**2. TEXTUAL DOCUMENTATION**

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

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### General data on the object

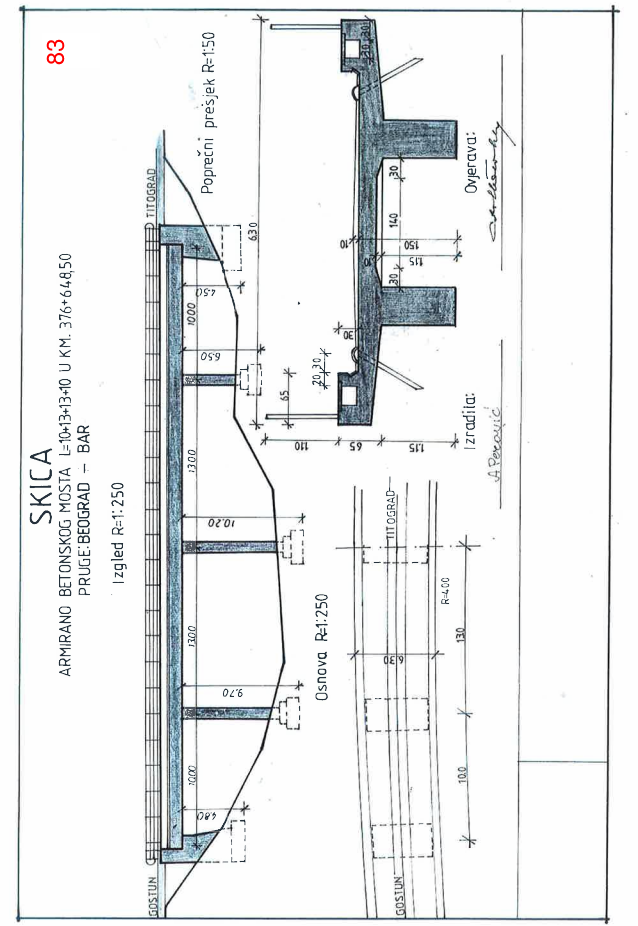
|  |  |
| --- | --- |
| EMPLOYER: | European Investment Bank |
| BENEFICIARY: | Željeznička infrastruktura Crne Gore AD Podgorica |
| STRUCTURE: | BRIDGE no. 83, at km 376+648.50 |
| PROJECT: | MAIN DESIGN FOR REHABILITATION OF BRIDGE  at km. 376+648.50 |
| SECTION: | Vrbnica - Bar |
| CHAINAGE: | 376+648.50 |
| PROJECT STAGE: | Main design |
| NAME AND DESIGNATION OF PROJECT SECTION: | VOLUME II – STRUCTURAL DESIGN  Bridge no.83, at km 376+648.50 |
| PROJECT ORGANIZATION RESPONSIBLE FOR DRAFTING BRIDGE STRUCTURAL DESIGN: | Cestra d.o.o. Beograd  Makenzijeva 1a, Beograd 11118 |

### Description of route location and alignment

The bridge is located at chainage km.376+648.50 on the Vrbnica-Bar railway line. Bridge is a continuous beam structure with four spans of 10.0+2x13.0+10.0m, i.e. of total length L=46.0m. The bridge extends over a dry ravine, while the terrain is naturally sloped from left to right.

The track on the bridge is in a transition curve L=90m with R=400m. The bridge structure is polygonal so that the track axis fails to coincide with the bridge axis. The level line is lowered 23.70‰ towards Podgorica. The track structure is that of CWR.

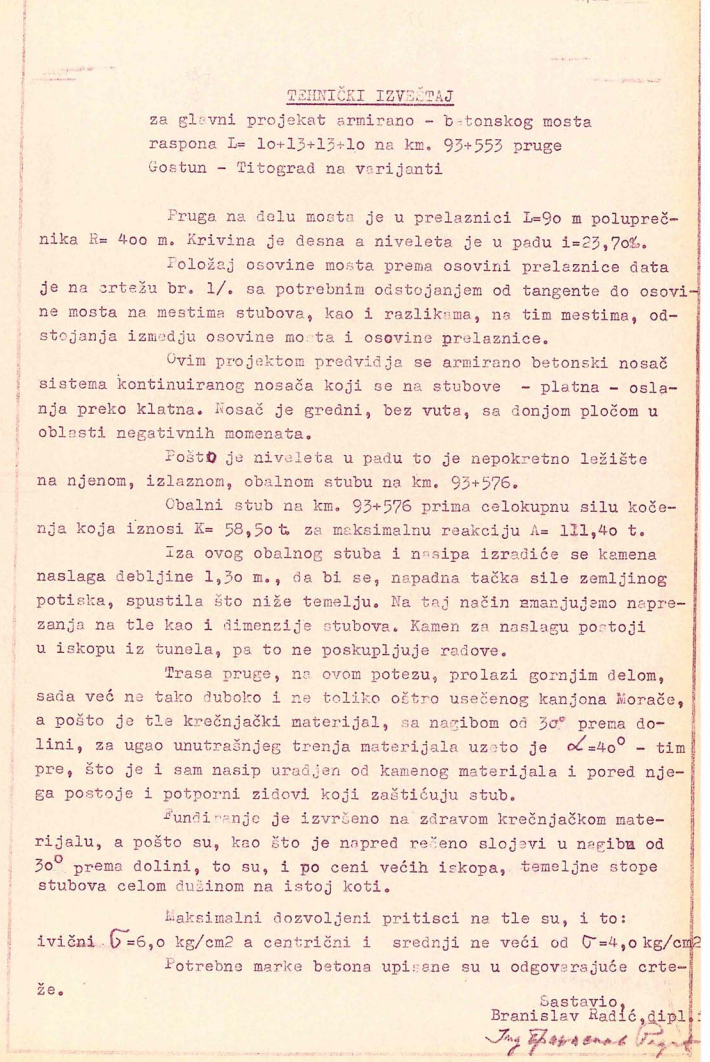
### Attachment 1 – Bridge layout plan from the ŽICG archives



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

The main structural design was done by the Association of Yugoslav Railways, Designing Institute, Belgrade, 1971.

The main design dates back to 1971



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

Taken from „*The report on the state of the bridge: the bridge at km* *376+648,50 the railway line Vrbnica – Bar” from 2015.*

General observation about the state of the bridge:

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

* the general bridge dimensions are in comply with the dimensions from the "Report about the current state of bridges on the Vrbnica-Bar railway line",while the certain differences in dimensions as well as missing dimensions are shown in appendix of this Report,
* 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 25 cm (in the middle of the slab with a protective coating and waterproofing and with presumed both sided incline of the slab of 2%).

Railway track on the bridge is in a transition curve and carried out in continuous welded rail (CWR). Sleepers are with different age, some with cracks and in the bad condition, and there are no safety rails on the bridge. Track ballast on the bridge is unclean. It’s necessary to change all worn-out and cracked sleepers and to installed safety rail on the inner side of the curve. After removing the track ballast in the sleeper zone, thickness of the track ballast below the lower edge of sleeper was found to be 27 cm.

Damages that could reduce the capacity and stability of the bridge structure were found during the detailed visual inspection of the bridge. RC deck slab in box type section in spans S1-S2 (in the zone of pier S2) and S3-S4 (in the zone of piers S3 and S4) is in very poor condition. Water penetrations through RC deck slab, concrete degradation of slab lower zone and deeply corroded reinforcement with decreasing cross-section. Also, main girders in the abutment S5 support zone (stationary support) are in poor condition (concrete degradation with a deep corroded reinforcement).

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

* due to damaged waterproofing, which is out of order water leaks through the RC deck slab, sidewalk cantilevers as well as the connection of main girders with RC slab and sidewalk cantilevers. In all areas of water leakings concrete is degraded with exposed and deeply corroded reinforcement,
* thin concrete protective layer with exposed reinforcement of RC deck slab lower zone
* concrete degradation of main girders lower zone at locations of measuring tapes installation as well as poor concrete zones of main girders between box type section
* concrete degradation with exposed and corroded reinforcement of main girders support zone at abutment S5 as well as in the support zone of the left main girder at abutment S1
* thin concrete protective layer with exposed and corroded reinforcement (stirrups) of main girders lower zone
* on the lot of places, there are discontinuities in the zones of connection between main girders and slab or sidewalk cantilevers without water penetration in those zones,
* lack of waterproof expansion causing a uncontrolled water from the track to superstructure and abutments
* concrete degradation of OCL cantilevers lower zone which compromises the quality of the connection of OCL columns. Also concrete bads under OCL columns are not made on both consoles and anchor bolts for the connection are short for embedded two nuts.
* lack of drainage of the installation channels
* prefabricated covers of the channels for installations are sporadically damaged
* lack of many sidewalk railing elements as well as sporadic interruptions of handrails and railing deformation by mechanical impact in two localities.

## 

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

* replace damaged waterproofing and rehabilitate all damaged bridge structure elements that suffered from water activities.
* rehabilitate the tapes installation locations, as well as main girders lower zones,
* rehabilitate concrete of main girders support zones,
* carry out protection of main girders lower zone exposed reinforcement,
* injected all discontinuities in the zones of connection between main girders and RC slab and sidewalk cantilevers and carry out an analysis of project documentation, and if it is possible determine the cause of the occurrence,
* installation of the watertight expansion joints at abutments S1 and S5,
* rehabilitate concrete in the lower zones of all OCL cantilevers, also perform grouting in the upper zone of cantilevers in places of reliance of OCL columns
* construct installation channels drainage system,
* replace damaged and degraded installation channel prefabricated covers,
* installation of missing sidewalk railing elements, repair interruptions of handrails as well as correcting geometry of railing in places of mechanical impact.

Urgent measures on the bridge construction:

Rehabilitation of RC slab in spans S1-S2 (at pier S2) and S3-S4 (at piers S3 and S4) on the part of box type section. Also, rehabilitation of main girders in the support zone on the pier S5 (stationary support).

### 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 376+648.50, on Vrbnica – Bar railway line˝ from 2015, which was 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 of bridge condition: bridge at km 376+648.50 98 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 structure is a system of continuous beams on four spans of L=10+2×13.0+10.0=46.0m and is situated in the vicinity of Podgorica. The bridge extends over a dry ravine, while the terrain is sloped. The track on the bridge is in a transition curve L=90.0m with the radius R=400m. The bridge structure is polygonal so that the track axis fails to coincide with the bridge axis. The track was produced as a CWR. The total width of the bridge is 6.30m, with 80 cm wide footpaths on each side of the bridge

The bridge structure comprises two reinforced concrete beams with a T-section fixed at intermediate supports with a lower slab forming a box section. Longitudinal girders are axially distanced by 2.60m from one another. The total height of girders is 1.50m, and the slab is 25 cm thick in the middle. The bridge deck is haunched on the underside and designed in a dual slope of 2%. Cantilevers of footpaths are 1.55 m and are haunched with maximum thickness of 30 cm. Longitudinal girder webs are constant, their width being 60cm. The thickness of the lower box plate ranges from 15-20cm in intermediate supports.

Girders are connected with cross members designed and in the thirds of the spans. Intermediate cross girders are 30 cm thick, whereas the end and intermediate supports are 50 cm thick. In terms of static, the structure is a continuous beam supported on the movable supports on the piers S1-S4, while on the pier S5 there is a fixed support. Movable supports are designed in the form of pendulums.

Girders, bridge deck and cross girders were made using the MB 300 concrete grade. Pendulums on piers S1-S4 were made of MB400 concrete. Piers were made of MB 300, whereas abutments and foundation pillows were made of MB 220. Temeljne stope were designed using MB 160.

Rebar was made of Č-37 steel grade.

Piers S2, S3 and S4 have a square cross-section measuring b×d=3.60×0.7m. Abutments basis measure b×d=2.70×4.5m – pier S1 and b×d=3.0×5.0m – pier S5. Foundations were to be done on a limestone mass.

Structure layout

Longitudinal section



Structure base



##### Current condition:

The track on the bridge is located in a transition curve and was produced as a CWR. The track axis in the transition curve deviates from the bridge axis. The track is a closed one with a crushed stone ballast on the bridge deck. Damp-proofing was placed on the upper deck with a concrete cover of 5 cm.

At the ends of the bridge deck, there are footpaths 80 cm wide. There are cable ducts on footpaths covered with prefabricated RC covers that form the footpath floor. Drainage on structure is handled using a slope of the bridge deck and gullies installed on both sides as part of footpaths. The handrail on the bridge structure was made with welded pipe sections. The handrail is 1100mm high.

RC cantilevers are planned for the overhead line poles.

existing cross-section



***Newly designed condition:***

The rehabilitation design provides for damp-proofing replacement on the bridge deck, reconstruction of the drainage system and reconstruction of footpaths.

Due to damp-proofing replacement, removal of crushed stone and the the existing damp-proofing cover, traffic closure is planned in the course of such works. Before damp-proofing placement, and if necessary, the bridge deck should be fixed using repair mortar. The new damp-proofing is a spray-type waterproofing.

The existing gullies shall be replaced by new ones. Gullies will be extended up to the bottom edge of the girder and are supported against girder webs in all aspects as per details given in Graphic Documents and the scale with Drainage Design.

Footpaths shall be reconstructed by adding prefabricated cornices, replacing the existing prefabricated slabs with new ones and repairing inner surfaces of the cable ducts. Damp-proofing and duct filling in the footpath is also planned. The filling for the footpath shall be made of sand placed in two layers with cable ducts. New footpath details are given in Graphic documents. The exiting drainage outlets in cable ducts on footpaths shall be closed and new drain tubes installed as per new layout in all things according to the details given in Graphic documents.

The newly designed condition plans for the strenghtening of the pier S4 and abutment S5, for the replacement of the pendulum on S4 with new bearings and for the widening of the footings of piers S2-S5 due to their poor bearing capacities.

In addition, the footpath handrail and expansions joints should also be replaced.

newly designed cross-section



***Superficial damage repair***

Superficial damage repair on outer girder surfaces in the form of crack repair by injection and repair of damaged covers. Following superficial damage repair works, it is necessary to protect all the outer girder surfaces with protective coatings.

The planned intervention areas for superficial damage repair are shown in Graphic documents.

***Interventions on the bridge during exploitation***

According to the existing documents obtained from ŽICG, we established that no changes occurred in the course of bridge exploitation.

### Static calculation – summary

### Tehnology of work execution and rehabilitation works

The construction site provides:

* storage space for the tools and equipment;
* storage space for the material;
* enclosed and secured space for combustible materials and fuels;
* office space for the Contractor and the Engineer;
* compounds for the workers;
* area for the machines;
* other.

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 formed 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 formed 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;
* providing 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 M83:

* there is no access road to the bridge;
* central construction site should be formed at Bratonožići junction at km 379+100;
* transport of personnel, equipment, machinery and material from Bratonožići junction to the bridge is carried out using railway rolling stock;

1. Superstructure

The items of works for which technology of execution is described in detail are as follows:

* 1. Placement of new damp-proofing under the track prism

Removal of a cover (fine-grained concrete) and removal of existing damp-proofing, sandblasting of concrete surfacing, applying repair mortar, producing new spray 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, applying damp-proofing and installation of new gullies.

* 1. Placement of new bridge expansion joints

Disassembly of existing expansions, treatment of concrete surfaces, fitting new expansion joints.

* 1. Repairing cable ducts

Removing sand from the ducts, local dislocation of SS and TT cables, sandblasting of concrete surfaces, applying repair mortar, installation of drain tubes and applying spray damp-proofing.

* 1. Repair of cornices on footpaths

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

* 1. Placement of new handrail on footpaths

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

It is essential execute new damp-proofing, new expansion joints and new gullies in a high-quality manner so as to eliminate harmful effect of water on the structure long term. Placement of damp-proofing and the repair mortar coating must be done adhering to the temperature, 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. items 1 and 2 in bridges with gullies at the structure axis are executed under traffic closure and voltage shut-down for a maximum period of time;
2. items 2 and 3 are executed under “railway closure for construction works” scheme in the 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) in the track length as per dynamic plan.
* 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. Works on bearings replacement

Works on pier S4

* installing the auxiliary steel structure, i.e. temporary steel supports for the presses - bearing capacity of min 200t and temporary NAL bearings;
* disassembling the existing pendulum after the structure has been placed onto temporary supports;
* drilling the anchors into the existing pier and laying newly designed dressed stones in cement;
* placing new NAL bearings into their designed place;
* undercasting;
* diassembling and removing of the auxiliary steel structure and temporary supports.

The stated works shall be executed under special railway traffic scheme.

1. Concrete pier strenghtening works

* Mechanical or manual excavation in cascades with shoring, from the existing ground level to the level necessary for the planned reinforcement of piers S4 and S5 and the widening of the footing on piers S2-S4 and the abutment S5;
* Removal of damaged and unbound parts of concrete surfaces of the piers;
* Marking the layout of the holes for the installation of the vertical and horizontal reinforcement for the bonding of the old and the new concrete and the widening of the footing;
* Drilling holes which are 80(100)cm deep, with diameter of ∅22mm at an angle of 15° from the horizontal axis for the installation of the reinforcement for the widening of the footings;
* Drilling holes which are 100(80)cm deep, with diameter of ∅26(22)mm at an angle of 15° from the verical axis for the installation of the vertical reinforcement for the piers S4 and S6;
* Drilling holes which are 80cm deep, with diameter of ∅22(18)mm at an angle of 15° from the horizontal axis for the installation of the horizontal reinforcement for the piers S4 and S5;
* Cleaning and degreasing prepared concrete surfaces;
* The production of SN primer coating for the bonding of the old and the new concrete;
* The installation of horizontal anchors ∅16mm for the widening of the footings and watering them with expansion plaster;
* The installation of vertical anchors ∅20(16)mm and watering them with expansion plaster for the reinforcement of piers S4 and S5;
* The installation of horizontal anchors ∅16(12)mm for the reinforcement of piers S4 and S5 and watering them with expansion plaster;
* The installation of the horizontal and vertical reinforcement for reinforced piers alongside welding with the existing reinforcement, wherever applicable;
* Making a layer of concrete C25/30 of the necessary thickness;
* Making protective bituminous coatings for the protection of concrete surfaces located below the ground level;
* Making a protective cement-based coating to protect concrete surfaces above the terrain level;
* Backfilling the reinforced parts of the piers.

The above mentioned works are executed in dry conditions.

1. Repair works on concrete pier surfaces

Repair works on concrete pier surfaces including crack injection works:

* Identifying and marking cracks larger or equal to 0.2mm;
* Cleaning the marked concrete surfaces;
* Sealing cracks with appropriate epoxy gel;
* Injecting cracks with epoxy resin;
* Cleaning the treated concrete surfaces;
* All works are performed in line with the relevant Technical Specifications.

Repair works on concrete pier surfaces with cover degradation:

* Identifying and marking the surfaces to be repaired;
* Removing damaged and unbound parts of concrete pier surfaces;
* Cleaning the exposed and corroded reinforcement;
* Cleaning and degreasing the prepared concrete surfaces;
* Applying repair mortar;
* Treating repaired surfaces so that they are aligned with the surface of the existing concrete;
* Curing repair mortars/concretes;
* All works are performed in line with the relevant Technical Specifications.

The preparation of protective cement-based coating for the protection of concrete surfaces (vertical pier surfaces, bearing beams, pendulums, wing walls) in line with Technical Specifications.

The above mentioned works are executed in dry conditions.

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 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.
4. The Contractor shall, as per design recommendations and his technical and technological capacities determine which period of railway closures are necessary and submit a timely request to ŽICG for railway closures longer than the approved single-day closures.
5. To the extent possible, traffic closures should be employed simultaneously on two or more bridges which are at the same inter-station distance.
6. 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:

* Original design - Main design of viaduct at km 93+553 of railway line Gostun - Titograd (developed by Institute for designing ZJŽ Belgrade, 1971.)
* Bridge condition report: Bridge in km. 376+648.50 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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**2.2.1 GENERAL**

Within the Main Design for the rehabilitation of the bridge no. 83, works on the track superstructure in the function of bridge rehabilitation were planned. Technical documents for the bridge no. 83 deal with track section 66.00m long, which includes the total bridge length and 10.00m before and after the bridge.

Based on the Conclusion of the Inspection Report on the bridge no. 83 superstructure condition, 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 railway tracks on the bridge are geometrically correct, in a transition curve (R=400 and L=90), and are welded as CWR. There are no 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. 1-3 (Listings) and 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 the bridge no. 83 is 55,525.31€.

**2.2.2 REQUIRED MEASURES AND SEQUENCE OF WORKS ON SUPERSTRUCTURE WHEN**

**EXECUTING BRIDGE REHABILITATION WORKS**

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 in segments up to 22.5m with the track removal whereby it is necessary to cut the existing track and drill rails for the connections at the joint, perform any disassembly of fasteners and sleepers as per technology of track and check rail removal;
* removal of the current crushed stone ballast all the way to the damp-proofing protective layer;
* installation of the track and new check rails both on the inside and the outside of the curve, in segments up to 22.50m 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 as per elements of current condition;
* disassembly of rail joints on running rails before welding;
* welding the track as CWR;
* installation of rail anchors in the track area before and after abutments, in accordance with the existing number and position of rail anchors;
* installation of devices against lateral track movement on the bridge and after the bridge in accordance with this design, that is, in line with the Plan for track development
* final track regulation.

Bridge superstructure works on 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.

**2.2.3 STATIC CALCULATION - 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 CR bridge structure is a system of continuous beams on four spans of L=10.0+2x13.0+10.0=46.00m. The bridge extends over a dry ravine, while the terrain is naturally sloped from left to right. The cross section of the spanning structure consists of two main RC girders with a bridge deck between them and cantilevered overhangs on both sides; there is a bottom RC slab which, together with the main girders and the bridge deck forms a box section. Cross girders are on piers, as well as in the thirds of the span. Abutments have parallel wings and piers are RC canvases. There is a fixed support on the pier S5, and the rest of the piers are supported on movable supports (pendulums). The bridge structure is in a straight line. The railway tracks on the bridge are geometrically correct, in a transition curve (R=400 and L=90), and are welded as CWR.

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***

a) The greatest normal forces in CWR occur in the area of a bearing (bar 45) and have the following values:

**in summertime Ns = 636.98kN**

**in wintertime Nw = -797.90kN**

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

**in summertime: R51 =-69.04kN,**

**in wintertime: R51 =105.21kN.**

(they refer to pier halves).

c) The inspection of track stability against buckling in the curve with a radius R=6=400m on the bridge in extreme summer temperatures employing the Mischenko energy model was made.

Calculation results are shown in chapter 3.2.3 Controlling track stability and bearing capacity, where values of critical lateral resistances of qkr=105.87Ncm<106N/cm were obtained, for which it is necessary to install sleeper anchors on every third sleeper

d) Inspection of crack size on rail cracking in winter was made on the location of highest tensile strength (bar 45). The following displacement values were obtained for disrupted rail sections: u10 = -1.25cm; u12 = 2.63 cm.

On rail cracking, the crack size shall be 1.25+2.63=3.88<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 12.67 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+12.67+6=30.59 kN/cm2< 46kN/cm2

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

**2.2.4 TRACK DEVELOPMENT**

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 appropriately executed (cross-section, drainage, stabilization)
2. Crushed stone ballast before, after and on the bridge must be uncontaminated, having the adequate 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 at 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 decrease the impact of CWR on bridge piers, longitudinal resistance at the length of 12m (on ¼ of the entire bridge span) from the movable support S1 to fixed support S5 was decreased, as per Track development plan. On the field, this decrease in the resistance is achieved by fitting shortened tie plates (cutting the shorter point of the plate by 4mm) at 12 m (20 sleepers) from S1 to S5.
8. Based on performed checks of track stability against buckling in the curve with the radius R=400 it is necessary to install devices against lateral track movement on the bridge as follows:

* on every third sleeper (a total of 37 devices), as per Track development plan. Devices are to be installed on to sleeper heads on the inside of the curve.

Devices against lateral track movement are installed on every third sleeper in the curve before the bridge, and also on every third sleeper after the bridge, all in line with the Plan for track development. This means that there are 11 devices before the bridge (from km 376+595.70 to km 376+615.50) and another 23 devices after the bridge (from km 376+681.50 to km 376+721.50). The before mentioned existing devices against lateral track movement are not included in the Priced Bill of Quantities.

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 at 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. New check rails shall be installed and interconnected 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).