# Technical description – the bridge construction

## General project data

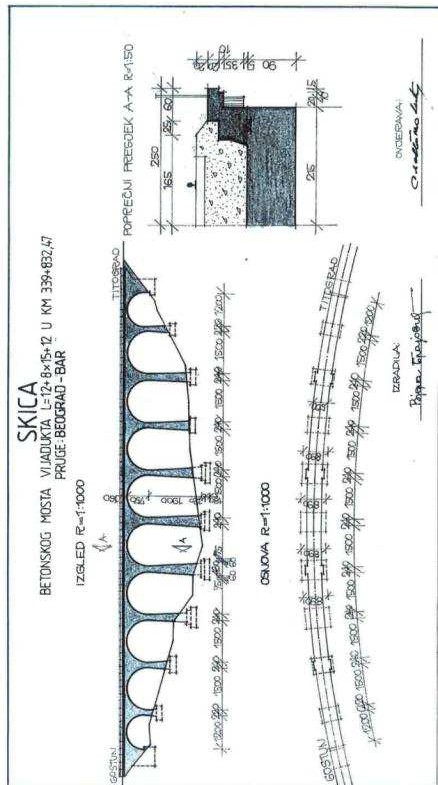
|  |  |
| --- | --- |
| PURCHASER: | The European Investment Bank |
| BENEFICIARY: | Railway Infrastructure of Montenegro - AD Podgorica |
| OBJECT: | BRIDGE no. 48 at km 339+832,47 |
| PROJECT: | THE MAIN PROJECT OF BRIDGE REHABILITATION  NO.48 AT KM 339+832,47 |
| SECTION: | Vrbnica - Bar |
| STATIONING: | 339+832,47 |
| PROJECT PHASE: | The main project |
| NAME AND PROJECT PART LABEL: | BOOK 2.1 - THE CONSTRUCTION PROJECT  Bridge no. 48 at km 339+832,47 |
| PROJECT ORGANISATION RESPONSIBLE FOR BRIDGE CONSTRUCTION PROJECT DEVELOPMENT: | Cestra Ltd Belgrade  Makenzijeva 57, 11000 Belgrade |

* + 1. **Location and route description**

The bridge bridges a deep valley with an occasionally torrential stream. The sides of the valley have a mild slope. The railway finished level is horizontal in the bridge area, and the object is partly in a transitional curve and partly in a circular curve with radius R=400 m.

## Attachment – The abstract from the Report on the existing bridges on the Vrbnica – Bar railway line

Picture 1 – The abstract from the report on the existing bridges on the Vrbnica – Bar railway line



## Description of the object construction – the current state

The bridge span structure consists of a series of ten concrete vaults.

The spans are: L = 12 + 8 x 15,0 + 12,0 m

Observing the original project, it is concluded that the vaults were designed to be unreinforced. The type of concrete is MB 220 (which corresponds to C 16/20). The vaults have hinged supports against the piers, and the connection is achieved by leaning and anchors made from round steel bars Č 37. Above the vaults and piers, there is a concrete fillet (concrete type MB 110). At the point of leaning of the vaults, their thickness is 120cm for the vaults with 12m span, and 130cm for the vaults with 15m span. At the crown of the vault, the thickness is 80cm for the vaults with 12m span, and 90cm for the vaults with 15m span.

Above the vault leaning location, expansion joints are planned to carry all the load above the vaults. The expansion joints are 2cm wide.

Above the piers, the head walls are interconnected by a reinforced concrete tie-beam (concrete type MB160, which corresponds to C 12/15). The head walls are also made of MB160 type of concrete.

The middle piers are made of lightly reinforced concrete of MB 160 type (which corresponds to C 12/15) and have the trapezoidal cross-section, variable by height. According to the original project, the piers are lightly reinforced and, like the vaults, can be treated as unreinforced because they do not have the minimum percentage of reinforcement. The piers are placed on plain concrete pads, which are placed over the plain concrete foundation. The connection between the piers and the pads is provided by the round bar Č 37 anchors. The concrete type of the pads and the foundation is MB 160 (which corresponds C 12/15). In the original design, the pier foundations are based on a layer of solid Paleozoic schist, and in the middle of the valley on a layer of fluvio-glacial sandy and gravel deposit. Observing the original construction project of the bridge, it was concluded that the bottom of the underlying joint at the construction location was shifted until the aforementioned layers were reached.

The abutments are also made of lightly reinforced concrete of type MB 160 (which corresponds to C 12/15). They have variable cross-section, and the foundation method is the same as that of the middle piers. On both abutments, there are parallel standing wing walls accompanying the abutments.

Above the vaults and the plain concrete fillet, there is a sloping layer with waterproofing. Above the waterproofing layer, a 5cm thick protection layer planned, made of plain concrete of unknown class.

Drainage on vaults is done through a vertical drain which is located at the crown of the vaults at all ranges.

The guard rail is made of metal tubes of circular cross-section.

On the right side of the pavement construction, there are pedestrian footways with integrated installation channels; and on the left side of the pavement construction, there are electrified pillar consoles. Niches (pedestrian shelters) are found on both sides

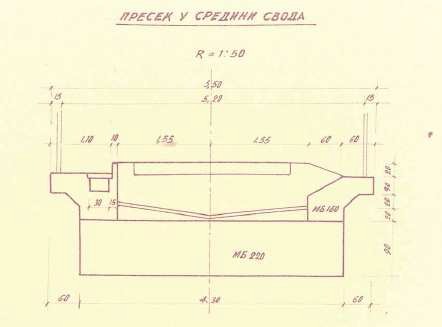
According to the opinion of an expert electrical technician:

On the bridge in question, in the concrete channel, on the right side, the following cables were laid:

* main railway cable of STCA (STKA) type
* optical cable G625 144V 6x24 - 9/125 in a plastic pipe Ø 40 + a spare plastic pipe Ø 40
* 2 x SPZ 33x0,9 – cables for input signal and advance sign

Also, on the bridge, there is an AB parapet for securing the road surface prism.

The state of the elements of the bridge construction and bridge equipment is stated in the previous phase of the project "*The report on the state of the bridge: Bridge at km 339+832,47 of the railway line Vrbnica - Bar*" from 2015, which the rehabilitation design engineer used as the basis in this phase of the project



*Picture 2 – The current cross-section*

Uklanjanje postojeće i postavljanje nove pješačke ograde/

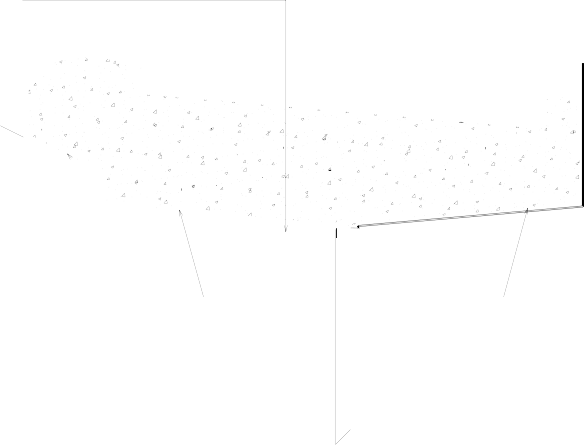
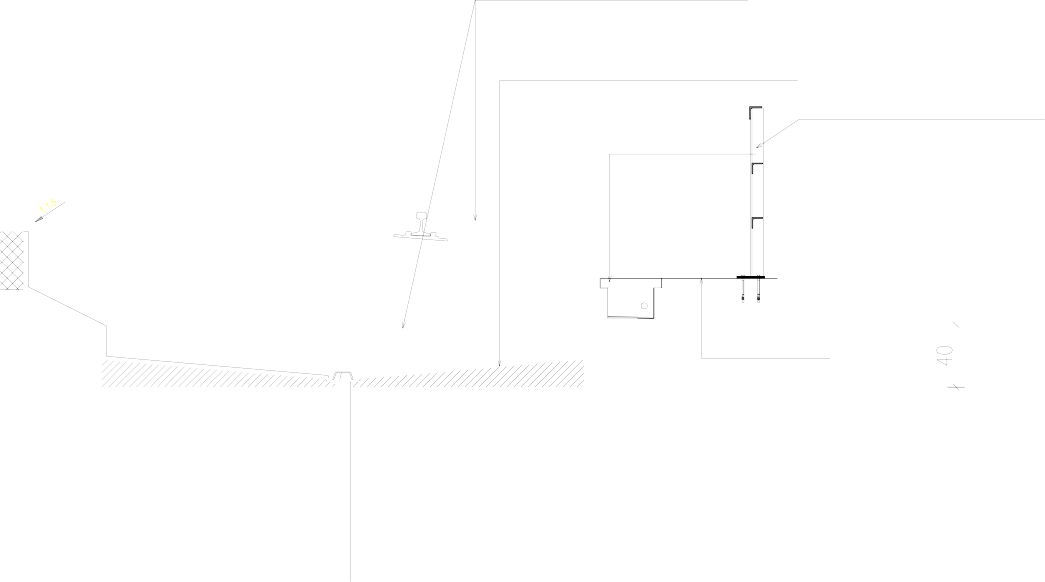
Removal of existing and installation of pedestrian fence

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 and insulation are to be removed.

Uklanjanje postojeće hidroizolacije i zamena novom prskanom hidroizolacijom / Removal of existing insulation and replacement with sprayed insulation



osa mosta bridge axis

Zamjena poklopaca/ Caps replacement

Uklanjanje postojeće i postavljanje nove pješačke ograde/

Removal of existing and installation of pedestrian fence

Novi ivični vijenac/

New cornice

Novi parapet/ New parapet

is in bad condition

Ugradnja prskane hidroizolacije/ Installation of sprayed insulation

Novi ivični vijenac/ New cornice

Zaštitni premaz/ Protective coating

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

Ugradnja cjevčica za odvodnjavanje

kanala za instalacije/

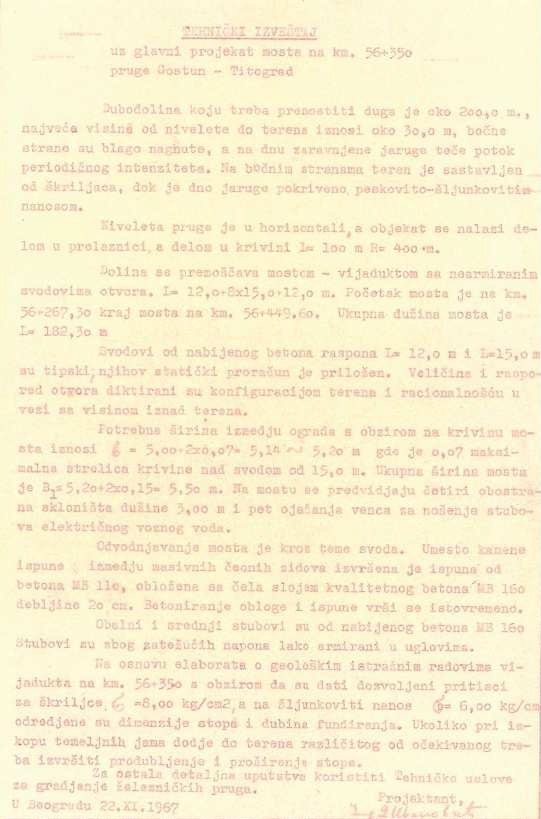
Installation of pipes for installation channel drainage

Zamjena slivnika/ Gully replacement

*Picture 3 – The newly-projected cross-section*

## Attachment – the abstract from the technical report of the original project

(Made by the Institute of Engineering of the Association of Yugoslav Railways, in Belgrade, in 1967)



## Damage on the bridge and the possible causes of its occurrence

A detailed overview of the damage with possible causes of occurrence was given in the previous phase of the project:

"*The Bridge Condition Report: Bridge at km 339+832,47, Vrbnica - Bar railway line” from 2015, made by the company Pro-Inženjering Ltd. from Belgrade*

A graphic display of the damage observed during the bridge inspection is given in the graphic documentation of the project in the drawing – The damage picture.

Based on "The Bridge Condition Report: The Bridge at km 339+832,47 Vrbnica - Bar railway line“ from 2015, the scope of damage, as well as the manner of its rehabilitation are examined. Having in mind that the rehabilitation works will begin after a period of time has passed from the already performed inspection of the construction, it is necessary to check the progression of the damage and a possibly bigger scope before the commencement of the works. The scope of the works and the investment value are based on the review carried out in 2015.

## The assessment of the state of the bridge with the proposed measures

Taken from „*The report on the state of the bridge: the bridge at km 339+832,47 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 on current state of the bridges on the Vrbnica-Bar railway line”, the following is concluded:

* global bridge dimensions comply with the dimensions from the "Report on current state of the bridges on the Vrbnica-Bar railway line", while certain discrepancies in dimensions as well as dimensions missing on the layout sketch enclosed to this Report.

The railway track on the bridge is in a curve and it is a continuous welded rail (CWR) track. The railway track on the bridge is in good condition, except for missing elastic washers under the sleeper screw heads on all rail to sleeper connections. Good track condition was expected since it was recently overhauled.

By detailed visual inspection of the bridge, occurrences and damages that reduce load bearing capacity and stability of the structure were not observed. However, visual inspection of the main arches showed some occurrences that, if progressing, might endanger the structure stability, and these are as follows:

* larger crack in the zone of concreting end (near the pier S9) of the arch S8-S9,
* smaller crack in the support zone of the arch S8-S9 on the pier S8,
* smaller cracks in the apexes of the arches S1-S2, S2-S3, S5-S6, S6-S7 and S8-S9.

The observed damages and deficiencies of the structure that negatively affect durability and functionality of the structure are as follows:

* Larger crack in the zone of concreting end (near the pier S9) of the arch S8-S9,
* Smaller crack in the support zone of the arch S8-S9 on the pier S8,
* Smaller cracks in the apexes of the arches S1-S2, S2-S3, S5-S6, S6-S7 and S8-S9.
* Damages of concrete of arch edges with exposed reinforcement in the spans S6-S7 and S7-S8,
* Due to damaged waterproofing, which is out of order, water leaks thru: arch supports, continued concreting of arches, joins of lateral walls and arches, as well as thru arches concrete,,
* Due to lack of drips on the pedestrian pathway cantilevers, soaking of concrete occurs in the bottom zone of the cantilevers with prominent calcifications in the edge zone. Also map cracking with

seepage was observed, as well as abundant leaking on concreting ends resulting in soaking of the superstructure.

* Superficial degradation with locally exposed and corroded reinforcement on the fasciae lateral sides,
* OCL masts cantilevers are constructed without drips resulting in soaking of the cantilever bottom zone, calcifications as well as concrete degradations with exposed reinforcement in the zone of anchor bolts,
* Superficial and profound damages of concrete of the vertical walls immediately above the piers as a result of seepage on concreting ends,
* The drainage gullies are missing in the arches apexes, resulting in abundant soaking and damages of the arch concrete,
* Larger concrete degradations with locally exposed and corroded reinforcement and calcification of concrete on support segments of the piers S2, S3, S4, S5, S6, S7, S8, S9 and S10, as well as on the lateral sides of the piers S3 and S8,
* Lack of drainage systems in the installation channels.

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

* Establish monitoring of the observed larger and smaller cracks in the span S8-S9 in order to determine their activity. Results from monitoring shall define method of crack rehabilitation,
* Carry out an additional structural analysis and check the existing documentation to determine the cause of smaller cracks occurrence in all above mentioned apexes,
* Rehabilitate damaged concrete of the arch edges in the spans S6-S7 and S7-S8,
* Rehabilitate the bridge drainage system and replace damaged waterproofing, to prevent leakage of water under the concrete slabs used for collection of water from the track. After completed drainage system and waterproofing rehabilitation and drained collected water, rehabilitate concrete in the areas of these joins where water leaking and concrete damages were observed during inspection, and provide water tightness to all joins above the water collection slabs,
* Rehabilitation of the pedestrian pathway cantilevers in the bottom zone with construction of drips, as well as the fasciae lateral sides,
* Provide water tightness on the pedestrian pathway cantilever concreting ends,
* Rehabilitation of concrete of OCL masts cantilevers with construction of drips,
* Rehabilitate damages of concrete of the vertical walls,
* Rehabilitate damages of concrete of the piers,
* Install missing drainage gullies and construct the drainage system of the installation channels.

For these works it is necessary to prepare technical documentation that must include technical description of works, the technology of works, estimated bill of quantity, as well as necessary technical details.

Urgent measures on the bridge construction

By detailed visual inspection of the bridge, occurrences and damages that reduce load bearing capacity and stability of the structure were not observed. However, visual inspection of the main arches showed some occurrences that, if progressing, might endanger the structure stability, and these are as follows:

* larger crack in the zone of concreting end (near the pier S9) of the arch S8-S9,
* smaller crack in the support zone of the arch S8-S9 on the pier S8,
* smaller cracks in the apexes of the arches S1-S2, S2-S3, S5-S6, S6-S7 and S8-S9.

**It is necessary to:**

Establish monitoring of the observed larger and smaller cracks in the span S8-S9 in order to determine their activity. Results from monitoring shall define method of crack rehabilitation,

Carry out an additional structural analysis and check the existing documentation to determine the cause of smaller cracks occurrence in all above mentioned apexes,

### NOTE:

* **Alongside the aforementioned measures, the strengthening of the vaults with carbon fabric is planned according to the details from the project documentation. Also, the complete change of waterproofing on the bridge is intended, as well as the protection of waterproofing with styrodur sheets, the change of drains, the change of installation channel covers and the change of guard rails for the pedestrian paths for the whole length.**
* **The installation of parapet is planned in order to secure the road surface prism. The explanation is given below:**



**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. **The construction technology**

REHABILITATION WORKS CARRIED OUT ON THE RAILWAY TRACKS OR RIGHT BESIDE THE TRACKS

### General

A more detailed description of construction technologies for the rehabilitation works carried out on the tracks or immediately beside the tracks is given here. Other items are carried out separately from the railway traffic and are not in the high voltage zone. The items for which a detailed description of construction technologies is given are:

### The installation of new waterproofing underneath the road surface prism

Removing the protective layer (microgranular concrete) and removing the existing waterproofing, sandblasting the concrete surface, applying the repair mortar, making the sprayed waterproofing.

### The installation of new vertical drains

Dismantling the existing vertical drains, processing the area with the repair mortar, the application of waterproofing and the installation of new drains.

### The installation of new bridge expansion joints

The bridge does not have expansion joints.

### The rehabilitation of the installation channels

Removing sand from the channel, local moving of SS and TT cables, sandblasting the concrete surfaces, applying the repair mortar, installing the water drainage pipes, sprayed waterproofing.

### The rehabilitation of sidewalk cantilever slabs of pedestrian paths

Mechanical removal of the top and lateral layers of the concrete sidewalks, sandblasting the concrete and rebar (reinforcement), the construction of the new part of sidewalk with a drip channel.

### The installation of the new guardrail fences for pedestrian paths

The removal of the existing guardrails for pedestrian paths, installing the new guardrail fences on the previously repaired sidewalk.

### The construction of reinforced concrete parapets of road bed

* + 1. the importation of materials, the construction of shoring for the stability of the road bed, temporary removal and the return of the part of the road bed prism, the importation of the concrete and the installation of the concrete of the parapet and dismantling the shoring,
    2. formwork construction, drilling holes in the concrete, the installation of anchors and grouting with eksmal (cementitious grouting mortar), the installation of reinforcement, concrete care and dismantling the formwork construction

It is necessary to make new waterproofing, new expansion joints and new vertical drains in high-quality manner in order to eliminate the harmful influence of water on the structure in the long run. The installation of waterproofing and the application of the layer of repair mortar must be carried out in accordance with the temperatural conditions, humidity and curing time. Also, it is necessary to avoid as much as possible the frequent interruptions and continuation of the works during the installation of waterproofing.

The following items are to be done under the special modes of railway traffic, as follows:

1. the traffic is stopped, and voltage turned off for as long as possible, then the items **Tč 1** and **Tč 2** are carried out for the bridges with vertical drains in the axis of the construction;
2. the usage of "railway closure due to construction" during daylight (i.e. from 1130 to 1630) with or without powering off electricity, then the items **Tč 2** and **Tč 3** and **7a** are carried out;
3. the low speed mode (up to 30 km/h) without powering off electricity, then the items **Tč 4**, **Tč 5**, **Tč 6** and **Tč 7b** are carried out**.**

The items defined as **Tč 2** up to **Tč 7** can be carried out also in the railway traffic modes under a) and b) if this does not impede the item defined as **Tč 1** from the description of the works.

### Works on the railway tracks (on the bridge and in the bridge area)

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

A description of the works on the items that are necessary to be done on the railway tracks is given here.

1. The previous works that are done before stopping the traffic:
   * installing and dismantling of the safety derailer devices in the railway track area behind the abutments;
   * installing and dismantling of the devices against the lateral movement of the sleepers in the railway tracks area behind the abutments;
   * cutting the railway tracks on the embankment at 10m from the abutments and at each 22,5m on the bridge, including drilling the tracks and installing joint bars.
2. The works during the interruption of traffic and electricity power cuts:
   * dismantling the railway tracks (the rails, guard-rails, sleepers, the road surface prism) for the full length of the railway tracks, according to the Programme and Progress Schedule;
   * installing the railway tracks with the existing rails, new road bed, new wooden sleepers and new rail fittings.
3. The works after the execution of construction works in the railway track area:
   * welding the rails as LRT, installing the guard-rails;
   * regulating the railway tracks in the direction and by the finished level, according to the elements of the existing state.

### Conclusion

1. The prerequisite for well-done waterproofing, vertical drains and expansion joints is to respect the conditions of installation and to do careful work without unrealistic demands on the shortening of the required time.
2. With the good preparation and good organization of the traffic of trains in service, and sufficient number of construction machines and experienced and professional workforce, the repair of waterproofing of the bridge deck on the 15m length of the bridge can be done during a one-day continuous interruption of traffic (24h) and afterwards the traffic can be reintroduced in low speed mode.

This is applicable for the time period from May to September on the Vrbnica – Podgorica section of the railway line, as well as for the time period from April to October on the Podgorica – Bar section of the railway line.

1. The contractor will, in accordance with the recommendations from the project and their own technical and technological capacities, determine in which periods of time the railway closure will be needed and submit a timely request to the RIM for obtaining the permit for the railway interruption which longer than the daily approved ones.
2. The interruptions of the traffic should be used simultaneously when possible on two or more bridges that are on the same interstation distance.
3. For the bridges with the span bigger than 15m, it is necessary to use long interruptions multiple times, but it is acceptable to arrange it with breaks which are not exceeding 2 days.

### The construction technology for the rehabilitation works carried out beside the tracks is compiled by:

**Bachelor with Honours in Civil Engineering, Predrag Nišević**

**OTHER WORKS**

These items can be done independently from the railway traffic according to the designed construction technology proposal and they are not in the high voltage area.

### Pier foundations

The works on the rehabilitation of foundations are not planned.

### Abutments and wing walls

The works on the reinforcement of the abutments and wing walls are not planned. The protection of the reinforcement on the damaged concrete surfaces consists of removing the corrosion and applying the anticorrosive protection. The surface damage to the concrete surfaces is to be repaired with repair mortar and concrete. The repair of fissures will be done by sealing. After the repairs, all available surfaces will be coated with a protective overcoat. All these works are carried out in accordance with the relevant Technical specifications which are an integral part of this project.

### Middle piers

The works on the reinforcement of the middle piers are not planned. The protection of the reinforcement on the damaged concrete surfaces consists of removing the corrosion and applying the anticorrosive protection. The surface damage to the concrete surfaces is to be repaired with repair mortar and concrete. The repair of fissures will be done by sealing. After the repairs, all available surfaces will be coated with a protective overcoat. All these works are carried out in accordance with the relevant Technical specifications which are an integral part of this project.

### Span construction

Having in mind the unreinforced vault construction in question, and the fact that at most of the span there are fissures, as well as the fact the original project did not include the temperatural load, there is a need for reinforcing the vaults at all ranges. It has been decided that the vaults be reinforced with CFRP (Carbon fiber reinforced polymer) fabric for the following reasons:

* + Easily adjustable to the geometry of the vault;
  + Installation with lower destruction of the base materials than with other methods;
  + Easy maintenance.

The vaults are reinforced with CFRP fabric longitudinally. Additional fabric is put in the cross direction of the CFRP fabric that goes longitudinally. The CFRP longitudinal fabric is secured with carbon connectors. These works are carried out in accordance with the relevant Technical specifications which are an integral part of this project, and in accordance with the instructions of the selected producer. The works should be carried out, if possible, during the traffic stoppage while the road surface is removed.

The protection of the reinforcement on the damaged concrete surfaces consists of removing the corrosion and applying anticorrosive protection. The surface damage to the concrete surfaces is to be repaired with repair mortar and concrete. The repair of fissures will be done by sealing. After the repairs, all available surfaces will be coated with a protective overcoat. All these works are carried out in accordance with the relevant Technical specifications which are an integral part of this project.

### Cantilever slabs

The works on the cantilever slabs are not planned. The protection of the reinforcement on the damaged concrete surfaces consists of removing the corrosion and applying anticorrosive protection. The surface damage to the concrete surfaces is to be repaired with repair mortar and concrete. The repair of fissures will be done by sealing. After the repairs, all available surfaces will be coated with a protective overcoat. All these works are carried out in accordance with the relevant Technical specifications which are an integral part of this project.

### Terrain in the bridge area

The whole area around the bridge is covered with large overgrowth, so a thorough cleaning is necessary.

## Structural design

## The list of templates used for the creation of technical documentation

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

* The original project – The main viaduct project at km 56+350 of the Gostun - Titograd railway line (done by the Institute of Engineering in Belgrade of AYR, 1968)
* Report on the condition of the bridge: The bridge at km 339+832,47 of the Vrbnica– Bar railway line (done 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 superstructure**
     1. **General**

Within the Main no. 48 Bridge Rehabilitation Project, the works are planned for the superstructure of the railway tracks, for the purpose of bridge rehabilitation. The technical documentation for the bridge no. 48 covers the section which is 187,40m long, which includes the total length of the bridge and 10.00m in front and behind the bridge.

Based on the Conclusion from the Inspection Report on the state of the superstructure on the bridge no. 48, as well as on the established current state in the period of the preparation of the relevant technical documentation, the necessary works on the superstructure of the bridge railway tracks have been defined. The railway tracks on the bridge are geometrically regular, in a curve (R=400 L=100), and on the part of the transition curve and of the circular curve. The tracks have guardrails, they are overhauled and of the LRT type (Long Railway Track).

Measures on the superstructure of the bridge railway tracks have been determined, alongside the Estimated Bill of Quantities, Technical Specifications, The Structural Design of the Superstructure and the Solution for the arrangement of the railway tracks with the graphic attachment – the Arrangement Plan for the railway tracks on the bridge.

The total value of the works on the superstructure for the bridge no. 48 amounts to €144.885,77.

## Measures on the superstructure

The following works on the superstructure are planned for the execution of works on the bridge rehabilitation (the installation of new waterproofing below the road surface prism, the installation of the new vertical drains and new bridge expansion joints), where both the length of the bridge and the 10m on the embankment from the abutment, both behind and in front of the bridge are taken into account:

* + - * Locking the LRT in front and behind the bridge, alongside mounting the devices against the longitudinal displacement of the rails;
      * Dismantling of the existing tracks, as well as dismantling the guard-rails, in segments up to 22,50m of length, with the removal of the tracks and the guard-rail, while cutting of the existing tracks should be carried out alongside the drilling of the rails for the joints, and possible dismantling of the joint kit and sleepers depending on the technology of track and guard-rail removal, as well as dismantling the devices against the longitudinal displacement of the rails in front of and on the bridge and in the area of the tracks in front of and behind the abutments;
      * the removal of the existing road bed, up to the protective layer of waterproofing;
      * installing the railway tracks, as well as the guard-rails, in segments up to 22,50m in length, with the new road bed, new sleepers and new rail fittings, alongside the installation of joints and rail fittings necessary for the structure of the new rails and guard-rails;
      * regulating the railway track in the direction and the level according to the elements of the current state;
      * dismantling of railroad track components before welding, with arranging the railway tracks in the S3 pier area because of the Automatic Railway Block signaling (ARB) according to the current state;
      * welding the tracks into the LRT;
      * dismantling the devices against the longitudinal displacement of the railway tracks, which are installed to lock the LRT in front and behind the bridge, with installing the device against the longitudinal displacement of the tracks in front and behind the bridge according to the existing state in respect to the number and location of the existing devices, as well as installing the existing devices against the longitudinal displacement of the tracks in front and on the bridge because of the ARB;
      * installing the devices against the lateral displacement of the railway tracks according to this project, that is, according to the railway tracks arrangement plan;
      * definitive regulation of the tracks.

The works on the bridge superstructure for the purpose of the rehabilitation of the bridge, in particular the dismantling and installation of the existing railway tracks, are carried out under traffic stoppage, and the low speed mode traffic should be enforced on the section of the bridge during the duration of rehabilitation works.

## Structural design - summary

The basic elements of the superstructure used in the unit stress and stability analysis are:

- the railway tracks type 49 E1, quality R260 (900A)

- wooden sleepers L=260cm, with center-to-center spacing of 60cm

- railway track joint kit type "K".

The bridge construction is a vaulted construction (a viaduct with fixed vaults), with ten spans L=2x14,20+2x17,30+6x17,40=167,40m and it is done in a horizontal curve according to the elements of the railway line route. The bridge construction is in the suburban zone of Kolašin, and in spans S1-S2, S3-S4 and S4-S5 it bridges a local road, while in the S4-S5 span it bridges a stream, and in other spans, it bridges a valley. The railway tracks on the bridge are geometrically regular, in curve (R=400m L=100m), on the part of the circular and the transitional curve, it has guard-rails and it is welded as LRT.

As there is no relative movement between the bridge and the LRT on the bridges without bearing pads, such as decks, framed culvert and vaults (“A study of various methods adopted by world railways to continue LWR over bridges”; also: UIC Code 774-3 - Track deck interactions - Recommendations for calculations), the calculations have been done for the temperatural change in the tracks excluding any impact of the bridge on the tracks (as if on open railway, that is, the tracks are basically considered as if they are on the embankment)

***Characteristic results***

1. For the LRT of 49E1 rails, the maximum compressive force is:

### N= -661,50kN

1. For the LRT of 49E1 rails, the maximum tensile force is:

### N= 817,14kN

1. The control check of the stability of the track against derailment was performed according to Mishchenko’s energy method in the curve with radius on the bridge R=400m, under extreme summer temperatures.

Critical lateral resistance is calculated to be q= 99,99N/cm<106 N/cm for which it is necessary to incorporate anti-lateral displacement devices on every third sleeper.

1. The control check of the size of the fissure in the rails in the winter showed that the size of the fissure upon occurrence will be 2,52cm<10cm that is, the safety of the traffic will not be compromised in the event of a possible fissure of the rails.

## The solution for the arrangement of the railway tracks

Based on the performed analyses and the obtained results of the calculations, the arrangement of the tracks should be carried out in the following manner and with the fulfillment of the following conditions:

1. The substructure in front of and behind the bridge must be completely and properly implemented (cross-section, drainage, stabilization).
2. The road bed in front, behind and on the bridge must be unpolluted, of prescribed quality and granulometric composition, with a road surface prism which is intended for the LRT. On the sections where the devices are installed to prevent railway track displacement, additional compaction of the road bed prism should be carried out.
3. The railway tracks (on and off the bridge) must be put in the designed axis and height position before the welding, as well as completely regulated and packed.
4. The analysis was done under the assumption that the LRT is being welded with the rails and the railway tracks on the bridge.
5. The temperature necessary for releasing the voltage in the LRT is +230C ± 30C.
6. 74 units of safety derailer devices are to be installed at 50m of the tracks in front of and behind the bridge from the last sleeper on the road bed in front of (that is, the first sleeper behind) the bridge. The installed devices in front and behind the bridge are to be dismantled after successfully welding the tracks, but should be also installed in front of and behind the bridge according to the existing state in respect to the number and location of the existing devices. The existing devices against the displacement of the tracks are installed in front and behind the bridge from km 339+730,27 to km 339+830,27 (behind and in front of the ARB at the length of approximately 2x50m), that is, according to the existing state in respect to the number and location of the existing devices, only after successfully welding the tracks.
7. Based on the completed stability control checks against the derailment in the curve with the radius R=400m, it is necessary to install the devices against the lateral displacement of the tracks on every third sleeper (105 pieces in total), according to the Railway tracks arrangement plan.
8. In the curve in front and behind the bridge, the existing devices against the lateral displacement of the sleepers are installed on every third sleeper, according to the Railway tracks arrangement plan. The aforementioned existing devices against the lateral displacement of the tracks are not included in the Estimated Bill of Quantities
9. The permanent markings for the monitoring of longitudinal and transversal movements of the LRT (in the bridge area) should be placed in the following places:
   * at the first sleeper behind the bridge
   * at the first sleeper in front of the bridge.

The markings are buried on both sides of the tracks into stable grounds.

The markings are to be installed prior to the installation of the LRT, and they will be calibrated immediately after the termination of the LRT striking, in the presence of the Supervisory Authority.

Stationary markers can be used as permanent markers for the monitoring of the LRT, provided they are located in close proximity (up to 3m) of the designated points for markings. Permanent markings are not included in the Estimated Bill of Quantities.

1. The existing, already installed guard-rails can be used as the guard-rails of the bridge, and they should be connected at the end with an oak wedge. A new joint kit should be installed at the connection of the sleeper with the railway and guard rails on every sleeper, alongside the new additional kits at the end of the bridge and the new additional kit for the guard-rail joints.
2. All necessary maintenance work on the tracks must be carried out on time, in a high-quality fashion and at the allowed temperature intervals. It is also necessary to provide intensive surveillance of the section in the event of extreme temperatures on the rails (below -10°C and above +35°C).