# Technical description-bridge structure

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## General project data

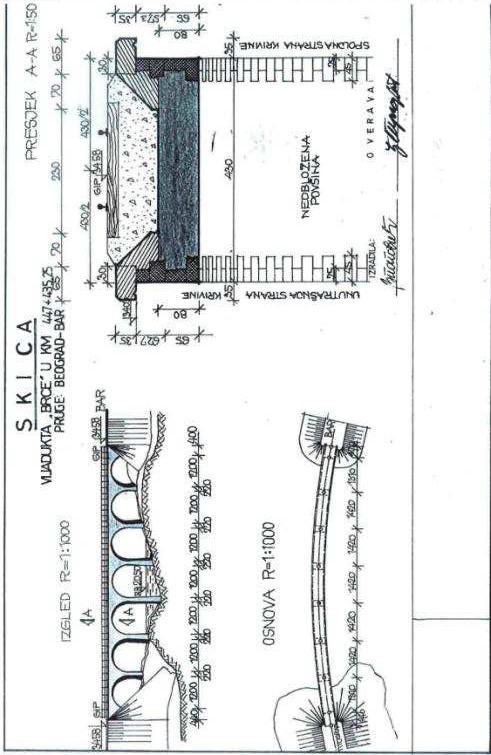
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| INVESTOR: | European Investment Bank |
| BENEFICIARY: | Railway infrastructure of Montenegro AD Podgorica |
| STRUCTURE: | Bridge no. 105 after one km of 447+435,25 |
| DESIGN: | Final design of the bridge reconstruction no. 105 after one km of 447+435,25 |
| SECTION OF THE RAILWAY: | Vrbnica - Bar |
| CHAINAGE: | 447+435,25 |
| DESIGN PHASE: | Final design |
| TITLE AND INDEX FOR THIS PART OF THE DESIGN: | Journal 2.1 -BUILDING CONSTRUCTION DESIGN  Bridge no. 105 after one km of 447+435,25 |
| 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, traffic roads and smaller stream with a bridge. The structure is in the residential area of Sutomore. In the bridge area the railway is in a horizontal and circular arc in radius R=300m.

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

Figure1- 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 seven concrete arches, a day bridge span of 12m.

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 reinforcement Č 37. There is a plain concrete filling directly above the arches and piers. The concrete fillers are only partially around and above the piers. Above these fillers, there are broken stone fillers and above them a road bed. The arches are of different sizes in cross section. In places of support, their thickness is 120cm and the crown of arches is 80cm thick.

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. The visible concrete surfaces are covered with stone, except arches’ lower parts. The expansion joints were placed in the concrete but not in the stone coating.

There are spandrel walls of various thickness above piers and arches. They are made of plain concrete.

Crown piers are made of lean reinforced (plain) concrete and their cross section is in the shape of trapeze and different in 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 limestone with smaller fissures. During the study of the original design, it was determined that the bottom of foundation junctions had been moved on the construction site because the layer of geoliss was deeper than it had been assumed.

Foundation geometry i.e. foundation junctions were changed which was recorded in the original design with drawings of new measurements. It was also determined from the original design that reinforcement had been added to the foundation.

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 at the junction on both abutment piers. There are slope round heads layered with stone at both abutment piers.

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. There is a layer of crushed stone above the waterproofing layer.

The drainage on arches was built with one vertical gully which is situated around supported piers, in comparison to other span bridges where the drainage was built in the crown of arches.

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

There are no sidewalks on the bridge and the all area of the bridge is layered with crushed stone. There are no consoles for electrification posts on the bridge. The electrification posts are attached laterally on both sides of the structure. There are niches (pedestrian shelters) on the left side of the bridge.

According to the opinion of an electrical engineer:

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

- Main wire cable type STKA

- Main cable TF KX4 2,4/9,6 -the property of Telecommunications company of Montenegro, the cable

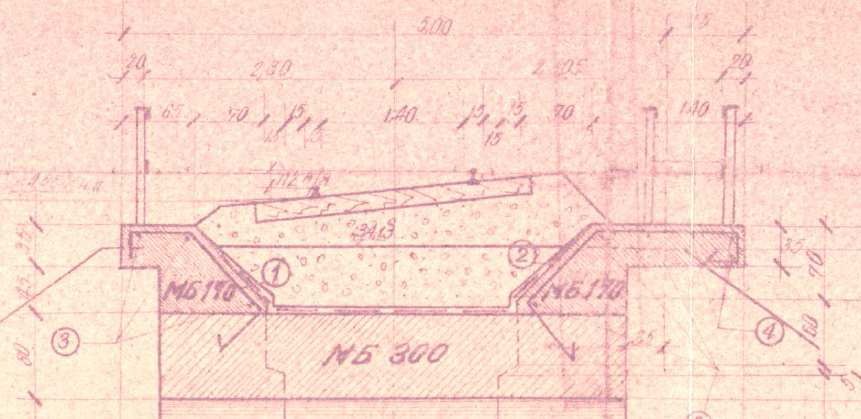
does not work

- Optical cable G625 144V 6x24 - 9/125 in polyethylene pipes Ø 40 + a spare polyethylene pipe Ø 40

- Optical cable 6x6 9/125 36V in polyethylene pipes Ø 40 + a spare polyethylene pipe Ø 40

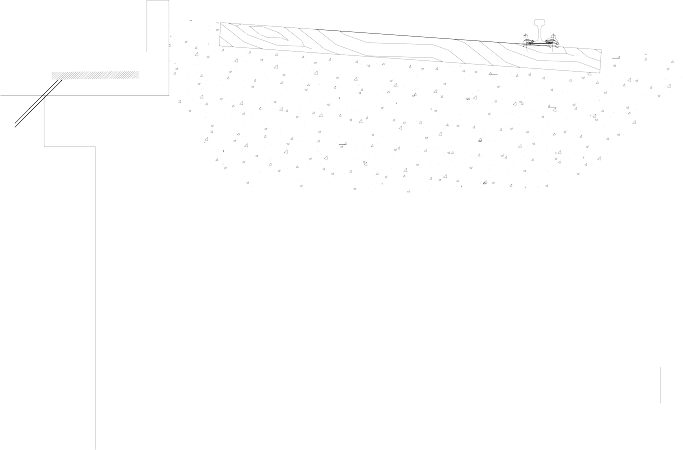
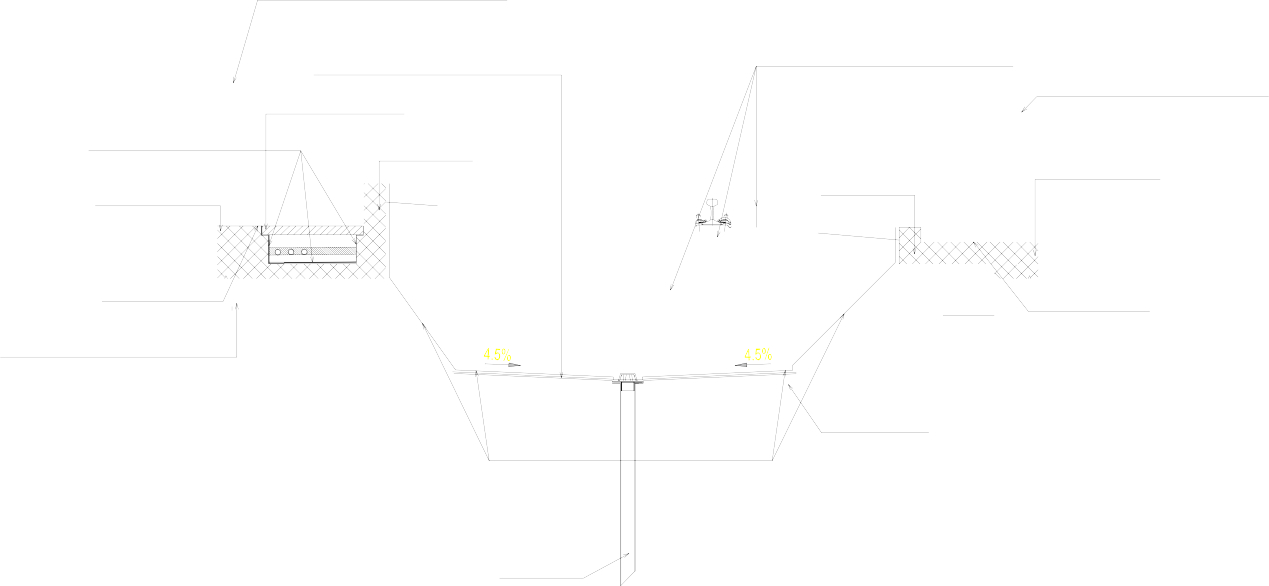
There is no standard AB parapet on the bridge that provides safety for prism surfacing but instead a bridge railing parapet has this function on one side and a prefabricated installation canal on the other side.

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 447+435,25 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*

Uklanjanje postojeće i postavljanje nove pješačke ograde/



Removal of existing and installation of pedestrian fence

Reparacija sloja za pad ukoliko je postojeći u lošem stanju/

Reparation of levelling layer if existing

Uklanjaju se šine, pragovi, tucanički zastor, zaštitni sloj i hidroizolacija. / Rails, sleepers, ballast, protective layer

osa mosta bridge axis

and insulation are to be removed.

Uklanjanje postojeće i postavljanje nove pješačke ograde/

Zamjena poklopaca/

Caps replacement

Ugradnja prskane hidroizolacije/

is in bad condition

Removal of existing and installation of pedestrian fence

Installation of sprayed insulation

Novi ivični vijenac/

New cornice

Novi parapet/ New parapet

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.

Nova AB ploča/ New RC slab

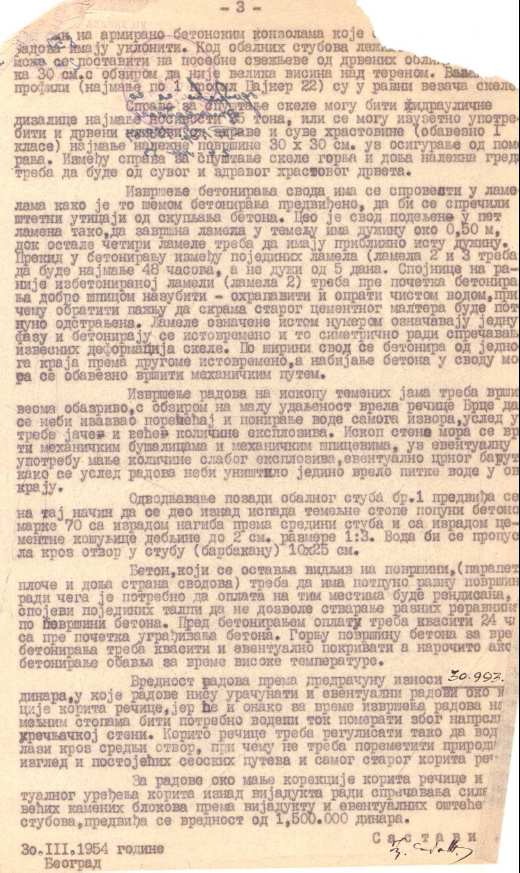
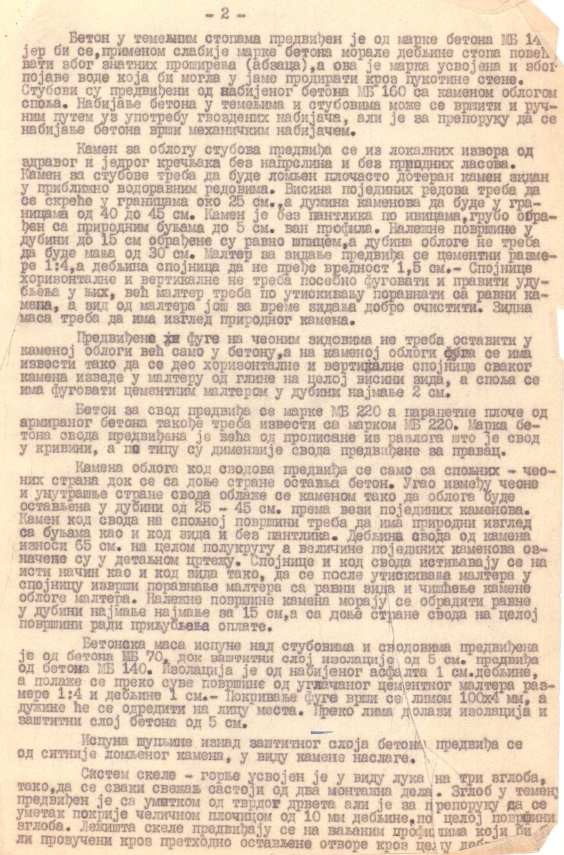
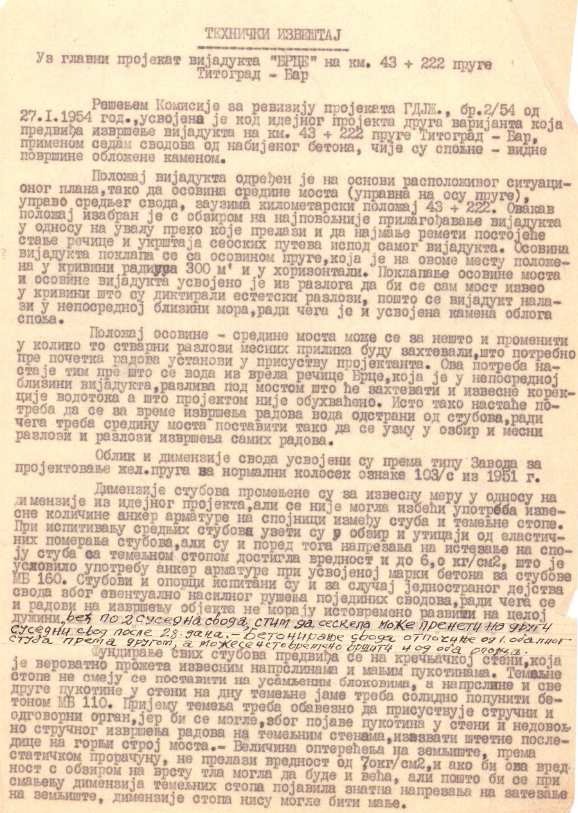
Zaštitni premaz/ Protective coating

Novi slivnik/ New Gully

*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, 1954)



## 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. 447+435,25 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 447+435,25 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 447+435,25 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). Lots of sleepers are worn-out and rotten. On lot of places,too,rail fastening is loose and there is only one safety rail (next to right main rail – inner side of the curve. There is increased dispersal of ballast from the bridge,on the both sides,especially on the left side which threatens the safety of the people and traffic beneath the bridge (bridge is located in inhabited place – touristic town of Sutomore).

It’s necessary to replace all worn-out and rotten sleepers and to fasten all rail fastenings. One more safety rail (next to left main rail) must be installed and proper connection to the sleepers of existing one (right safety rail) should be executed. Install the protective barriers on the sidewalk railings to prevent the dispersal of ballast from the bridge.

Damages that could reduce the capacity and stability of the bridge structure were not found during the detailed visual inspection of the bridge.

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

* 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,in connection zones between side vertical walls over the piers as well as through the concrete of the piers itself,
* zones of increased concrete segregations of the arched slabs in all spans,
* short anchor bolts in the upper zone of connection of overhead contact line (OCL) column in the span S3-S4 which can result in unscrewing of bolts and by that,stability of column could be threatened,
* damages and missing elements of the sidewalk railings,
* surface degradation of concrete of both sidewalk fasciae,
* **missing of protective barriers to prevent the ballast dispersal from the bridge which threatens the safety of the people and traffic beneath the bridge (bridge is located in inhabited place – touristic town of Sutomore).**

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

* 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,
* installation of adequate length anchor bolts in the upper zone of connection of OCL column in the span S3-S4,
* rehabilitation of existing damaged ones as well as installation of missing sidewalk railing elements,
* rehabilitation of concrete of both sidewalk fasciae,
* **installation of protective barriers to prevent ballast dispersal from the bridge.**

**Urgent measures on the bridge construction**

Due to increased ballast dispersal from the bridge which threatens the safety of the people and traffic beneath the bridge (bridge is located in inhabited place – touristic town of Sutomore) it’s necessary to install protective barriers on the both sidewalk railings,on the whole bridge length, to prevent ballast dispersal. This needs to be executed as a urgent measure on the bridge construction.

**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 gullies and pedestrian railing along entire length has been predesigned, as well as the construction of new installation canals and the extension of sidewalk consoles.**

* **It is predesigned to put a new slab anther the road bed with a water slope that would provide drainage through new gullies on the crown of arches, as well as placing a new sprayable waterproofing and waterproofing protection with polystyrene panels.**

**• Installation of the parapets is predesigned to provide a protection for the motorway prism.**

**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**. Construction of a new drainage system**

Excavation of the filling hole to the required level, placing concrete on AB plates, installation of gutters through the new AB plates and the crowns of arches.

2. **Installation of the leveling layer** from the repair mortar of the mortar as a base for waterproofing.

3. **Installation of sprayed waterproofing** on a supported slab and lateral sides of the "tub".

4. **Filling the joints** from the inside of the "tub" above the piers with permanently elastic material.

5. **Construction of canals for installations, new curbs and treads**

Removing of concrete mobile barriers, temporary local shifting of SS and TT cables, sand blasting of existing console surfaces, constructing new AB curbs, treads and installation canals, installation of water drainage tubes, sprayed waterproofing, sand and placing cables in canals and placing covers.

6. **Installation of new sidewalk rails**

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

It is necessary to do a quality construction of new drainage system, 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 maximum possible period of time during a day and night with or without a power cut, the items Tč 2, Tč 3 are executed;

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

d) Directing the traffic over steel temporaries in the hardening phase of concrete AB drainage slabs if the total stopping of traffic cannot be increased by more than 2 days. Temporary type B to produce a 1.4m wide slab above the piers, a temporary type A to produce of a 12.8m wide slab around piers.

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

For the execution of the mentioned works for items Tč 1, Tč 2, Tč 3 and Tč4, 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 one 15m span;

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

* If the temporary type A is used, then the installation and removal of rails is done with temporaries.

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.

**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 surface damages of rock layer and joints will be repaired with washing the rock under pressure and filling the damaged joints with mortar.

**C. Crown piers**

The reinforcement of crown piers was not predesigned. The surface damages of rock layer and joints will be repaired with washing the rock under pressure and filling the damaged joints with mortar.

**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 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**

These works apply to lower and lateral cantilever surfaces. 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.

**F. Terrain in the bridge area**

The area around abutment piers is clean. The area around the bridge is partly covered with larger plants, so cleaning is required. In addition, on sloperound heads there are smaller plants that need to be cleaned.

## Design

## 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 43+246 of railway line Gostun - Titograd (developed by Institute for designing ZJŽ Belgrade, 1966.)
* Bridge condition report: Bridge in km. 447+435.25 of railway line Vrbnica - Bar (developed by Pro-inženjering, 2015.)
* Geotechnical elaborate (2018.)
* Geodetic survey (2018.)
* Hydrotechnical design (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. 105 works on the railway structure were predesigned, which are in the function of the bridge reconstruction. Technical specifications for the bridge no. 105 include sections of the railroad 121,40 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. 105, 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), the whole length of it is in the circular arc and it was constructed as long rail (DTŠ).

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.105 is 103.807,88 €.

## 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, 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 the rails and the safety rails, removing the device against the lateral movement of rails on the bridge and around the railway in front of and behind 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 around the railway in front of and behind the abutment piers in accordance with the existing conditions of the quantity and position of devices.

• 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, in particular 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

The bridge construction is an arched construction (viaduct with folded arches), with seven spans L=15,30+5x14,20+15,10=101,40m. The structure is situated in residental area of Sutomore and it is completely layered with ractangular chipped stone except the lower layer of concrete on arcuated girders. The bridge was constructed in the curvature. The railway on the bridge is in right geometry in a curvature line (R = 300m L = 80m), in the whole length it is a circular arc, and 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).

## 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 and behind the bridge from the last sleeper on the road bed in front of the bridge (from the first one behind the bridge).

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 101 pieces), in accordance with the Development plan for the bridge railway.

In the curb in front of and behind the bridge, existing devices against the lateral movement of sleepers are installed on every third sleeper (a total of 34+34=68 pieces), in accordance with the Development plan for the bridge railway. The existing devices against lateral displacement of the railway are not included in 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).