**2. TEXTUAL DOCUMENTATION**

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**2.1. Technical description – the bridge construction**

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### General data on the object

|  |  |
| --- | --- |
| EMPLOYER: | European Investment Bank |
| BENEFICIARY: | Željeznička infrastruktura Crne Gore AD Podgorica |
| STRUCTURE: | Bridge no. 28 at km 323+076.82 |
| PROJECT: | MAIN DESIGN FOR REHABILITATION OF BRIDGE no. 28 at km 323+076.82 |
| SECTION: | Vrbnica – Bar |
| CHAINAGE: | 323+076.82 |
| PROJECT STAGE: | Main design |
| NAME AND DESIGNATION OF PROJECT SECTION: | VOLUME 2.1 – STRUCTURAL DESIGN  Bridge no. 28 at km 323+076.82 |
| PROJECT ORGANIZATION RESPONSIBLE FOR DRAFTING BRIDGE STRUCTURAL DESIGN: | Cestra d.o.o. Beograd  Makenzijeva 57, 11118 Beograd |

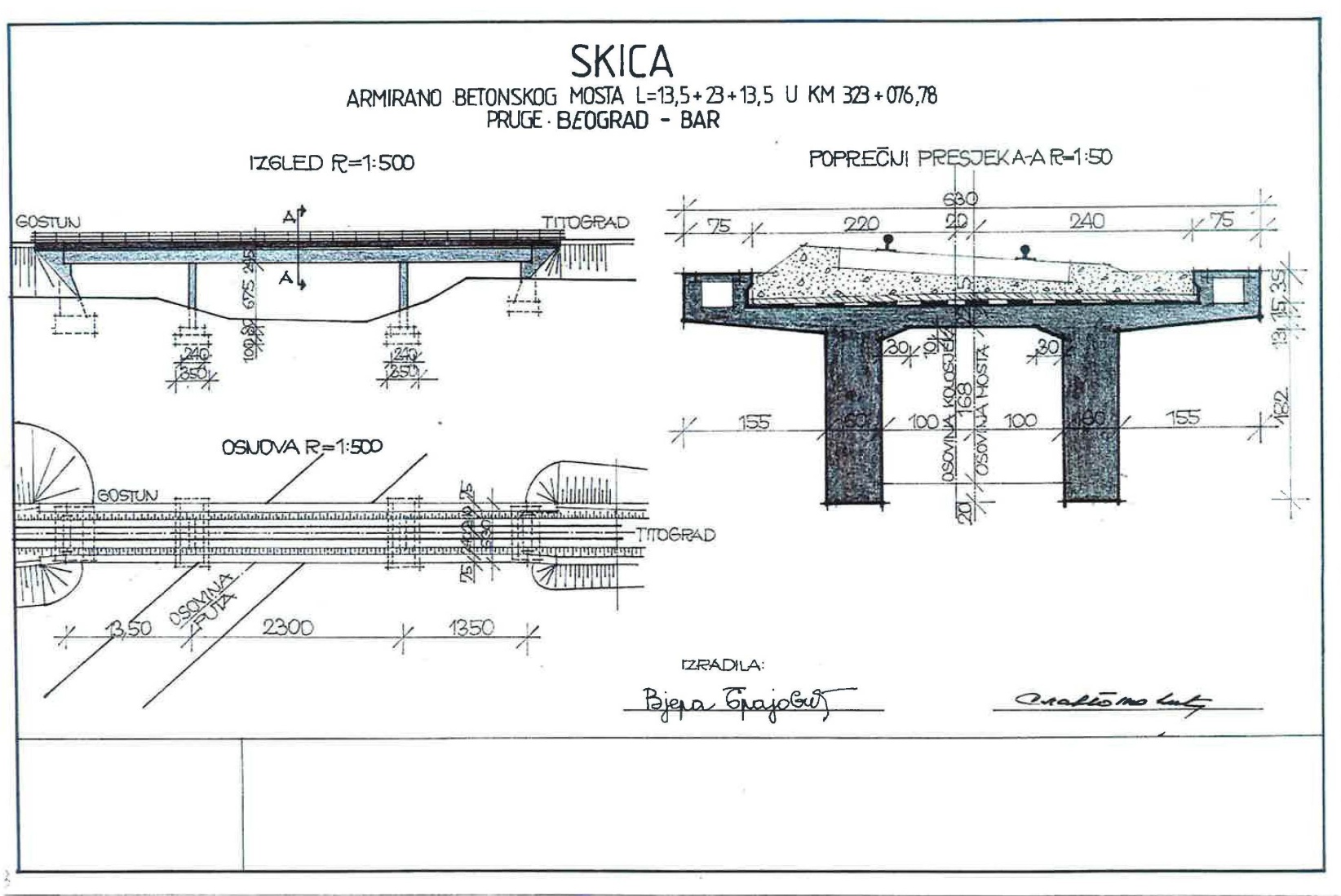
### Location and route description

The bridge is a continuous structure with 3 spans L=13.50+23.00+13.50 m which, in its intermediate span, extends over the Bijelo Polje-Kolašin trunk road at an angle. The bridge structure is located in the tame part of the Tara river valley.

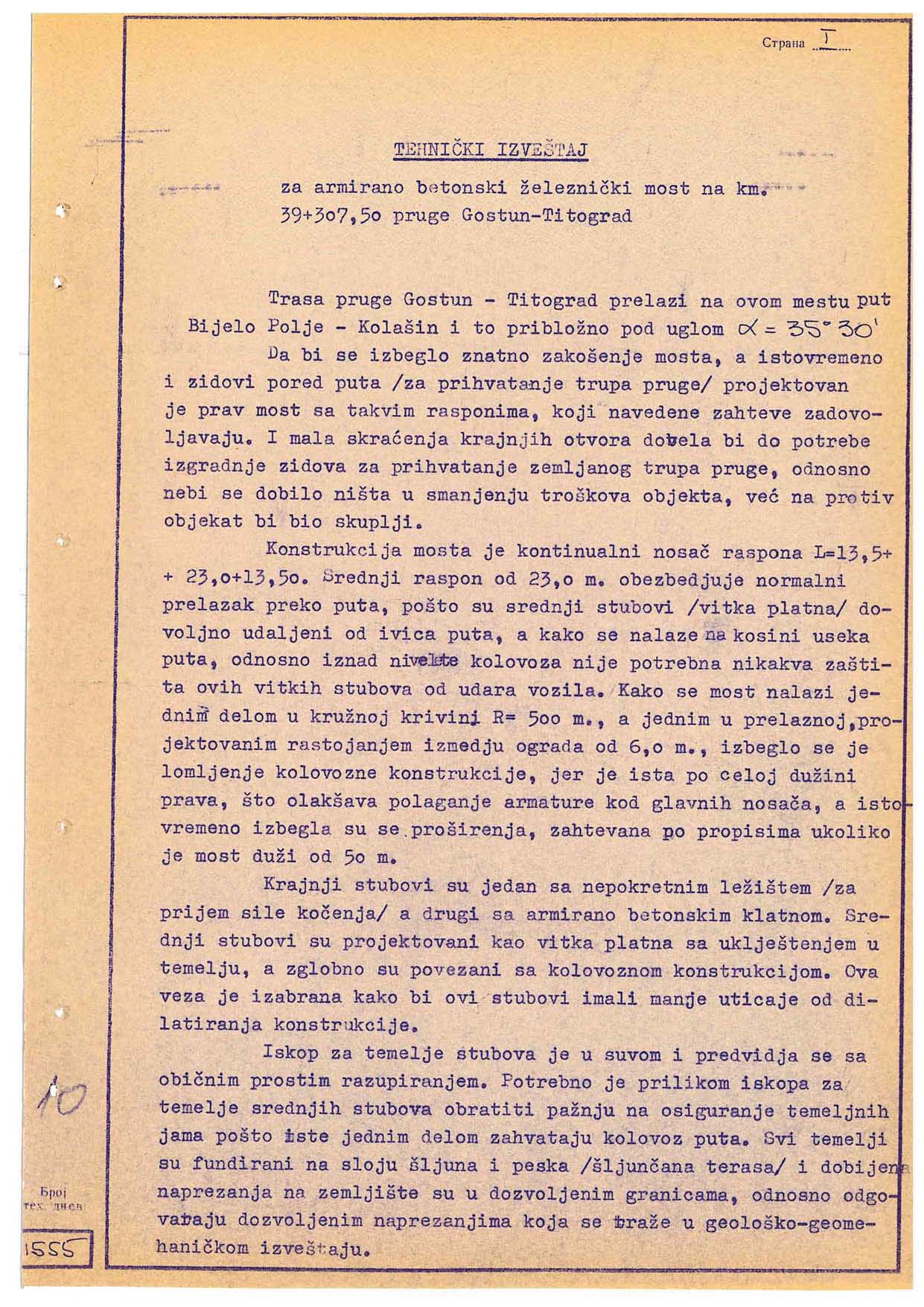
The track is located partially in a circular curve and partially in a transitional curve with the internal rails by the right main girder, while rails are welded as CWR.

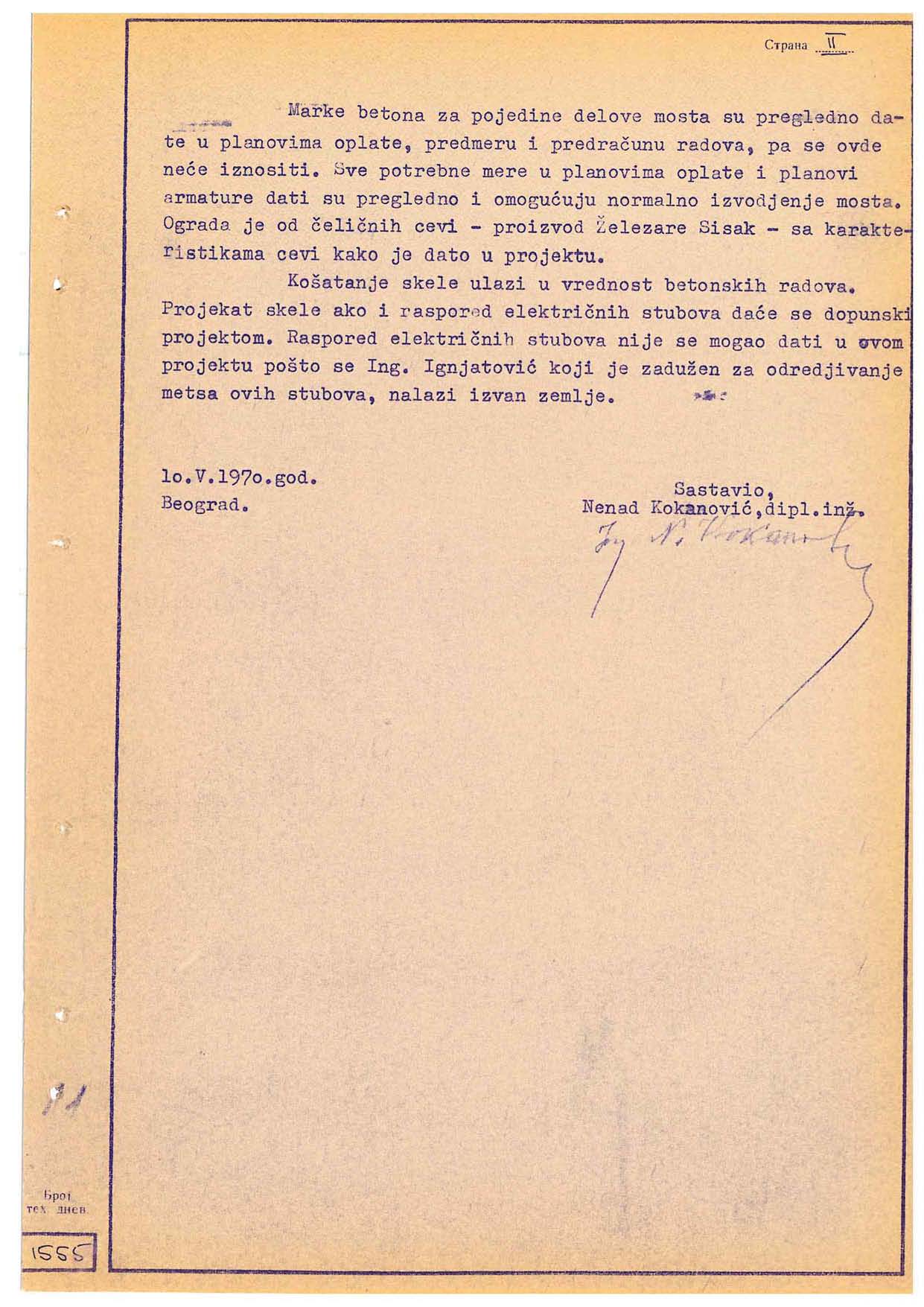
In the structure area there is sufficient space for construction site capacities.

### Attachment 1 – The abstract from the Report on the existing bridges on the Vrbnica – Bar railway line



### Attachment 2 – Technical Report from the original design





### Attachment 3 – Assessment of bridge condition with proposed measures (Bridge inspection report from 2015)

Taken from „*The report on the state of the bridge: the bridge at km 323+076,82 the railway line Vrbnica – Bar” from 2015.*

## General observation about the state of the bridge:

Measuring of the dimensions of the structural elements and comparing with the dimensions given in layout sketches from "Report about the current state of bridges on the Vrbnica-Bar railway line" it was observed:

* 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 23 cm (in the middle of the slab with a protective coating and waterproofing).

Railway track on the bridge is in 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 37 cm (on the inner side of the curve).

Damages that could reduce the capacity and stability of the bridge structure were not found during the detailed visual inspection of the bridge. However, poor condition of left sidewalk fascia and connections of sidewalk railing jeopardizes the safety of traffic beneath the bridge as well as safety of ZICG staff on the bridge.

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

* total degradation of concrete of the left sidewalk fascia with exposed and corroded reinforcement,
* total degradation of sidewalk railing connections to the left sidewalk fascia – connections doesn’t exists and railing tends to fall down,
* the absence of concrete protective layer to the reinforcement of right main girder in span S2-S3 which results in exposed and corroded reinforcement,
* blocked RC pendulum (and proper movement of construction at the same time) on pier S4 due to deposits of gravel,track ballast and earth,
* lack of drainage of the installation channels.

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

* rehabilitation of concrete of left sidewalk fascia as well as rehabilitation of sidewalk railing connections,
* rehabilitation of concrete and reinforcement in the lower zone of right main girder in span S2-S3,
* provide drainage of the installation channels,
* cleaning the zone of RC pendulum on pier S4 due to proper movements of construction.

Urgent measures on the bridge construction:

In accordance to the safety of traffic beneath the bridge as well as the safety of ZICG staff on the bridge it is urgent to do rehabilitation of left sidewalk cantilever fascia as well as rehabilitation of sidewalk railing connections on that side.

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

A detailed summary of damage with possible causes was given in the previous project stage:

*˝Report on bridge condition: bridge at km 323+076.82 on Vrbnica – Bar railway line˝ from 2015 prepared by Pro-Inženjering d.o.o. in Belgrade*

A graphic representation of damage observed on bridge inspection is given in graphic documents of the design file in the drawing – Photograph of damage.

Based on the "Report on bridge condition: bridge at km 323+076.82 on Vrbnica – Bar railway line˝ from 2015, the scope of damage was analysed alongside the methods for its rehabilitation. Scope of works and investment value were based on an inspection performed in 2015.

### Description of bridge structure – current condition

The bridge is a continuous structure with 3 spans L=13.50+23.00+13.50 m which, in its intermediate span, extends over the Bijelo Polje-Kolašin trunk road at an angle.

The cross-section consists of main reinforced-concrete (RC) beam girders, which, together with the RC bridge deck 20 cm thick, form a T-section measuring 60x210cm. The bridge deck is haunched and supported against main and cross girders which are placed in terminal fields at one-third of a span, while they are at one-fifth of a span in the middle field. In the area of piers S2 and S3 the cross-section includes the bottom RC slab with variable thickness of 15-25cm, which, together with main girders and the bridge deck forms a box girder. Cross girders in field are 35 cm thick, while over piers they follow the thickness of the actual piers of 60cm. Terminal cross girders are executed with the size of 50x210 cm in the cross-section.

The bridge structure is supported against piers S1, S2 and S3 over a steel slab, whereas on abutment S4, it is supported against RC pendulum. The S1 abutment receives horizontal impacts, piers S2 and S3 are connected to main girders with joints, while forces are transferred on abutment S4 via RC pendulums.

Piers are executed as RC canvases 60 cm thick and the respective height of 671 and 709 cm. In the external cross-sections the piers with a constant width of 320cm were executed. Piers were funded on RC footings which were executed as cascades measuring 80x240 cm and 100x350 cm in the cross-section.

Abutments were made of plain concrete as massive piers with variable thickness. RC sleeper beams were placed on piers measuring 90x150cm in the cross-section. Abutments were funded on footings made of plain concrete measuring 125x300cm in the cross-section.

The track on the bridge is located partially in a circular curve and partially in a transitional curve with the internal rails by the right main girder, while rails are welded as CWR.

From the upper side of the bridge deck damp-proofing was placed with a concrete cover. The track drainage was resolved by means of gullies on both sides of the bridge structure. The gullies were placed in the middle of the cantilever belonging to the footpath at regular spacing. In the S2-S3 span below the gully, there is a horizontal gutter placed to prevent the running of water onto the road. The horizontal gutter on the left is in good condition while the one on the right is damaged.

The handrail on the footpath on the bridge structure was made of metal pipes with a welded circular cross-section. The handrail is 1100 mm high.

The following cables were laid on the bridge structure in the left concrete duct:

- main railway STKA cable

- optic cable G625 144V 6x24 - 9/125 in PE pipe Ø 40 + a spare PE pipe Ø 40

- power cable for video surveillance PNK 4x16 Al.

There is no drainage in the cable ducts.

The poles for the overhead contact line are located at spans S1-S2 and S3-S4 on the left of the bridge structure. In the places where overhead contact line poles are connected to the bridge structure there are RC cantilevers.

For the reinforced concrete elements the round concrete steel of Č0200V (240/360Mpa) grade was used

Concrete grade used in structural elements:

Main girders - MB300 - which corresponds to concrete grade C25/30 according to EN 1992-1-1

Abutments - MB160 - which corresponds to concrete grade C12/15 according to EN 1992-1-1

Sleeper beams - MB220 - which corresponds to concrete grade C16/20 according to EN 1992-1-1

Abutment footings - MB160 - which corresponds to concrete grade C12/15 according to EN 1992-1-1

Piers - MB160 - which corresponds to concrete grade C30/37 according to EN 1992-1-1

Pendulums - MB400 - which corresponds to concrete grade C30/37 according to EN 1992-1-1

Pier foundation - MB300 - which corresponds to concrete grade C25/30 according to EN 1992-1-1

Pier foundation - lower part - MB160 - which corresponds to concrete grade C12/15 according to EN 1992-1-1

Wing walls - MB220 - which corresponds to concrete grade C16/20 according to EN 1992-1-1

### Static calculation – summary

### Rehabilitation works

It is necessary to perform the following rehabilitation works on the bridge:

* controlled demolition of concrete in footpaths (while keeping the present reinforcement) and dismantling of existing handrail,
* dismantling and removal of present expansion joints,
* controlled demolition of concrete in RC bridge deck, the parapet, walls of the cable ducts and the parapet in the crushed stone ballast bed in order to install new expansion joints,
* replacing the present damp-proofing on the entire bridge,
* installation of new waterproof expansion joints on both abutments,
* placement of new gullies,
* repairing cornices,
* placement of new handrails on footpaths,
* repairing cable ducts,
* placement of cable duct lids made of corrugated sheet metal in places where expansion joints are put,
* strengthening of abutment S4,
* placement of shock absorbers for the absorption of seismic force on abutment S4,
* repair works on concrete surfaces and anti-corrosive measures on reinforcement in places where concrete surfaces are damages,
* production of drip caps in the cantilevers of overhead contact line poles,
* replacement of damaged anchor bolts connecting the overhead line pole and the RC cantilever,
* unblocking and clearing the area around pendulums,
* cleaning concrete deposits, straw and other waste on the inside of box girders,
* applying protective concrete coating on all visible concrete surfaces after preparing the concrete surface using abrasive methods.

**NOTE:**

When placing shock absorbers for the absorption of the seismic force on abutment S4, the Contractor shall make a standard shock absorber connection with the structure (using a frontal slab and anchors bolts - defined by the Manufacturer) minding the existing reinforcement in the structural element to which it is connected. In addition, when placing shock absorbers the Contractor should take into account the temperature and act in all things according to Manufacturer's instructions.

**2.1.10. Technology of work execution**

REHABILITATION WORKS EXECUTED ON THE TRACK OR IMMEDIATELY BY THE TRACK

Given that each structure has different conditions for the transport of personnel, equipment, machinery and materials, the following principles were adopted:

1. The construction site is erected in the area of the structure in case:

* there is an asphalt road or a good macadam road;
* there is free space for construction site capacities.

1. The construction site is erected in the area of the nearest railway station and in that case the following applies:

* transport of personnel and material to the bridge is carried out using railway rolling stock during the whole time of works as per established procedures and possible time slots;
* make sure to provide a building for the security personnel, a building for workers' accommodation and the tool warehouse at the bridge location.

**The following was adopted for bridge no. 28:**

* the trunk road goes under the bridge, clearance height Hs = 4.6 m
* it is possible to form a construction site at the bridge location,
* it is possible to transport personnel, equipment, machinery and materials to the bridge using the asphalt road.

1. **General**

Here is a detailed description of the technology for the items of rehabilitation works executed on the track or immediately by the track. Other items of works are executed independently of railway traffic and are not in the high voltage area.

The items of works for which the execution technology is described in detail are the following:

1. **Placement of new damp-proofing under ballast prism**

Removal of the cover layer (fine-grained concrete) and removal of existing damp-proofing, sand blasting the concrete surface, applying repair mortar, producing new sprayed damp-proofing with a cover made of prefabricated sheets of extruded polystyrene.

1. **Placement of new gullies**

Disassembly of existing gullies, treatment of the area with repair mortar, application of damp-proofing and installation of new gullies.

1. **Placement of new bridge expansions**

Disassembly of existing expansions, treatment of concrete surfaces, fitting new expansions

1. **Repairing cable ducts**

Removing the existing cable duct lids along the entire bridge length, removing sand from the ducts, local displacement of SS and TT cables, sandblasting concrete surfaces, applying repair mortar, fitting tubes for water infiltration, producing the sloping layer and sand blasting the damp-proofing layer.

1. **Repairing cantilever cornices on footpaths**

Machine removal of the top and lateral surface of concrete cornice, sandblasting the concrete and rebar, producing new section of the cornice with a drip cap.

1. **Placement of new handrail on footpaths**

Removal of existing handrail on footpaths, the placement of new handrail on previously repaired cornices.

It is essential to make new damp-proofing and new expansions in a high-quality manner so as to eliminate harmful effects of water on the structure long term. Placement of damp-proofing and the repair mortar coating must be done adhering to temperature requirements, humidity and hardening times. It is also important to avoid frequent resumption of works when damp-proofing as much as possible.

The above-mentioned items of works are executed under special railway traffic management schemes as follows:

1. **item 1** is executed under traffic closure and voltage shutdown in the maximum period of time;
2. **items 2 and 3** are executed under “railway closure for construction works” scheme in day-time slots (e.g. 1130 to 1630) with or without power shutdown;
3. **items 4, 5 and 6** are executed under low-speed traffic scheme (30 km/h) without power shutdown.

Works defined under items 2 through 6 may be executed under railway traffic scheme a) or b) if this does not interfere with the works defined under item 1 in the Description of works.

1. **Track works (the bridge and the bridge area)**

For the execution of works under items 1, 2 and 3, it is necessary to remove the rails, sleepers and crushed stone ballast all the way to the damp-proofing layer.

Here is the description of items of track works that need to be executed.

1. Works to be executed before traffic closure:

* assembly and disassembly of rail anchors in the track area after abutments;
* assembly and disassembly of sleeper anchors in the track area after abutments;
* cutting rails in the embankment at 10m from abutments and at every 22.5m on the bridge with rail drilling and fitting of rail connectors

1. Works executed under traffic closure and power shutdown

* track disassembly (rails, check rails, sleepers, ballast prism) of one 15m span;
* assembling the track using existing rails, the new crushed stone ballast, new wooden sleepers and new rail fasteners.

1. Works executed after construction works in the track area

* welding rails as CWR, placement of check rails;
* regulating the track by direction and the level line according to current condition elements.

1. **Strengthening works on abutment S4**

Abutment strengthening works entail the extension on the spot made of concrete grade C25/30 (foundation strengthening with concrete grade C16/20). Before the works in this item are executed, it is necessary to prepare concrete surfaces, mark and drill holes, place anchors and reinforcement adhering in all things to the details given in graphic documents and the relevant items in Technical Specifications.

1. **Placement of shock absorbers for the absorption of seismic force on abutment S4**

Shock absorbers for the absorption of seismic force with the bearing capacity of 500 kN each and the possibility of displacement due to temperature effects: ±50mm are placed only on abutment S4 - the placement of 2 pieces in all things according to the layout given in graphic documents. The measurements of shock absorbers, connection plates, the diameter of anchors and depth of anchoring should be adopted in all things corresponding of the bearing capacity and expansion capacity given in the table of the selected manufacturer (not provided in graphic documents). The item includes preparing concrete surfaces, marking and drilling holes, anchor placement and the fitting of connection plates.

1. **Conclusion**
2. The prerequisite for quality execution of damp-proofing works, gullies and expansion joints is to adhere to installation requirements and work carefully without any unreasonable demands to shorten the time required for such works.
3. With good preparation and good management of work train traffic, sufficient number of pieces of construction machinery and experienced and qualified workforce, it is possible to repair damp-proofing on the deck at 15m of the bridge under one-day continuous closure (24h) and go to low-speed traffic afterwards.

This applies to the Vrbnica-Podgorica railway section for the period May-September and the Podgorica-Bar section for the period April-October.

1. The Contractor shall, as per design recommendations and his technical and technological capacities determine which periods of railway closures are necessary and submit a timely request to ŽICG for railway closures longer than those approved on a daily basis.
2. To the extent possible, traffic closures should be employed simultaneously on two or more bridges which are at the same inter-station distance.
3. In bridges with spans over 15m, repeated use of long closures is necessary, although it is acceptable to employ such closures with breaks in between closures that are not longer than 2 days.

### 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 design - Main design of RC bridge at km 39+307,50 of railway line Gostun - Titograd (developed by Institute for designing ZJŽ Belgrade, 1970.);
* Geological study about investigation works for the viaduct at km 39+320,17 of railway line Gostun - Titograd (developed by Institute for designing ZJŽ Belgrade, 1965.);
* Bridge condition report: Bridge in km. 323+076,82 of railway line Vrbnica - Bar (developed by Pro-inženjering, 2015.);
* Geotechnical elaborate (2018.);
* Geodetic survey (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

**2.2. Technical description – the superstructure**

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### General

Within the Main Design for the rehabilitation of bridge no. 28 works on the track superstructure are planned, which are to serve as bridge rehabilitation. Technical documents for bridge no. 28 analysed a track section 70m long, which includes the entire bridge length and 10m before and after the bridge.

Based on the Conclusion of the Inspection Report on the condition of bridge 28 superstructure and establishing the current condition in the drafting period of the relevant technical documents, works to be done on the bridge track superstructure were defined. The track on the bridge has regular geometry in the curve (R=500m L=70m), partially in a transition curve and partially in a circular one, welded as CWR. The track has both check rails.

Measures were adopted to be taken on the bridge track superstructure with the drafting of Priced BoQ, Technical Specifications, Superstructure Static Calculation with the calculation of bridge-track interactions, with schedules no. 1-13 (Listings) and a graphic schedule – Calculation model of bridge-track interactions with the results for summer and winter temperatures (axial forces in the rail in summer and winter and the displacement diagram for summer and winter) and the Solution on bridge track development with the graphic schedule – Plan for track development on the bridge.

Total value of superstructure works for bridge no. 28 is €55,250.81.

### Measures on the superstructure

For the execution of rehabilitation works (placing new damp-proofing under the ballast prism, installation of new gullies and expansion joints) the following works on the superstructure were planned, where the bridge length and the length on the embankment of 10 m from abutments, before and after the bridge are taken into account:

* arresting CWR before and after the bridge with the installation of rail anchors;
* disassembly of the existing track and disassembly of check rails in segments up to 22.5m accompanied by the removal of the track and check rails, whereby it is necessary to cut the existing track and drill rails for the connections at the joint, any disassembly of fasteners and sleepers as per track technology used for the removal of the track and check rails;
* removal of current crushed stone ballast all the way to the damp-proofing protective layer;
* installation of the track and check rails in segments up to 22.5m with new crushed stone, new sleepers and new fasteners, with the fitting of tie plates for running rails with a trimmed shorter point by 4 mm at length as per Plan for track development on the bridge with a fitting of connectors and the necessary fasteners for joining running rails and check rails;
* regulating the track by direction and the level line according to current condition elements;
* disassembly of rail joints on running rails before welding;
* welding the track as CWR;
* installation of rail anchors and devices against lateral track movement in the track area before and after abutments, in line with present condition regarding the number and the position of devices;
* installation of devices against lateral track movement as per this Design, or the Plan for track development;
* final track regulation.

Bridge superstructure works for bridge rehabilitation, particularly the disassembly and the assembly of the existing track, are executed under traffic closure while low-speed traffic scheme should be employed on the bridge section during rehabilitation works.

### Structural design – summary

The basic elements of the superstructure used in the calculation of track stresses and stability are as follows:

- 49 E1 rails, grade R260 (900A)

- wooden sleepers L=260cm, at axial spacing of 60cm

- "K"-type fasteners.

The bridge is a continuous structure with 3 spans L=13.50+23.00+13.50=50.00 m which, in its intermediate span, extends over the Bijelo Polje-Kolašin trunk road at an angle. The cross-section is formed of main RC beam girders and a haunched RC bridge deck also supported against RC girders (both in supports and spans). In the area of piers S2 and S3 the cross-section comprises a lower RC slab thus forming a box girder. The bridge structure is supported against piers S1, S2 and S3 via a steel slab and an RC pendulum against the abutment S4. The S1 abutment receives horizontal impacts, piers S2 and S3 are connected to main girders with joints, while forces are transferred to pier S4 via RC pendulums. The track on the bridge has regular geometry in the curve (R=500m L=70m), partially in a transition curve and partially in a circular one, welded as CWR. The track has both check rails.

With characteristics of all rods in the calculation model known, the calculation of stress resulting from temperature changes in summer and winter conditions was made. The calculation was made using STAAD software. The obtained results are in line with the starting assumptions of model operation. All results are given in chapter 3.2 Superstructure static calculation, based on which the Plan for track development was made.

***Characteristic results***

The greatest normal forces in CWR occur in the area of a movable bearing (bar 52) and have the following values:

**in summertime Ns = 633.78 kN**

**in wintertime Nw = -819.13kN**

b) The reactions of fixed bearings on the bridge are as follows:

**in summertime: R47 =73.38kN,**

**in wintertime: R47 =-149.35 kN.**

(they refer to pier halves).

c) The inspection of track stability against buckling in the curve with a radius R=500m on the bridge in extreme summer temperatures employing the Mischenko energy model was made.

Calculation results are shown in chapter 3.2.3 Checking track stability and bearing capacity, where values of critical lateral resistances of q= 97.22Ncm<106N/cm were obtained, for which it is necessary to install sleeper anchors at every third sleeper.

d) Inspection of crack size on rail cracking in winter was made on the location of highest tensile strength. The following displacement values were obtained for disrupted rail sections:u24 = -2.85cm; u26 = 2.02 cm.

On rail cracking, the crack size shall be 2.85+2.02=4.87<10cm, i.e. traffic safety shall not be at risk in case of rail cracking.

e) The stress check in rail foot was done for stress UIC - 71 scheme 49 E1 rails, grade R260 (900A) and the speed of 80 km/h. The obtained stress was of 13.01 kN/cm2. When the stress resulting from the highest axial temperature force and residual stress obtained from rail steel rolling is added to this, the total rail stress is as follows:

σ = 11.92+13.01+6=30.93 kN/cm2< 46kN/cm2

meaning there is enough safety to withstand all other, secondary effects that have not been considered in the calculation.

### The solution for the arrangement of the railway tracks

Based on the performed analysis and the obtained calculation results, the track should be developed in the following way meeting the following requirements:

1. The substructure before and after the bridge must be completely and properly executed (cross-section, drainage, stabilization)
2. Crushed stone ballast before, after and on the bridge must be uncontaminated, having the recommended quality and grain size distribution, with a ballast prism intended for CWR. On sections where rail anchors are placed, additional tamping of ballast prism should be performed.
3. Before welding, the track (on the bridge and outside the bridge) must be completely regulated by direction and the level line as per the elements of the current condition.
4. The calculation was made under the condition that both the railway line and the track on the bridge are welded as CWR.
5. The required temperature for CWR tempering is +230C ± 30C.
6. 74 pieces of rail anchors are fitted on about 50m of the track before and after the bridge starting from the last sleeper in the ballast before (or the first one after) the bridge.
7. In order to reduce the impact of CWR on bridge piers, longitudinal resistances were reduced in the length of 12m (at 1/4 of total bridge span) from movable support S4 to fixed support S1, as per Plan for track development. On the ground this reduction in resistances is achieved by fitting trimmed tie plates (by trimming a shorter point by 4 mm) at the distance of 12m (20 sleepers) from S4 to S1.
8. Based on performed checks of track stability against buckling in the curve with the radius R=500m, the arrangement of sleeper anchors on the bridge was obtained:

* Sleeper anchors are placed at every third sleeper (a total of 39 pieces). The devices are fitted on sleeper fronts from the inside of the curve as per Plan for track development.

In the curve before and after the bridge (before abutment S1 and after abutment S4) on the open track sleeper anchors are fitted at every third sleeper in all details as per Plan for track development. The existing devices against lateral track movement mentioned above are not included in the Priced BoQ.

1. Permanent labels for monitoring CWR longitudinal and transversal displacement (in the bridge area) should be put in the following places:

- at the first sleeper after the bridge

- at the first sleeper before the bridge.

Labels are buried on both sides of the track on stable soil.

Labels are placed before completing CWR formation, and are calibrated immediately after CWR tempering in the presence of the Supervisor.

Chainage labels can be used as permanent labels for CWR monitoring, provided they are in the immediate vicinity (within 3 m) of the places where labels are placed. Permanent labels are not included in the Priced Bill of Quantities.

1. As check rails, the exiting rails already laid on the bridge shall be used, which are interconnected at its end with an oak key, whereby the new fasteners are installed on the sleeper connection with the running rails and check rails, which connection is made at each sleeper, in addition to new fasteners for bridge ends and new additional fasteners for check rail joints.
2. All the necessary track maintenance works should be done on time, in a quality manner and within the allowed temperature ranges. It is also necessary to ensure enhanced supervision on the section at extreme rail temperatures (below -10°C and over +35°C ).