJ br. 1/91, **1991**.

[6] Landović, A.,Bešević, M., Prokić, A., Đurić, N.: *Presentation of short span reinforced concrete bridges*, International Conference CIBv (9; Brasov; **2017**), Transilvania University publishing house from Brasov, 2285-7656, vol,10,(1), pp. 261-268., ISBN 2285-7656.

PRIMERI SANACIJE AB MOSTOVA MANJIH RASPONA

Rezime: *U radu su prikazane izvedene sanacije na dva mosta preko reke Paklešnice, kao i sanacija mosta preko Kravaričkog potoka kod Šumarske kuće u K.O. Gornji Lajkovac opština Mionica. Pre izrade kontrolnih statičkih proračuna mostova i ispitivanja kvaliteta ugrađenih materijala: betona i armature, izvršeno je detaljno snimanje svih potrebnih dimenzija postojećih mostova. Na osnovu izvršenih merenja i sprovedenih statičkih analiza dobijenih rezultata za merodavne uticaje, izvršene su potrebne mere sanacije.*

Ključne reči: *sanacija, AB mostovi, manji rasponi*