# Technical description – the bridge construction

## General project data

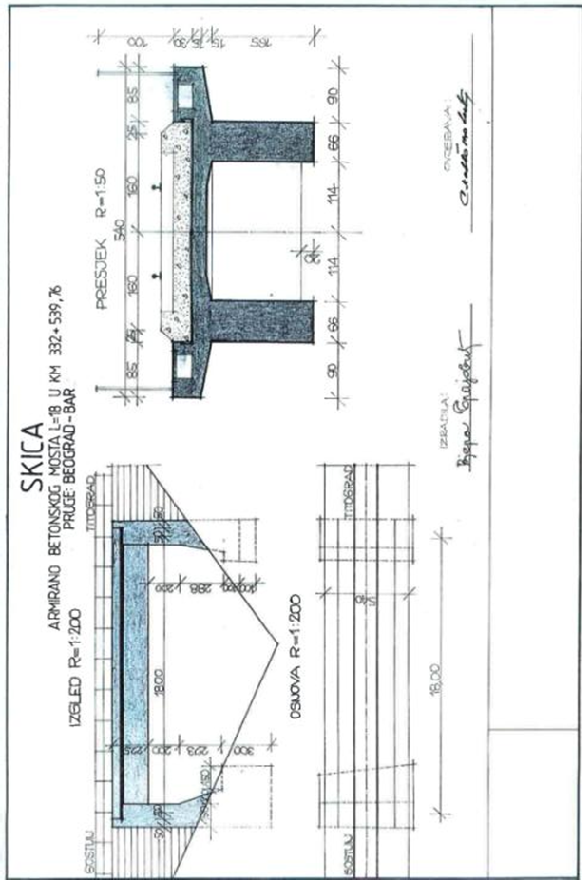
|  |  |
| --- | --- |
| PURCHASER: | The European Investment Bank |
| BENEFICIARY: | Railway Infrastructure of Montenegro - AD Podgorica |
| OBJECT: | BRIDGE no. 41 at km 332+539,76 |
| PROJECT: | THE MAIN PROJECT OF BRIDGE REHABILITATION  NO.41 AT KM 332+539,76 |
| SECTION: | Vrbnica - Bar |
| STATIONING: | 332+539,76 |
| PROJECT PHASE: | The main project |
| NAME AND PROJECT PART LABEL: | BOOK 2.1 - THE CONSTRUCTION PROJECT  Bridge no. 41 at km 332+539,76 |
| PROJECT ORGANISATION RESPONSIBLE FOR BRIDGE CONSTRUCTION PROJECT DEVELOPMENT: | Cestra Ltd Belgrade  Makenzijeva 57, 11000 Belgrade |

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

The bridge in question bridges a narrow, shallow and dry obstacle. The bridge is in direction, and the railway tracks are in a circular curve R=400m. The tracks are in longitudinal slope towards Vrbnica, and it is equal to 1.61%.

## Attachment 1 – 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 existing state

The bridge span structure is a simply supported beam system. The bridge span is 18.0m. The width of the bridge is 540cm. In cross-section sense, the span structure consists of two girders interconnected by the bridge deck. The main girders are 66cm wide and 200cm high. They are formed at the mutual axial distance of 294cm. They are connected by a bridge deck which is 25cm thick, formed with a double-sided slope of 2%. Above the abutments and at the quarters of the span there are cross girders. The cross girders are 40cm thick. The leaning of the bridge deck construction on the abutments is solved at the S1 abutment through direct leaning onto the bearing beam. It is assumed that the span construction is connected with the bearing beam with round steel bar anchors. At the S2 abutment, the leaning of the span construction is solved through the use of pendulums. The bridge deck construction is made of reinforced concrete with rebar type Č 37.

The following table presents the characteristics of the materials of the existing structural elements.



|  |  |  |
| --- | --- | --- |
|  | | |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

The abutments are made of lightly reinforced concrete and are variable in cross-section in height. The S1 abutment is 250 to 150cm thick, and the abutment S2 is 200 to 150 cm thick. The width of both abutments is 540cm. There are no wing walls on the abutments. Alongside the abutments there are rings of retaining walls which are separate constructions. The bearing beam and the parapet of the abutment are made from reinforced concrete. The abutments are placed on plain concrete foundations, of cascadingly varying thickness. The foundation engineering was performed on a layer of limestone, in accordance with the Original project.



The dilatation of the bridge deck construction was done with a copper “omega” tin covered with bitumen. The width of the dilatation is 3cm.

On the bridge deck, there is a waterproofing layer with a concrete protection layer which is 5cm thick.

The drainage is solved by the double-sided slope of the bridge deck. On the both sided of the bridge, near the main girders, there are five vertical drains.

The bridge railing is made of metal tubes of circular cross-section which is at places corroded and deformed.

At both sides of the bridge deck construction, there are 70cm wide footways with integrated installation channels. The installation channel covers are prefabricated.

There are no niches (pedestrian shelters) nor the electrified pillars consoles on the bridge.

Alongside both abutments there are retaining walls which secure the stability of the embankment. The rehabilitation engineer had insight into the original construction design with all the introduced changes.

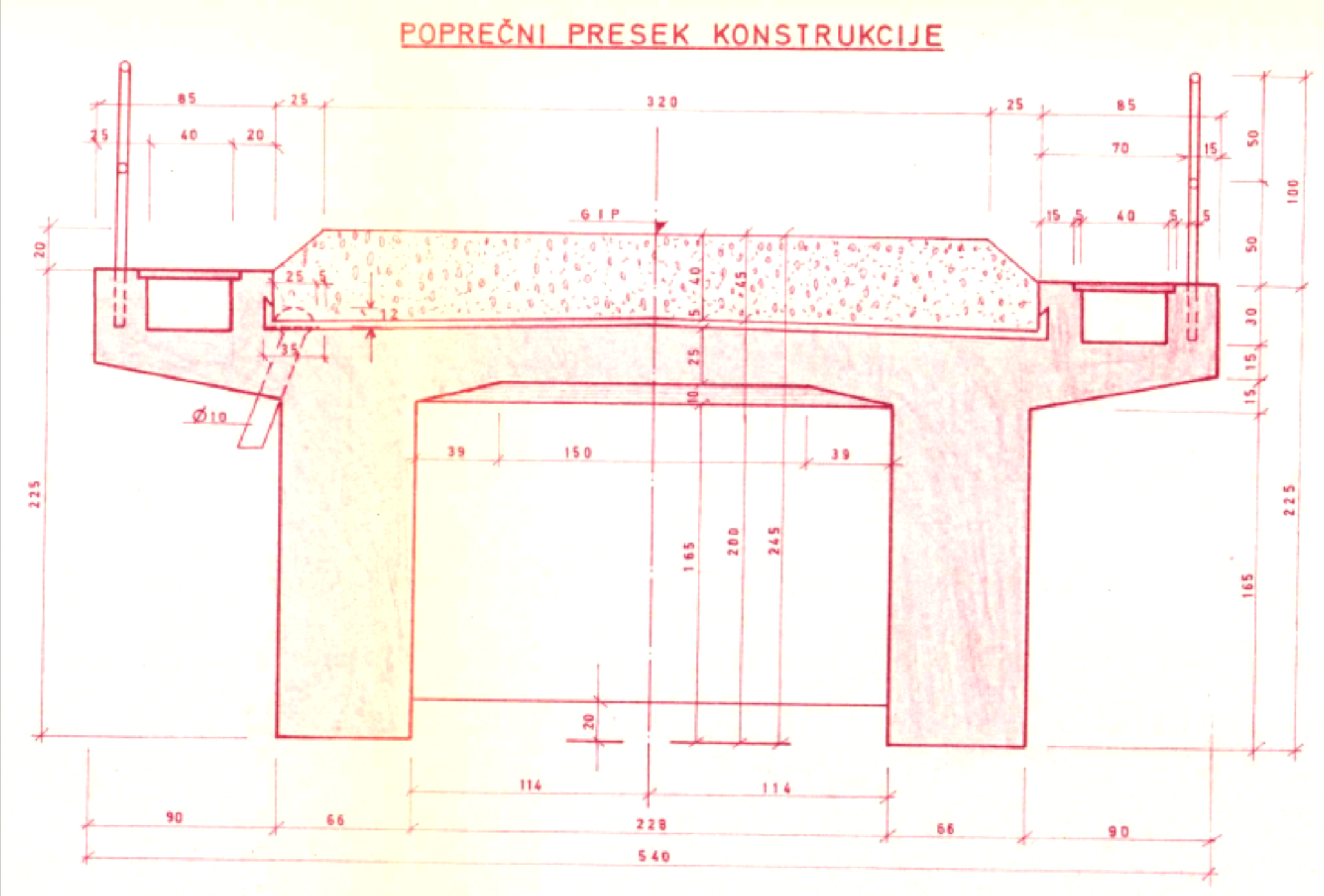
By testing the hardness of concrete with the "Schmidt" hammer, it has been established that the existing concrete has characteristics which are the same or better than the projected ones. In order to be cautious, the design engineer will use the characteristics of the materials from the original project in the calculations and analyses.

According to the opinion of an expert electrical technician:

On the bridge in question, in the concrete channel, on the left 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

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. 332+539,76 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*

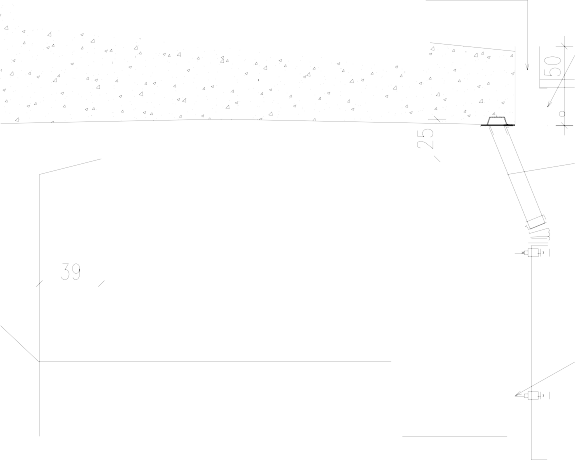
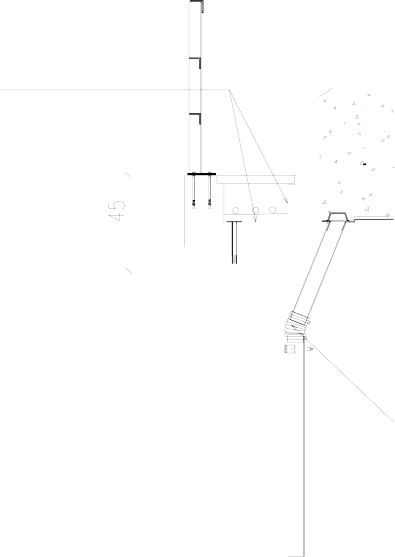
Uklanjanje postojeće i postavljanje nove pješačke ograde/

Removal of existing and installation of pedestrian fence

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

Uklanjanje postojeće i postavljanje

nove pješačke ograde/ Removal of existing and installation



of pedestrian fence

Uklanjaju se šine, pragovi, tucanički zastor, zaštitni sloj i hidroizolacija. /

Rails, sleepers, ballast,

osa mosta bridge axis

Novi parapet/

New parapet

replacement with sprayed insulation

protective layer and insulation are to be removed.

Ugradnja prskane hidroizolacije

Installation of sprayed insulation

Zamjena poklopaca/ Caps replacement

Novi parapet/ New parapet

Ugradnja prskane hidroizolacije

Installation of sprayed insulation

Zamjena poklopaca/ Caps replacement

Ugradnja cjevčica za odvodnjavanje

kanala za instalacije/

Installation of pipes for installation

channel drainage

oslonac cijevi pipe support

kanalizaciona cijev GRP DN110

sewer GRP DN110

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.

dilataciona spojnica od EPDM-a DA 110/110 za spoj slivnika DA 110 i vertikalnog ogranka DA110, spojnica je fiksirana obujmicama od nerđajućeg čelika

expansion joint of EPDM-a DA 110/110 for gully joint DA 110 and vertical branch DA110, joint is fixed with clips of

stainless steel

Ugradnja cjevčica za odvodnjavanje kanala za instalacije/

Installation of pipes for installation channel drainage

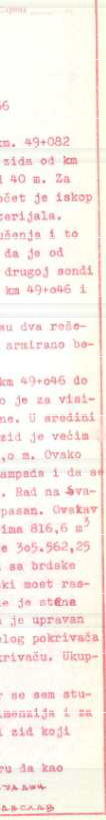
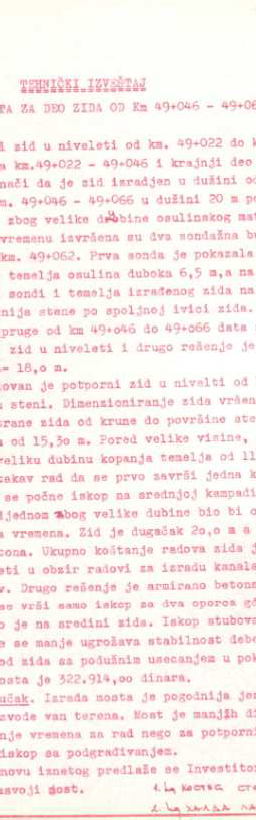
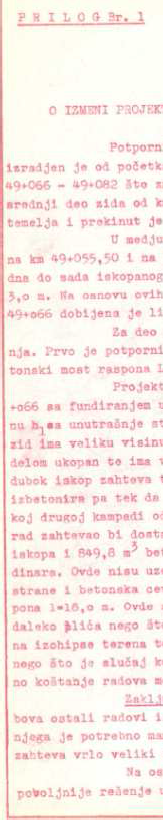
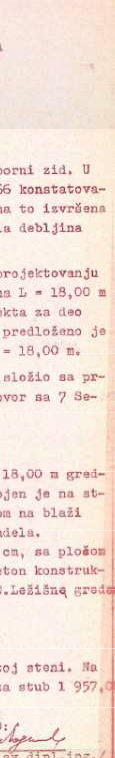
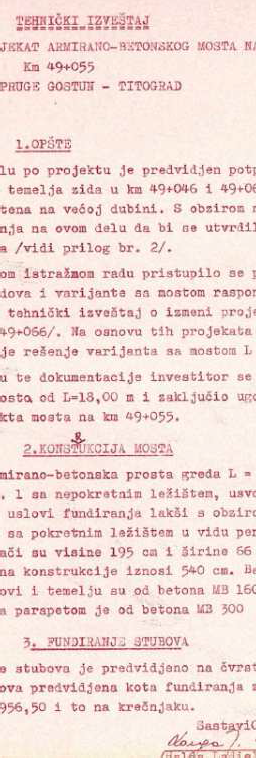
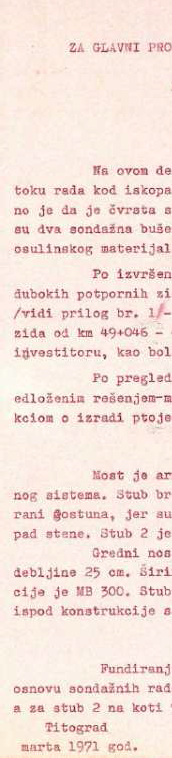
oslonac cijevi pipe support

kanalizaciona cijev GRP DN110 sewer GRP DN110

*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 1971)



## 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 332+539,76, 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: Bridge at km *332+539,76* 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 324+983,98 the railway line Vrbnica – Bar” from 2014.*

General observation about the state of the bridge:

1. 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:

* all dimensions of the bridge are in compliance with the dimensions from the "Report about the current state of bridges on the Vrbnica-Bar railway line",
* after removing the track ballast and measuring of all necessary dimensions, thickness of the RC slab was determined indirectly and it was found to be 30 cm (in the middle of the slab with a protective coating and waterproofing).

1. Railway track on the bridge is straight continuous welded rail (CWR) and in a good condition. After removing the track ballast in the sleeper zone, thickness of the track ballast below the lower edge of sleeper was found to be 30 cm.
2. Damages that could reduce the capacity and stability of the bridge structure were not found during the detailed visual inspection of the bridge.
3. The observed damages and deficiencies of the structure which negatively affect the durability and functionality of the structure are the following:

* the left main girder and the pier S2 pendulum are partially showered with solid material of different structure, whereby they reduce and prevent the functioning of main girder,
* lack of a protective concrete layer and parts of the concrete of the lower zone of both main girders and the occurrence of exposed and corroded reinforcement,
* concrete degradation of upper surface and side face of sidewalk fasciae.

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

* to carry out removal of accumulated solid material (rocks, concrete parts, crushed stone, wood...) and form natural terrain profile underneath the bridge,
* concrete rehabilitation of main girders lower zone,
* rehabilitation of concrete segregation of main and cross girders,
* concrete rehabilitation of sidewalk fasciae upper surface.

#### NOTE:

* **Alongside the aforementioned measures, 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 rail fences for the pedestrian path.**
* **Also, it is necessary to secure the creation of shoring construction during the works which should secure the construction works zone. The shoring construction will be created according to the project of the contractor.**
* **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

Dismantling the existing expansion joints, processing the concrete surfaces and installing new 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 and creating sprayed waterproofing.

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

Sandblasting the concrete and the reinforcement, repairing concrete surfaces with repair mortar and protective concrete overcoats. New sidewalks are not planner for this bridge, only the rehabilitation of the existing ones, as no signs of catchment were seen on the pedestrian path consoles.

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

The removal of the existing guardrail fences 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, careful demolition of the existing parapet while keeping the existing reinforcement, the importation of the concrete and the installation of the concrete of the parapet and dismantling the shoring construction,
    2. creating the formwork, drilling holes in the concrete, installing anchors and grouting with eksmal, installing the 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 **Tč** **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 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) longitudinally for the full length, 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 bridge does not have middle piers.

#### Span construction

There are no works on the strengthening the span construction.

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.

#### 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 area around the bridge is partially covered with overgrowth, and partially covered with slope debris. It is necessary to clean up the bridge area. Upon carrying out the works, it is necessary to secure the whole span area of the bridge with shoring according to the Contractor’s project.

Aside from that, it is necessary to clean out the supporting area, especially the area around the abutment S2, where there is significant slope debris in the pendel area, and the functioning of the pendel is disabled.

## 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 49+056 of the Gostun - Titograd railway line (done by the Institute of Engineering in Belgrade of AYR, 1971)
* Report on the condition of the bridge: The bridge at km 332+539,76 of the Vrbnica– Bar railway line (done by Pro-Inženjering, 2015)
* Geotechnical survey
* Geodetic survey
* Expert opinion on the works on the railway tracks
* The impact of the works on the environment
* Occupational safety report
* Report on the traffic organization during the execution of works

## 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. 41 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. 41 covers the section which is 38,00m 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. 41, 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 construction are in a curve (R=400 L=110), and on the part of the circular curve. The tracks are the LRT (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 on the bridge.

The total value of the works on the superstructure for the bridge no. 41 amounts to 27.679,31 €.

* + 1. **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 movement of the rails;
    - dismantling the existing railway tracks in segments of up to 22,50m in length, with the removal of the tracks, where cutting the existing tracks should be performed alongside drilling the rails for the joints, including possible dismantling of the joint kit and sleepers depending on the technology of the track removal;
    - the removal of the existing road bed, up to the protective layer of waterproofing;
    - installing the railway tracks 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;
    - 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;
    - welding the tracks into the LRT;
    - installing the devices against the longitudinal displacement of the railway tracks on the bridge, which are installed to lock the LRT in front of and behind the bridge;
    - installing the devices against the lateral displacement of the railway tracks on the bridge;
    - 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 of reinforced concrete, with girder cross-sectional design and with static system of simply supported beam with the span L=18,00m. The construction consists of two main bearing girders, the road bed with the consoles, the cross girders over the abutments and at the quarters of the bridge. An immovable bearing is at the abutment S1 (towards Vrbnica), while at the abutment S2 (towards Bar) there is a construction placed against an AB pendel. The construction is in direction. The abutments are at an insignificant height above the ground level, with short wing walls further on. The railway tracks on the bridge construction are in a curve (R=400 L=110), and on a part of a circular curve. The tracks are LRT.

Having in mind the regulations from the Rulebook on the maintenance of the railway tracks superstructure (“Official Gazette of Montenegro, no. 42/2016“ published on 11/7/2016), as well as the valid EN standards and the UIC Announcements, and in addition to the stance that there is no relative displacement between the bridge and the LRT (“*Study of various methods adopted by world railways to continue LWR over bridges*“) the calculations and analyses are done for the temperatural change impacts on the rails without any impact of the bridges on the rail (just like on open tracks, that is, as if the tracks were practically observed 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 equals q= **99,99N/cm<106 N/cm** for which it is necessary to incorporate anti-lateral displacement devices on each 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 traffic, additional compaction of the road surface prism should be carried out.
3. The railway tracks (on and off the bridge) must be in the direction and in the level before the welding, as well as completely regulated according to the elements of the existing state.
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. Before locking the LRT, 74 units of derailer devices are to be installed at 50m in front of and behind the bridge, and they should be dismantled after the final welding.
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 derailer devices against the lateral displacement of the tracks on every third sleeper, in the following manner: 22 pieces of derailer devices against the lateral displacement from km 332+520,76 to km 332+558,76 in curve (R=400 and L=110). It is important to mention here that outside of the bridge section, there should be a check of the installed devices against the lateral displacement of the rails on every third sleeper, in the following manner: 23 pieces of derailer device against the lateral displacement of the rails in front of the bridge (from km 332+480,76 to km 332+520,76 in curve R=400 and L=110), and 23 pieces of derailer devices against the lateral movement of the rails behind the bridge on every third sleeper (from km 332+558,76 to km 332+598,76 in curve R=400 and L=110).

The aforementioned existing devices against the lateral displacement of the tracks are not included in the Estimated Bill of Quantities.

1. 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 on 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. 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).