# Technical description-bridge structure

## General project data

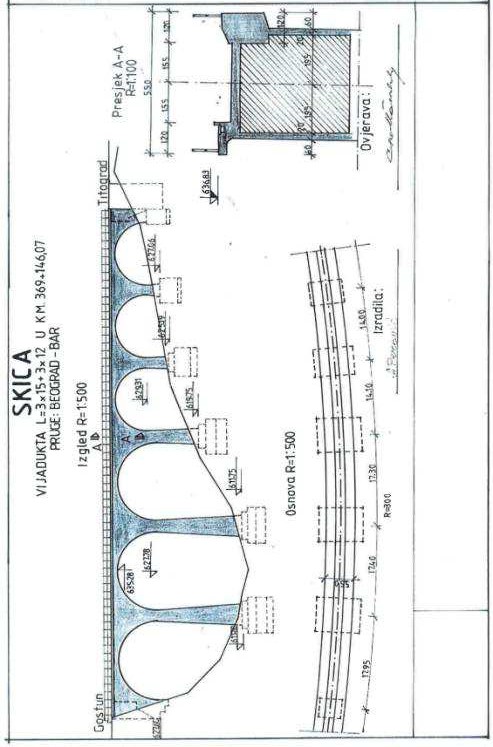
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| INVESTOR: | European Investment Bank |
| BENEFICIARY: | Railway infrastructure of Montenegro AD podgorica |
| STRUCTURE: | Bridge no. 76 after one km of 369+146,07 |
| DESIGN: | Final design of the bridge reconstruction no. 76 after one km of 369+146,07 |
| SECTION OF THE RAILWAY: | Vrbnica - Bar |
| CHAINAGE: | 369+146,07 |
| DESIGN PHASE: | Final design |
| TITLE AND INDEX FOR THIS PART OF THE DESIGN: | Journal 2.1 -BUILDING CONSTRUCTION DESIGN  Bridge no. 76 after one km of 369+146,07 |
| CONTRACTOR RESPONSIBLE FOR THE BRIDGE STRUCTURE DESIGN: | Cestra d.o.o. Belgrade  Makenzijeva 57, 11000 Belgrade |

* + 1. **Location and railway description**

The railway Vrbnica- Bar crosses a deep valley with a bridge. The ground in horizontal direction is very steep at the structure’s cite. The finished road level is in lengthwise drop of 0.2% towards Bar. In the bridge area the railway is in a transition curve and circular arc in radius R=300m.

## Attachment- an excerpt from the report about the existing bridges on the railway Vrbnica-Bar

Figure 1- An excerpt from the report about existing bridges on the railway Vrbnica- Bar



## Bridge structure description- existing condition

## The bridge structure span consists of a row of six concrete arches.

## The arches are: L = 3 x 15,0 + 3 x 12,0 m.

## During the study of the original design, it has been determined that the arches had been designed as not reinforced. The arches were freely supported on land piers, and the connection was achieved with slabs and anchors of smooth reinforcing steel Č 37. There is a plain concrete filling above the arches and piers. The arches are of different sizes in cross section. In places of support, their thickness is 120cm for the spans of 12m, and 130cm for the spans of 15m. The crown of arches is 80cm thick for the spans of 12m and 90cm thick for the spans of 15m. The elements’ features of the existing structure are presented in the table below.



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Expansion joints are predesigned above the pier support, which ensure that the whole load above the piers is carried by them. Expansion joints are 2cm wide.



Spandrel walls are connected to each other with reinforced concrete rod above the piers.

Crown piers are made of lean reinforced concrete and their cross section is in the shape of trapeze and of different heights. According to the original design, the piers are leanly reinforced so as same as the arches they could be treated as plain concrete piers because they do not contain a minimum percentage of reinforcement. The piers are supported on plain concrete pads and then over plain concrete foundations. Smooth reinforcement steel anchors Č37 provide the connection between piers and pads. According to the original design foundation piers are founded in the layer of solid limestone, which parts have been removed due to larger fissuring. During the study of the original design, it was determined that the bottom of foundation junction had been moved on the construction site because the layer of solid limestone was deeper than it had been assumed. Foundation geometry changes were registered and drawn in the graphic specification.

Abutment piers are made of lean reinforced concrete as well. Their cross section differs, and the foundation is the same as the foundation of crown piers. There are two parallel standing wings on both abutment piers. There are retaining walls along both abutment piers S7.

There is a slope with waterproofing above the arches and plain concrete filling. A layer of plain concrete of 5cm thickness and unknown class is predesigned as a protection above the waterproofing. The drainage on piers was built with one vertical gully which is situated in the crowns of arcuated girders in all spans.

Bridge railing was made of metal pipes with circular cross section.

There are sidewalks on the left side of the roadway structure with integrated installations and there are

consoles for electrification posts on both sides. There are niches (pedestrian shelters) on both sides too.

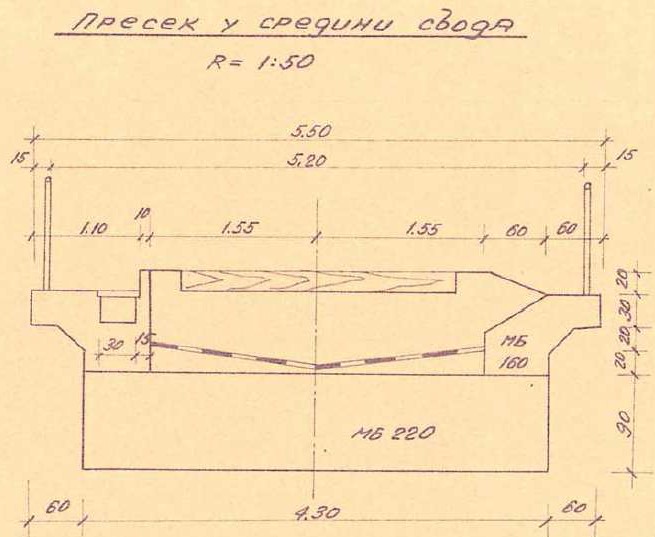
Opinion of an electrical engineer:

There are following cables on both sides of the bridge in question:

* Main wire cable type STKA
* Optical cable G625 144V 6x24 - 9/125 in polyethylene pipes Ø 40 + a spare polyethylene Ø 40
* Optical cable 6x6 9/125 36V in polyethylene pipes Ø 40 + a spare polyethylene pipe Ø 40
* Electrical cable for connecting surveillance cameras PNK 4x16 Al
* SPZ 33x0,9- a cable for the input signal and advance signal

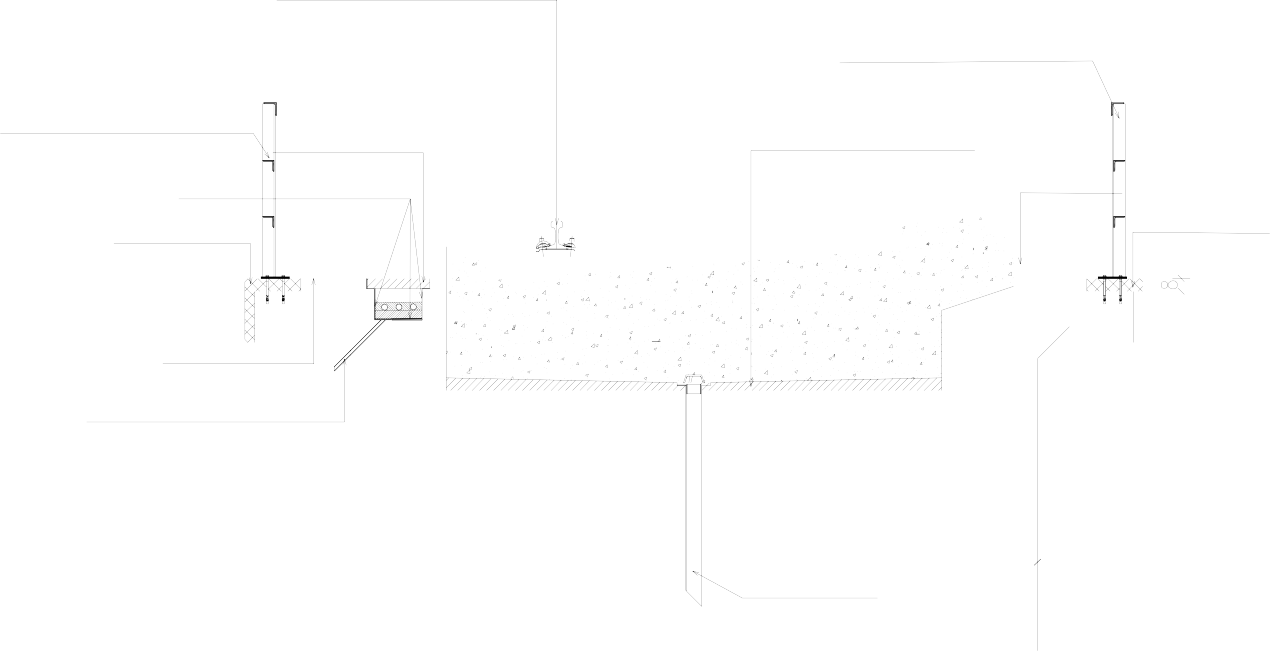
Furthermore, there is AB parapet on the bridge that provides safety to prism surfacing on the left side.

The condition of the bridge structure’s elements and equipment was stated in the previous design phase “Report on the condition of the bridge: The bridge after one km of the railway 369+146,07 Vrbnica – Bar” from 2015 which was used as a base in this phase of the design by the reconstruction designer.



*Figure 2- Existing cross section*

Uklanjaju se šine, pragovi, tucanički zastor, zaštitni sloj i hidroizolacija. / Rails, sleepers, ballast, protective layer and insulation are to be removed.



Uklanjanje postojeće hidroizolacije i zamena novom prskanom hidroizolacijom /

Uklanjanje postojeće i postavljanje

nove pješačke ograde/ Removal of existing and installation

osa mosta bridge axis

of pedestrian fence

Uklanjanje postojeće i postavljanje

nove pješačke ograde/ Removal of existing and installation

of pedestrian fence

Removal of existing insulation and

replacement with sprayed insulation

Zamjena poklopaca/ Caps replacement

Reparacija sloja za pad ukoliko je postojeći u lošem stanju/ Reparation of levelling layer if

Ugradnja prskane hidroizolacije/ Installation of sprayed insulation

Novi ivični vijenac/

New cornice

existing is in bad condition

Novi parapet/ New parapet

Novi ivični vijenac/ New cornice

Zaštitni premaz Protective coating

Ugradnja cjevčica za odvodnjavanje

kanala za instalacije/ Installation of pipes for installation

channel drainage

Ekstrudirani polistiren (stirodur) debljine 20mm - zaštita hidroizolacije od oštećenja pri ugradnji tucanika.

Extruded polystyrene (styrofoam) thickness of 20mm - protection of waterproofing from damages when installing a ballast.

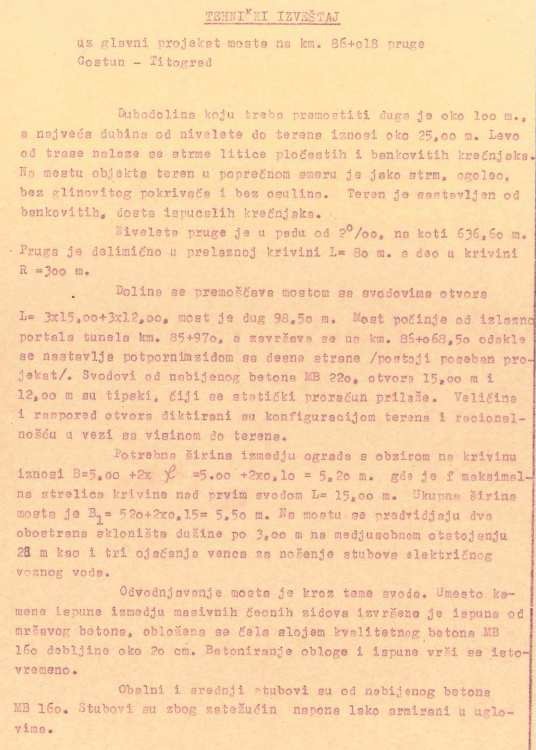
Zaštitni premaz Protective coating

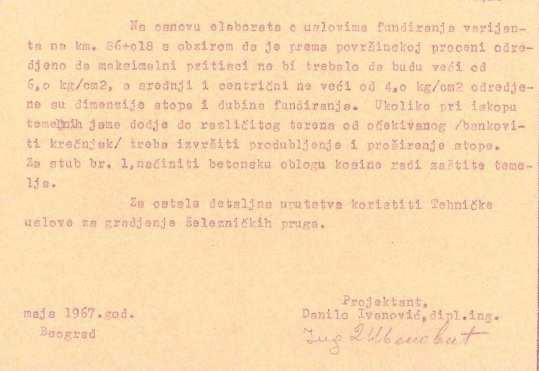
Zamjena slivnika/ Gully replacement

Figure 3- Newly designed cross section

## Attachment -excerpt from the technical report of the original design

(Designed by The National Institute of Design ZJŽ Belgrade, 1967.)





## Bridge damage and possible causes

The detailed review of damage and possible causes was included in the previous design phase:

“Report on the condition of the bridge: The bridge after one km of the railway 369+146,07 Vrbnica – Bar” from 2015, designed by the company Pro-Inženjering d.o.o Belgrade.

A graphic display of the damage noticed by reviewing the bridge is given in the graphic specifications in drawing – A photo of the damage.

According to “Report on the condition of the bridge: The bridge after one km of the railway 369+146,07 Vrbnica – Bar” from 2015, the extent of damage and its repair was considered. Since the reconstruction works will start with a time distance in relation to the performed structure review, it is necessary to see the progression of damage and their possible larger extent before the construction work starts. The scope of the works and the investment value are based on the review carried out in 2015.

## Assessment of the condition of the bridge with the proposal of taking measures

Taken from „*The report on the state of the bridge: the bridge at km 369+146,07 the railway line Vrbnica – Bar” from 2015.*

## General observation about the state of the bridge

By measuring the dimensions of structural elements and by comparison with layout sketches from the“Report about the current state of bridges on the Vrbnica-Bar railway line”, the following is concluded:

* the general bridge dimensions comply with the dimensions from the "Report about the current state of bridges on the Vrbnica-Bar railway line",while the certain differences in dimensions as well as missing dimensions are shown in appendix of this Report,

Railway track on the bridge is in curve and carried out in continuous welded rail (CWR). Railway track is generally in good condition except that lots of sleepers are in cracks and worn-out. On some places,rail fastening is loose and there is only one safety rail (next to left main rail – inner side of the curve) with poor condition of connections to the sleepers.

It’s necessary to replace all worn-out and cracked sleepers and to fasten all rail fastenings. One more safety rail (next to right main rail) must be installed and proper connection to the sleepers of existing one (left safety rail) should be executed.

Damages that could reduce the capacity and stability of the bridge structure **were found** during the detailed visual inspection of the bridge. A large scale of vertical side walls concrete degradation,in the zone of the pier S4, threatens the stability of sidewalk cantilevers as well as the railway track on the bridge.

The observed damages and deficiencies of the structure which negatively affect the durability and functionality of the structure are the following:

* a large scale of vertical side walls concrete degradation,in the zone of the pier S4,threatens the stability of sidewalk cantilevers as well as the railway track on the bridge,
* because of damaged waterproofing,water penetrates through all support zones of arched slabs,concrete continuing zones of arched slabs,through concrete of the arched slabs itself, in the connection zones between arched slabs and side vertical walls,as well as in connection zones between side vertical walls over the piers,
* cracks on the arched slabs in the middle of the spans S3-S4 and S4-S5,
* degradation of concrete of the arched slabs in the zone of drainage gullies,
* inadequate rehabilitation works in the lower zone of the left sidewalk cantilever in the span S3-S4. Above the pier S3,where cantilever for electric power was previously,concrete in the lower zone of cantilever is badly damaged with exposed and corroded reinforcement. Also,due to rock impacts,there are degradations of concrete of the left wingwall cantilever of abutment S7,
* transverse cracks in the both sidewalk cantilevers (on each 2-3m) with water leakings that leads to heavy water soakings of the lower zone of the cantilevers and damages of the concrete. Also,on each place of concrete continuing of the cantilevers there are heavy water leakings and in the zones of railing connections there are holes in the cantilevers with water penetration,
* missing of a drips on the edges of the sidewalk cantilevers,niches and overhead contact line (OCL) cantilevers which results in heavy water soakings of the concrete in the lower zone with prominent calcifications,
* surface washed concrete on many piers (abutments) due to the heavy water penetration through connections between arched slabs and piers. Larger zones of concrete segregation in the lower zones of the piers S4 and S5,
* poor quality of concrete of the right wingwall of the abutment S7 with prominent segregations almost on whole surface especially in the zones of concrete continuing,
* degradations of concrete on the right side of the pier S4,with exposed and corroded reinforcement,
* degradations of concrete on the right side of the foundation of the pier S3,
* local breaks of handrail of the sidewalk railings,
* prefabricated RC covers of the channels for installations are mainly damaged with exposed and corroded reinforcement.

## Proposed measures from the aspect of the bridge structure durability and functionality

* making of the new segments of the vertical side walls in the zone of the pier S4 where the large scale degradations have been observed,
* rehabilitation of the bridge drainage system with replacement of damaged waterproofing to prevent water penetration underneath the slabs used for water acceptance from the railway track superstructure. After completion of rehabilitation of drainage system and waterproofing as well as dewatering of trapped water, perform concrete rehabilitation in the zones of all joints where during inspection water penetration and damages have been observed and provide impermeability of water on all joints above slabs for water acceptance,
* installing the system for monitoring of the crack activities in apex of the arch slabs in spans S3-S4 and S4-S5,
* rehabilitation of concrete of the arched slabs in the zones of drainage gullies,
* rehabilitation of the damaged zones of the sidewalk cantilevers,
* provide water tightness on the sidewalk cantilevers on all places where transverse cracks were observed as well as in the all zones of concrete continuing,
* making of drips on the edges of sidewalk cantilevers,niches and overhead contact line (OCL) cantilevers,
* rehabilitation of the damaged concrete surfaces of the piers,right wingwall of the abutment S7 as well as the foundation of the pier S3,
* repairing of the local breaks of handrail of the sidewalk railings,
* replace of the damaged prefabricated RC covers of the channels for installations.

For these works it is necessary to make the technical documentation which must include a technical description of works, the technology of the works, estimated bill of quantity, and the necessary technical details.

**Urgent measures on the bridge construction:**

A large scale of vertical side walls concrete degradation,in the zone of the pier S4, threatens the stability of sidewalk cantilevers as well as the railway track on the bridge.

Urgent measure on the bridge construction is making of the new segments of the vertical side walls in the zone of the pier S4 where the large scale degradations have been observed.

**Note:**

**• In addition to the already mentioned measures, it is predesigned to strengthen the arches with carbon boards, according to details from the design specifications. Also, a complete replacement of waterproofing on the bridge, protection of waterproofing with extruded polystyrene panels, replacement of gullies and replacement of pedestrian fences along entire length has been predesigned.**

**• Installing the parapets is predesigned to provide a protection for the motorway prism. The explanation is as it follows:**



**Surfacing prism on railway bridges Vrbnica-Bar**

Since long rails (DTŠ) were built in reinforced concrete bridges, it is necessary to provide conditions defined by railway structure maintenance regulations in the final design of reconstruction.

This implies providing necessary width of surfacing prism behind the face side of sleepers or additional reinforced concrete structure that would secure the lateral stability of surfacing prism i.e. railway.

Necessary conditions for long rails on the railway are provided with additional solutions.

Existing cross sections of the most of bridges (mostly spans with fillers) do not have a ‘full’ profile that would provide unhindered mechanical maintenance of the railway. It is not possible to solve this problem in the final design of reconstruction because the expansion of bridges would be irrational, expensive and somewhere even impossible.

Therefore, technical services of Railway infrastructure company of Montenegro (ŽICG) successfully maintain the mentioned bridges but with limited machine potentials and with increased effort.

* + 1. **Execution of work technology**

RAILWAY AND NEXT TO THE RAILWAY RECONSTRUCTION WORK

A. General

Detailed description of technology for work items on the railway and next to the railway reconstruction. Other items of work are not connected to the railroad and they are not in the high voltage area. The items of work that are described in detail are:

1. **Installation of new waterproofing under railway prism.**

Removal of the protection layer (fine concrete) and existing waterproofing, sand blasting of concrete surfaces, placing repair mortar, installation of new sprayable waterproofing membrane.

2. **Installation of new vertical gullies**

Removal of old gullies, placing repair mortar, placing waterproofing and installation of new gullies.

3. **Installation of new bridge expansion joints**

Removal of existing expansion joints, processing concrete surfaces, installation of new expansion joints. (there are no expansion joints on the bridge)

4. **Repair of the installation canal**

Sand removal from the canal, moving SS and TT cables, sand blasting of concrete surfaces, placing repair mortar, placing pipes for water drainage, sprayed membrane of waterproofing

5. **Repair of curbs along the sidewalk**

Mechanical removal of upper and side layer of concrete curbs, sand blasting of concrete and reinforcement, construction of new curbs with a drip edge.

6. **Installation of new sidewalk rails**

Removal of the existing sidewalk rails, installation of new rails on previously repaired curbs.

7. **Construction of reinforced concrete parapets of the road bed tub**

a) Transportation of the material, construction of the fence for the stability of the road bed, temporary removal and putting back a part of surfacing prism, transportation and placing of concrete parapet and removal of the fence

b) Construction of concrete form, drilling the concrete, installation of anchors with placing cement mortar, assembling the reinforcement, concrete curing and removal of concrete form.

It is necessary to do a quality construction of new waterproofing and new vertical gullies to eliminate the harmful influence of water on the structure for a longer time. Installation of the waterproofing and the repair mortar layer must be carried out in accordance with the conditions of temperature, humidity and rate of hardening of concrete. Also, it is necessary to avoid as much as possible the continuation of the works during the installation of waterproofing.

The mentioned items of work are carried out under the special schedule of railway transport system, as follows:

a) closing the traffic with a power cut in the maximum possible period of time, the items Tč 1 and Tč 2 are executed on the bridges with gullies in the axis of the structure;

b) the use of a "construction railroad shut down" during the daytime (e.g. 11.30am to 4.30pm) with or without a power cut, when the items Tč 2, Tč 3 and 7a are executed;

c) Easy driving mode (30 km / h) without a power cut, items Tč 4, Tč 5, Tč 6 and Tč 7b are executed.

The items of work from Tč 2 to Tč7 can also be carried out in the railway traffic order a) and order b) if this does not interfere with the work of item Tč 1 as it is defined in the description of the works.

B. **Railway construction (bridge and the area next to the bridge)**

For the execution of the mentioned works for items Tč 1, Tč 2 and Tč 3, it is necessary to remove the rails, sleepers and the road bed all the way to the protective layer of waterproofing.

This is a description of the items of work on the railway that are necessary.

1) Works carried out before stopping the traffic:

• installation and removal of devices against the movement of rails in the railroad area behind the abutment piers;

• installation and removal of devices against the lateral movement of sleepers in the railroad area behind the abutment piers;

• cutting the rail in the embankment at 10m from the abutment piers and at every 22.5m on the bridge, with the drilling of the rails and mounting the rail joints.

2) Works during the closed traffic and power out:

• removal of the railroad (rails, protective rails, sleepers, surfacing prism) in the length of the railroad according to the dynamic design;

• mounting of railway with existing rails, a new roadbed, new wooden sleepers and new railway equipment.

3) Works after the end of construction works in the railway area:

• Rail welding on long rails, installation of safety rails;

• regulating the railway in the direction and the leveling of the existing elements.

**C. Conclusion**

a) The precondition for quality works of waterproofing, gullies and expansion joints is to meet the requirements of installation and to do careful work without unrealistic demands on the shortening of the required time.

b) With the good preparation and good organization of the working trains’ traffic, enough construction machines and experienced and expert work force it is possible to repair the waterproofing of the railway along 15 m of the bridge in one-day of closing (24h) and then let the traffic in the light traffic mode. This is valid for the period of May-September on the railway Vrbnica - Podgorica and the period of April-October on the railway Podgorica-Bar.

c) The contractor will, in accordance with the recommendations of the design and its technical and technological capacities, determine which period of closing of the railway is necessary and submit a request in a timely manner to the Railway infrastructure company of Montenegro (ŽICG) for obtaining the closing of the railroads that are longer than the daily approved closings.

d) The closing of the traffic should be used, if possible, simultaneously on two or more bridges that are in the same distance between the stations.

e) In the case of bridges with larger spans than 15m, it is necessary to use a long closing multiple times, but it is acceptable to organize it with breaks not exceeding 2 days.

**The execution of work on the railway reconstruction was designed by:**

**Graduate civil engineer Predrag Nišević**

**OTHER WORKS**

These items of work can be executed independently of the railway traffic and are not in the high voltage zone, according to the preliminary design of the execution work technology.

**A. Foundation piers**

The reconstruction of the foundations was not predesigned.

**B. Abutment piers and wings**

The reinforcing of the abutment piers and wings was not predesigned. The protection of the reinforcement at the places of damaged concrete surfaces consists of the removal of corrosion and application of anti-corrosion protection. The surface damages of concrete will be repaired by applying repair mortars and concrete. The cracks will be repaired with fillers. After repairing the damage, all visible surfaces will be covered with a protective coating. All these works are executed in accordance with the technical specifications that are an integral part of this design.

**C. Crown piers**

The reinforcement of crown piers was not predesigned. The protection of the reinforcement at the places of damaged concrete surfaces consists of the removal of corrosion and application of anti-corrosion protection. The surface damages of concrete will be repaired by applying repair mortars and concrete. The cracks will be repaired with fillers. After repairing the damage, all visible surfaces will be covered with a protective coating. All these works are executed in accordance with the technical specifications that are an integral part of this design. The urgent work on the bridge is the construction of new vertical walls’ elements on each side of the S4 pier. Large cracks (caverns) in the concrete of spandrel walls need cleaning and removing all unconnected parts of concrete. It is then necessary to cover the cracks with self-placing concrete, in accordance with the technical specifications that are an integral part of this design.

**D. Span structure**

Considering that it is not a reinforced structure and that cracks appeared on most of the spans, as well as the fact that there was not a temperature resistance test in the original design, the need for reinforcing arches in all spans has appeared. It has been decided that the arches are reinforced with Carbon Fiber Sheets (CFRP) for the following reasons:

• Easy adjustment of the geometry of the arch;

• Placing with less destruction of basic material than with other methods;

• easier maintenance.

The arches are reinforced with Carbon Fiber Sheets in the vertical direction. Carbon Fiber Sheets are also placed in the transverse direction over sheets in the vertical direction. Carbon Fiber Sheets in the vertical direction are also supported with carbon connectors. All these works are executed in accordance with the technical specifications that are an integral part of this design, as well as according to the instructions of the selected manufacturer. If possible, the work should be executed during the closed traffic while the surfacing is removed.

The protection of the reinforcement at the places of damaged concrete surfaces consists of the removal of corrosion and application of anti-corrosion protection. The surface damages of concrete will be repaired by applying repair mortars and concrete. The cracks will be repaired with fillers. After repairing the damage, all visible surfaces will be covered with a protective coating. All these works are executed in accordance with the technical specifications that are an integral part of this design.

**E. Cantilever**

The reinforcement of cantilevers was not predesigned. The protection of the reinforcement at the places of damaged concrete surfaces consists of the removal of corrosion and application of anti-corrosion protection. The surface damages of concrete will be repaired by applying repair mortars and concrete. The cracks will be repaired with fillers. After repairing the damage, all visible surfaces will be covered with a protective coating. All these works are executed in accordance with the technical specifications that are an integral part of this design.

**Terrain in the bridge area**

Cleaning is required in the bridge area.

## Static calculation - summary

## The list of resources for development of technical specifications

The design engineer used the following documents for the creation of the rehabilitation project:

* The original design - Main design of viaduct at km 86+018 of railway line Gostun - Titograd (developed by Institute for designing ZJŽ Belgrade, 1968.)
* Bridge condition report: Bridge in km. 369+146.07 of railway line Vrbnica - Bar (developed by Pro-inženjering, 2015.),
* Geotechnical elaborate (2018.),
* Geodetic survey (2018.),
* Expert opinion for works on track (2018.),
* Influence of work scope on environment (2018.),
* Traffic organization during work execution elaborate (2018.).

## List of applied regulations

LAWS AND RULEBOOKS REGARDING THE CONTENTS OF THE TECHNICAL DOCUMENTATION

* Railway law. Official Gazette of RMN, N° 27/2013;
* Law on safety, organization and efficiency of rail transport of Montenegro of 27/12/2013, in force since January 2014;
* Law on spatial development and construction of structures. Official Gazette of RMN, N°51/08, 40/10, 34/11, 47/11, 35713, 39/13;
* Law on construction products N° 18/2014;
* Law on geological researches. Official Gazette of RMN, N° 28/93, 27/94, 42/94, 26/07;
* Law on occupational safety. Official Gazette of RMN, N° 34/2014;
* The Rulebook on content and production of technical documentation - Official Gazette of RMN, N° 23/14, 32/15, 75/15;

RULEBOOKS FOR THE DESIGN

* (316) Rulebook on technical standards for determining the size of the load and categorization of railway bridges, culverts and other structures on railway lines. Edition 1992

EN STANDARDS

* MEST EN 1990:2013-Eurocode - Basis of structural design.
* MEST EN 1990:2013/NA:2013- Eurocode - Basis of structural design - National Annex.
* MEST EN 1991-1-1:2017/NA:2017- Eurocode 1: Actions on structures - Part 1-1: General actions - Densities, self-weight, imposed loads for buildings - National Annex
* MEST EN 1991-1-3:2017-Eurocode 1 - Actions on structures - Part 1-3: General actions - Snow loads.
* MEST EN 1991-1-3:2017/NA:2017- Eurocode 1 - Actions on structures - Part 1-3: General actions - Snow loads - National Annex
* MEST EN 1991-1-4:2016-Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions.
* MEST EN 1991-1-4:2016/NA:2016- Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions - National Annex.
* MEST EN 1991-1-5:2017/NA:2017- Eurocode 1: Actions on structures - Part 1-5: General actions - Thermal actions - National Annex
* MEST EN 1992-1-1:2017/NA:2017 - Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings - National Annex
* MEST EN 1997-1:2017- Eurocode 7: Geotechnical design - Part 1: General rules - National Annex;
* MEST EN 1997-1:2017- Geotechnical design - Part 1: General rules;
* MEST EN 1998-1:2015 - Eurocode 8: Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings.
* MEST EN 1998-1:2015/NA:2015 - Eurocode 8: Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings - National Annex
* SRPS EN 1991-1-5:2012 - Eurocode 1: Actions on structures - Part 1-5
* SRPS EN 1991-1-1:2012 - Eurocode 1: Actions on structures -Part 1-1
* SRPS EN 1991-1-3:2012 - Eurocode 1: Actions on structures -Part 1-3
* SRPS EN 1992-1-1:2015 - Eurocode 2: Design of concrete structures: Part 1-1
* SRPS EN 1997-1:2004 - Eurocode 7: Geotechnical design - Part 1
* HRN EN 1991-1-7:2012 - Eurocode 1: Actions on structures - Part 1-7
* HRN EN 1991-1-7:2012/Cor.1:2015 - Eurocode 1: Action on structures -Part 1-7
* HRN EN 1991-1-7:2012/A1:2015 - Eurocode 1: Action on structures -Part 1-7
* HRN EN 1991-2:2012 - Eurocode 1: Action on structures -Part 2
* HRN EN 1992-2:2013 - Eurocode 2: Design of concrete structures -Part 2
* HRN EN 1998-2:2011 - Eurocode 8: Design of structures for earthquake resistance - Part 2
* HRN EN 1998-3:2011 - Eurokod 8: Design of structures for earthquake resistance -Part 3
* HRN EN 1998-3:2011/Cor.1:2014 - Eurokod 8: Design of structures for earthquake resistance -Part 3
* HRN EN 1998-5:2011 - Eurokod 8: Design of structures for earthquake resistace - Part 5
  1. **Technical description- the structure**
     1. **General description**

Within the final design of the bridge reconstruction no. 76 works on the railway structure were predesigned, which are in the function of the bridge reconstruction. Technical specifications for the bridge no. 76 include sections of the railroad 115.25 meters long, which includes the total length of the bridge and 10.00 meters in front and behind the bridge.

Based on the conclusion from the Inspection Report on the structural condition of the bridge no. 76, as well as the establishing the existing condition in the period of making the relevant technical specifications, the necessary works on the bridge structure are defined. The railway on the bridge is the right geometry, in the curvature (R = 300m L = 80m), partly in the transition curve and partly in the circular arc. It was constructed as long rail (DTŠ). There is a safety rail only on the inside of the curvature.

The measurements of the bridge railway structure have been determined, with the preparation of the Bill of quantities, Technical Specifications, the Structural design and the solution for the bridge railway development with an attachment of graphs-Development plan for the bridge railway.

Total price of works on the bridge structure no. 76 is 99,724.42 €.

## Measurements of the upper structure

The reconstruction works include (installation of new waterproofing under the surfacing prism, installation of new gullies and new bridge expansions) the following works on the upper bridge structure, considering the length of the bridge and the length at the embankment of 10.00m from the abutment piers in front of and behind the bridge:

• stopping of the long rail in front and behind the bridge, with mounting of devices against vertical movement of rails;

• removal of existing rails, as well as the removal of the safety rail on the inside of the curvature, in sections up to 22,50 m long, with the removal of the rail and the safety rail. At the same time the cutting of the existing rail should be carried out together with drilling the rails for the joints. A possible removal of the attached equipment and sleepers, depending on the technology of removing rails and safety rails, removing devices against the vertical movement of rails on and behind the bridge installed due to the end switch junction for Dubočica, as well as the removal of devices against the lateral movement of rails on the bridge and in the railway area in front of and behind the abutment piers;

• removal of the existing road bed, up to the protective layer of waterproofing;

• assembling of rails, as well as safety rails on the inside of the curvature and new safety rails on the outer side of the curvature, in segments up to 22,50 m long, with a new road bed, new sleepers and a new railway equipment, with assembling of joint and necessary railway equipment for joining rails with safety rails;

• regulating the railway in the direction and the road level according to the elements of the existing condition;

• removal of railroad joint components before welding;

• welding the rails on the long rail;

• installation of devices against vertical movement of rails in front of and behind the bridge in accordance with the existing conditions of the quantity and position of devices, as well as the installation of the device against the longitudinal movement of the rails on and behind the bridge until the starting point of the end switch junction for Dubočica, and the removal of excess temporary installed devices against vertical movement of rails for stopping the long rail, but after the final welding;

• assembling of devices against the lateral movement of rails according to this design, i.e. Development plan for the bridge railway

• Final regulation of the railway.

Works on the upper bridge structure in the function of the bridge reconstruction, particularly the removal and installation of the existing railway, are carried out during closed traffic, and there should be a light traffic mode on the bridge section during the reconstruction works.

## 

## Structural design-summary

The basic elements of the structure used in calculating stress and stability of the railway are:

-rail type 49 E1, quality R260 (900A)

- wooden crossties L = 260cm, with axial spacing of 60cm

- K-type fastening railway equipment

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The bridge construction is an arched construction (viaduct with folded arches), with six spans L = 17.95 + 17.40 + 17.30 + 14.10 + 14.00 + 14.50 = 95.25m. It is constructed in the horizontal curvature in accordance with the elements of the railway line. The structure bridges a dry ravine with a natural slope from left to right. The bridge railway is a curvature line (R = 300m L = 80m), partly a transition curve and partly a circular arc. It was constructed as long rail (DTŠ).

Since there is no relative movement between the bridge and the long railroad between the non-bearing bridges, such as slabs, culverts and arches ("Study of various methods adopted by the world railways to continue LWR over bridges, as well as the regulations of the UIC announcement 774-3-Interaction railway-bearings-Recommendations for calculations-UIC Code) calculations include the effects of temperature changes on the rail without the influence of bridges on the rail (as on the open rail, i.e. the rail was observed practically on the embankment).

**Characteristic results**

a) For a long road of 49E1 rails, the maximum crushing strength is:

**N = -661.50kN**

b) For a long road of 49E1rails, the maximum tensile strength is:

**N = 817.14 kN**

c) The stability control of the railway against the displacement was executed, according to the Miščenka’s energy method, in the curvature of the radius R = 300m of the bridge, at extreme summer temperatures.

Critical lateral resistance was calculated **q = 112.32N/cm <118 N/cm** for which it is necessary to install the devices against lateral movement of the rails on every other sleeper.

d) The inspection of the crack size after cracking of the rails during the winter, it was determined that the width of the cracks would be 2.52cm <10cm, i.e. the safety of the traffic will not be compromised during the possible cracking of the rails.

## Solution of the railway development

Based on the analyzes performed and the obtained calculated design results, the development of the railway should be carried out in the following manner and with the respect of the following conditions:

1. The lower part of the structure in of front of and behind the bridge must be completely and properly executed (cross-section, drainage, stabilization).

2. The road bed in front of, behind and on the bridge must be clean, of proper quality and granulometric composition, with a surfacing prism predicted for the long rail. On the sections where devices against movement of rails are installed, additional compaction of the surfacing prism should be executed.

3. The railway (on the bridge and outside the bridge) before welding must be in the direction and road level which are completely regulated according to the elements of the existing condition.

4. The budget is calculated provided that both rails and the railway are welded on the bridge in the long rail.

5. The required stress relief temperatures in the long rail are +230C 30C.

6. 74 units of devices against the rail movement are installed on about 50 m of railway in front of the bridge and 164 temporary devices at a length of 24.56 m in front of the starting point of the end switch junction to Dubočica (there are 4 devices installed on each sleeper, i.e. 41x4 = 164 devices). Built-in devices in front of the bridge are installed after the final welding in accordance with the existing conditions of the quantity and position of devices. On the bridge and behind the bridge, devices against the rail movement are installed in accordance with the existing conditions of the quantity and position of devices, with the removal of excess temporary installed devices for stopping the long rail, but after the final welding.

7. Based on the performed stability control of the railway against the displacement in the curvature of the radius R = 300m, it is necessary to install devices against the lateral movement of sleepers on every second sleeper (in total 96 pieces), in accordance with the Development plan for the bridge railway.

In the curb in front of the bridge and behind the bridge, existing devices against the lateral movement of sleepers are installed on every other sleeper (a total of 34 + 12 = 46 pieces), in accordance with the Development plan for the bridge railway. The existing devices against lateral displacement of the railway are not included the Bill of quantities.

8. Permanent markings for the monitoring of vertical and transverse movements of the long rail (around the bridge) should be placed in the following places:

- at the first sleeper behind the bridge

- at the first sleeper in front of the bridge.

Markings are put up on both sides of the track on a stable ground.

Markings are put up prior to the completion of works of the long rail and are calibrated immediately after the starting of the long rail, in the presence of the Supervising Authority.

Stationary markings can be used as well as permanent markings for tracking the long rail, provided they are in close proximity (up to 3 m) of the designated points for markings. Permanent markings are not included in the Bill of quantities.

9. As the safety rail on the inside of the curve, the existing one is used, and on the outer side of the curve, a new safety rail is installed. They are interconnected by an oaken peg, with new fastening equipment installed at the connection between a sleeper and running and safety rails which is placed on every sleeper, as well as additional new equipment for the bridge’s end and additional new equipment for the safety rail joints.

10. All necessary maintenance work of the railway must be executed on time, in good quality and within limited temperature intervals. Enhanced surveillance of the section should also be ensured in the events of extreme rail temperature (below -10C and above +35C).