Review paper
UDC 625.11:656.222.4.01
DOI: 10.7251/afts.2018.1018.009D
COBISS.RS-ID 7322648

RESEARCH METHODOLOGY OF RAILWAY ROUTE DOBOJ – ZENICA, SECTION km 103+500 – MAGLAJ

Đurić Neđo[1], Stevović Svetlana[2], Đurić Dijana[2], Perišić Milan[1]

[1]*Technical institute Bijeljina, Bijeljina, Bosnia & Herzegovina, e. mail: nedjo@tehnicki-institut.com*
[2]*Innovation Centre, Faculty of Mechanical Engineering in Belgrade, Serbia*
[2] *Faculty of Civil Engineering, Subotica, University of Novi Sad, Serbia*

ABSTRACT

Researched section of the railway route presents a part of the route from Sarajevo to Doboj, built with two tracks. First track was built in 1947, and the second in 1978. In construction methods are present differences, considering the time when it was constructed and the way of construction. Both tracks were used for years for movement of trains of various purposes and speeds up to 100 km/hour. Over time, the railroad worsened, especially at the beginning of the nineteenth century, when the train speed was reduced on some sections to less than 40 km/hour. Revitalization of the railway was done by sections with the task to prepare it for train speed of 120 km/hour.

Evaluation of railway route situation is given based on surveys carried out in the field and laboratory tests of taken samples. The route was researched rigorously in its corridor, since it has a movement restriction on its wider area. Regular train lines were maintained which slowed investigations and some research works could not have been applied. Therefore, were applied researches that were possible to realize in high quality.

Key words: *railway tracks, embankment, slopes*

INTRODUCTION

Route of researched railway section is located on the corridor that connects Adriatic sea with northern and western Europe. Earlier was capable for speeds that correspond to European standards, and today is far beyond that. Given that this is a significant corridor, it was approached to its revitalization per sections, with the task of meeting conditions of train movement up to 120 km / hour.

Researched section is on the route Zenica – Doboj, length 5,9 km, which has two tracks, left and right. Railway along the entire route is electrified, traffic was conducted regularly, and terrain along the route is largely impervious. All this dictated type, scope and also dynamics of works Researches possible to realize were applied, and that gave sufficient data to extract characteristic sections by the degree of their stability.

Research area, ie section of the railway chainage km 103+500 – Maglaj is located on the north part of Bosnia and Herzegovina in the area of Maglaj, figure 1. Railway is laid in the valley of the river Bosna, formed by river cutting of impermeable rocks of diabase - chert formation. It represents an important part of the railway corridor V, which consists of the existing railway, length 661 km, with general direction Budampest –Sarajevo – Adriatic Sea, figure 1.

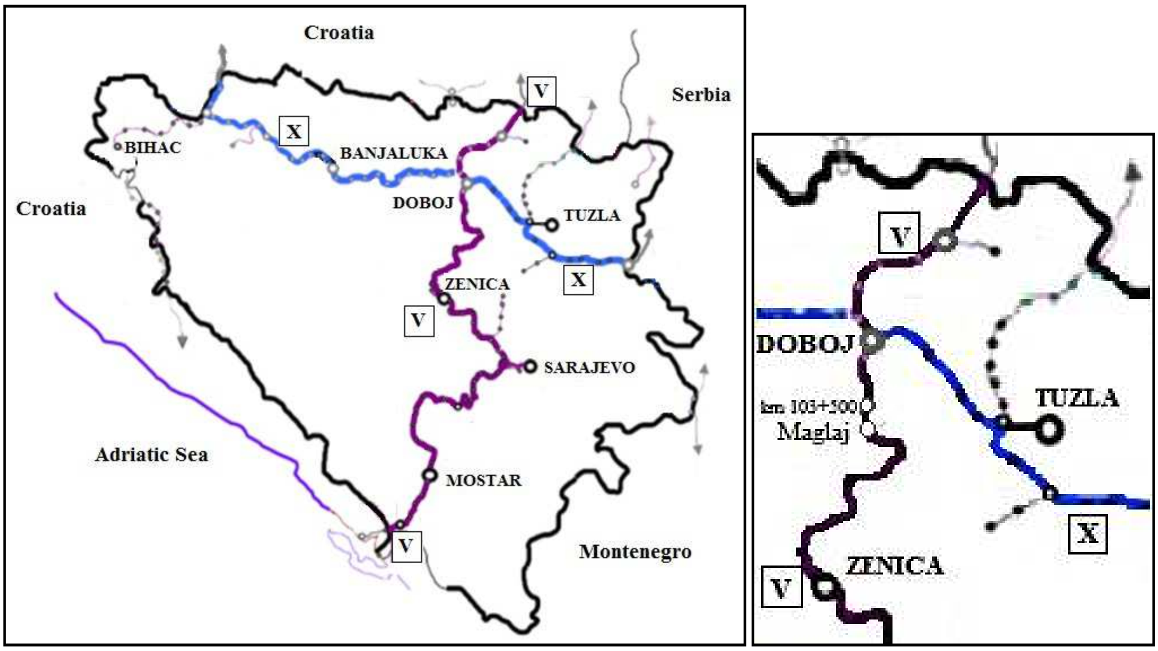

Figure 1. Railway corridor V, route of the railroad Doboj – Zenica, section km 103+500 – Maglaj

With reconstruction is planned remediation of the station track of train station Maglaj, as well as of open route part of left and right track of railway, with the task to include:

- a complete repair of the superstrcture of both tracks,
- remediation of foundation – railway planum, regulation of drainage and rehabilitation of damaged culverts and channels
- rehabilitation of drainage systems in objects and tunnels
- construction of supporting objects that maintain the stability of the railway, such as retaining walls, reduced and plate culverts, and contact network.

CONDUCTED RESEARCH OF THE TERRAIN ALONG THE ROUTE OF THE RAILWAY

Researched area of the railway and its surrounding were the subject of regional research. Geological structure of the terrain was analyzed from Basic Geological Map SFRY, sheet Zavidovici (Geological Survey of Sarajevo, 1962 - 1965), R 1: 100 000 [1]. For the assessment of the geotechnical properties of the terrain and railrway, research works were conducted, dictated by the characteristics of the terrain and the position of the route of the railway and objects along the route.

Conducted terrain research included a reconnaissance and engineering geological mapping of the terrain along the route of the railway, and evaluation of the state of the railway hull and present deformations. Fifty - two (52) exploratory trenches were conducted that were engineering geologicaly mapped and disturbed and undisturbed samples for laboratory testing from the hull of railway, base layer, the railway embankment and the subsoil were taken, [2,3,4,5,6,7].

Reconnaissance of the terrain

Reconnaissance of the terrain along the railway was carried out in order to observe the morphology of the terrain, the situation along the existing railway of the open route and train station. Contoured weak points on the railway were also registered, emphasized characteristics of the terrain from the aspect of security for further investigations and necessary remediation measures or maintenance.

Open railroad, chainage km 103+511 – km 107+112

- chainage km 103+511 – km 103+796 right track, ie km 103+794 left track, on the exit portal of tunnel „Orline“ unstable slope, can be seen rock fragments falling of behind the retaining wall into drainage channel, which is partly covered with fragments,
  - terrain mined on both sides of the railway
  - required actions for maintenance of the railway,

- chainage km 103+794 – km 104+280 railway in low embarkment < 1,0 m, below steep slope on the left - east side, no noticed deformation in railwayplanum, nor the cracks in verges or subsidence of verges, but can be noticed slope surface erosion, ie less rockslides of tiny fragments,
  - chainage km 103+850 ravine with water, culvert in poor condition
  - chainage km 104+230 ravine without water, culvert in poor condition
  - chainage km 104+280 ravine without water, cuclvert in poor condition
  - drainage channel partially covered with material that erodes the slope
  - terrain mined on both sides of the railway
  - required implementation of actions in the regular maintenance of complete railway route,

- chainage km 104+280 - km 104+300 railway in low embarkment ≤ 1,0 m, retaining wall without noticed deformation, no noticed deformation of railway planum, verges and slope of embankment, drainage channels in poor condition,
  - terrain mined on both sides of the railway
  - required implementation of actions in regular maintenance of channels,

- chainage km 104+300 – km 104+413 railway in low embarkment, under steep slope on left (east) side of the railway, drainage channels in poor condition,
  - terrain mined on both sides of the railway
  - required actions for regular maintenance of channels
  - chainage km 104+413 source of drinking water Q = 0,15 l/s, drainage channel to the half is filled with water from the source
  - required actions for source and drainage channel planning,

- from chainage km 104+413 – km 104+650 railway in smaller cut on the left (east) side, bottom part of the landslide is in the terrain above the railway (chainage km 104+480 – km 104+630), not noticed deformations in railway planum and verges of embankment,
  - terrain mined on both sides of the railway
  - required monitoring of landslide above the railway,

- stac. km 104+650 – km 104+810 railway in the embankment up to the bridge, embankment height increases in the direction of the bridge, no deformity in railway planum and embankment, drainage channels are not regulated,
  - terrain mined on both sides of the railway
  - required actions for maintenance of channels,

- chainage km 104+810 – km 104+845, AB underpass and a bridge over the stream Parnica,
  - chainage km 104+845 – km 105+100 from AB underpass of railway in smaller embarkment and on the left side of the railway is a gentle slope which steeps to the east, not observed deformations in track planum and embankment
  - chainage km 104+845 – km 104+920 km, is noticeable shell shaping of the terrain, and low secondary scars of approximately 0.50 m, frontal scar deep in the hinterland of the slope behind the residential buildings where is an active landslide
  - terrain mined on both sides of the railway
  - required project of research and remediation of landslide,

- chainage km 105+100 – km 105+250 railway in low embarkment < 1,0 m, in kerf and cut, kerfs of slope stable, drainage channels unorganized, partly flooding of track before regulation of culverts and streams, deformations in the form of "syringe thresholds" occasionally,
    - chainage km 105+200 along left track, no deformation in embarkment planum
    - terrain mined on both sides of the railway
      required actions for maintenance of canals and the railway,

- chainage km 105+250 – km 105+400 railway in embarkment higher than 1,0 m and low kerf, on the left side average about 0.5 m, drainage channels are not regulated, not noticed deformations in tracks planum and embankments,
    - terrain mined on both sides of the railway
    - required actions for regular maintenance of channels,

- chainage km 105+400 – km 105+500 railway in embarkment and kerf, on left side, noted movement of parts of retaining wall, dredging of the terrain, shell shaping of the terrain above the railway - landslide,
    - terrain mined on that side
    - required project of the research and remediation of landslides
    - required stabilization of slope by draining and planting vegetation,

- chainage km 105+500 – km 105+750 railwa in embankment height of 1,0 - 2,0 m and kerf, on the left side a steep stable slope, retaining wall under the railway and drainage channel disordered,
    - terrain mined on both sides of the railway,

- chainage km 105+750 – km 105+807 right track, ie km 105+852 left track, bridge over the river Jablanica, railway in high embankment > 2,0 m, not noted deformation in track planum and embankment, not observed cracks in verges and sides of embankment, drainage channels not regulated,
    - terrain mined on both sides of the railway
    - required making of adequate drainage between the two embankments,

- chainage km 105+852 – km 106+000 railway in high embankment < 2,0 m, not observed deformations in track planum and embankment, as well as cracks and subsidence in verges and sides of embankment,
    - terrain mined on both sides of the railway
    - required making of adequate drainage between two embankments,

- chainage km 106+000 – km 106+350 railway in embankment height to 1,0 m, not noted deformations in tracks planum and embankment,

- chainage km 106+350 – km 106+620 railway in high embankment > 2,0 m to the bridge over the river Bosna, not noted deformations in track planum and embankment, nor cracks and subsidence in the verges and sides of embankment,
    - terrain mined on both sides of the track to the bridge over the river Bosna
    - required making of adequate drainage of railway between two embankments,

- chainage km 106+620 – km 106+790 bridge over the river Bosna,

- chainage 106+790 – km 107+112 railway in high embankment > 2,0 m, not noted deformation in track planum, nor in embankment planum,
    - required making of adequate water drainage along the railway,

- chainage km 108+590 – km 108+614 railway in low embarkment and kerf, drainage channel at the bottom of the kerf are not regulated, also inflow of waste water from the factory into a drain channel,

  - required actions of regular maintenance of channel and ragulation of inflow of waste waters,

- chainage km 108+614 - km 108+ 900,
  - along the right track in high embankment and high kerf on the right side to the entrance portal of the tunnel „Sikola 1“
  - along the left track to the entrance portal of the tunnel "Sikola 1" in the embankment, and from an entrance portal in kerf
  - noticed the rockslides sections, centimeter to decimeter dimensions, from kerfs, particularly intensive from peak zone of the kerf, which represents the crust of decomposition of paleorelief
  - required arrangment of the surface of kerf and its regular maintenance.

Engineering geological mapping of the terrain

With engineering geological mapping of the terrain were determined lithological boundaries, thickness of lithological members, composition, set, genesis, deformation and history of occurrence, [3,8,9,10]. Particular attention was paid to the phenomena of instability, dredging areas and other similar phenomena in the terrain, which may be of importance for the reconstruction of the railway [11,12,13,14,15]. Mapping separated lithological members with engineering geological characteristics.

Embankment (n) is of heterogeneous composition, which builds foundation of railroad, and is mainly built from sandy gravel and derbis with variable percentage of fine-grained fractions, then sand and gravel sand.

Modern riverbed sediments (a) and alluvial sediments of river Bosna (al) are established on sections:

- chainage km 104 + 350 – km 104 + 410
- chainage km 105+ 770 – km 108 + 200
- chainage km 108+200 – km 108+290 on the left (east) side of the railway.

Greater part of the route of the railway is laid over alluvial sediments of the river Bosna. Sediments are heterogeneous, created as a result of different conditions of deposition of fine-grained and coarse sediments of the river Bosna and major and minor side tributaries. In natural conditions are stable, as well as in conditions during building. Conditionally are favorable for large loads of shallower zones and for deeper cutting.

Proluvial sediments (pr) are represented with clay that is silty sand, and debris of paleorelief rocks (peridotite, dacite, gabbro micro etc.). They are formed by depositing the material of permanent and temporary surface flows. Registered on sections:

- chainage km 1104+730 – km 104+840
- chainage km 107+970 – km 108+050.

In the surface zone sediments are less consolidated, and in deeper zones, with fragments of derbis material, are better consolidated. In the natural conditions are stable, and are conditionally stable and unstable at deeper cuttings and higher loads, ie represent weak spots on the route of the railway.

Sediments of slopes (dl) are silty sand and clayey sediments. Contain derbis from rocks paleorelief (peridotite, dacite, microgabbro). In natural conditions, mild slopes are stable environment, while steep to very steep slopes represent conditionally stable to unstable environment characterized by dredging and shell shaping of the terrain, as well as slip processes (landslides). Identified on sections:

- chainage km 104+450 – km 104+730
- chainage km 104+840 – km 105+030

- chainage km 105+100 - km 105+370
- chainage km 108+200 – km 108+570.

In delluvial sediments are registered zones of unstable terrain ie landslides. Diluvial sediments in the close vicinity of landslide represent a labile slope.

Neogene-Miocene dacite (M) are extracted on the surface on sections:

- chainage km 104+410 – km 104+450
- chainage km 105+030 – km 105+050
- chainage km 105+630 – km 105+770 on the left side of the railway.

Those are solid volcanic rocks of good physical and mechanical characteristics. In natural conditions, but also in terms of construction, heavier loads and deeper cuts represent stable environment in which can be performed high slopes.

Sandstone and sandy clay with rock fragments (J,K) sandstones are forming the terrain to the left - east from the railrway route, behind the narrow strip of alluvial sediments that build immediate environment, and on section chainage km 105+770 – km 106+100. From chainage km 106+100 to km 106+250 route of the railway is placed directly through the Jurassic-Cretaceous sandy clay with rock fragments. Clays are sandy with variable percentage of content sections (clastics) and occasionally exceed in clayey sand with debris. In terms of construction, larger loads, environment is conditionally stable, and in deeper cuttings, because of very negative influence, water environment is conditionally stable to unstable.

Igneous rocks of Jurassic volcano-sedimentary formation ($J_{2,3}$) are represented with: microgabbros and massive peridotites.

- Microgabbros represent a senior member of deep igneous rocks, of Jurassic volcanogenic sedimentary formations. The railway is placed through the rocks that are build of microgabbros on section chainage 108+570 – 108+900. Microgabbros belong to solid volcanic rocks of good physical and mechanical characteristics, high load capacity which allows performing of stable high cuts.

- Massive peridotites are lower depth members of igneous rocks of Jurassic volcanogenic sedimentary formations. They represent a solid igneous deep rocks of good physical and mechanical characteristics, high load capacity and they allow performing of stable high kerfs.Railway route is laid over massive peridotites from:
    - chainage km 103+500 to km 104+350,
    - chainage km 104+350- km 104+410,
    - chainage km 105+050 – 105+100,
    - chainage km 105+370 to km 105+630.

According to the degree of stability and suitability of terrain, are singled out:

- unstable terrains (N),
    - sediments of delluvial slopes (dl) with a very steep inclination
    - fossil landslide, on the left - east side of the railway, which had previously been partially remediated, chainage km 104+480 – km 104+630 (dl)
    - active landslide registered in the section chainage km 104+845 – km 104+920 on left side of the railway (dl)
    - sandy clay sediments with clastics in terms of deeper kerfs of the slope (J,K)
    - microgabbros on chainage 108+570 – 108+900, zone at the top of the kerf, where is present intense rockslides of parts of different dimensions ($J_{2,3}$)
    - massive peridotites in parts of the terrain exposed to surface erosion processes ($J_{2,3}$)
    - areas with less steep slopes where was deposited surface cover of decomposed degraded material thickness of 0.50 to a maximum of 2.5 m ($J_{2,3}$)

- active landslide on part of the route chainage km 105+400 – km 105+500 over the railroad ($J_{2,3}$),

- conditionaly stable terrains (US),
  - sediments of delluvial slopes with steep inclination (dl)
  - sandy clay sediments with clastics (J,K)
  - zones of micro-gabbro and peridotite massive rocks with increased cracking ($J_{2,3}$)

- and stable terrains (S),
  - other sections along the railway route.

Conducted research work

The revitalization of the railway required determination of geotechnical characteristics of the superstructure and foundation, in order to give the project solution for the track hull, planum and slopes. Research of the terrain along the route of the railroad was limited, considering that the terrain is mined almost in its entire length. Terrain research included the drilling of exploration diggings on the sides of the hull of the railway to a depth of subsoil. Fifty-two (52) exploration trenches were conducted, table 1. Depth of digging is determined for each trench especially in the location of trench. Railway route has two tracks, which viewed from Doboj to Zenica are called right and left, [5].

Table 1. Review of realized terrain research works

Trenches depth (m)	Total	Track		Between tracks	Station	Samples	
		Right	Left			Disturbed	Undisturbed
< 1,0	19	7	7	4	1	17	2
1,0 - 2,0	25	8	8	5	4	22	3
> 2,0	8	1	2	4	1	6	2
Total	52	16	17	13	6	45	7

Trenches were in detail mapped, photographed, figure 2a, and also were taken disturbed and undisturbed samples covered with the same material. Based on terrain mapping, results of laboratory tests, profiles of all trenches were made, figure 2b, as well as transverse profiles of the terrain along the route of the railroad.

Figure 2a. Characteristic exmple of trench IJ – 7 on chainage km 105+450,00

Detailed engineering geological mapping of trench profile was carried out during the construction and after its completion. Performed were the determination of lithologic members, macroscopically defined grain size distribution, humidity, plasticity, hardness, and the selection of representative samples for geotechnical laboratory tests.

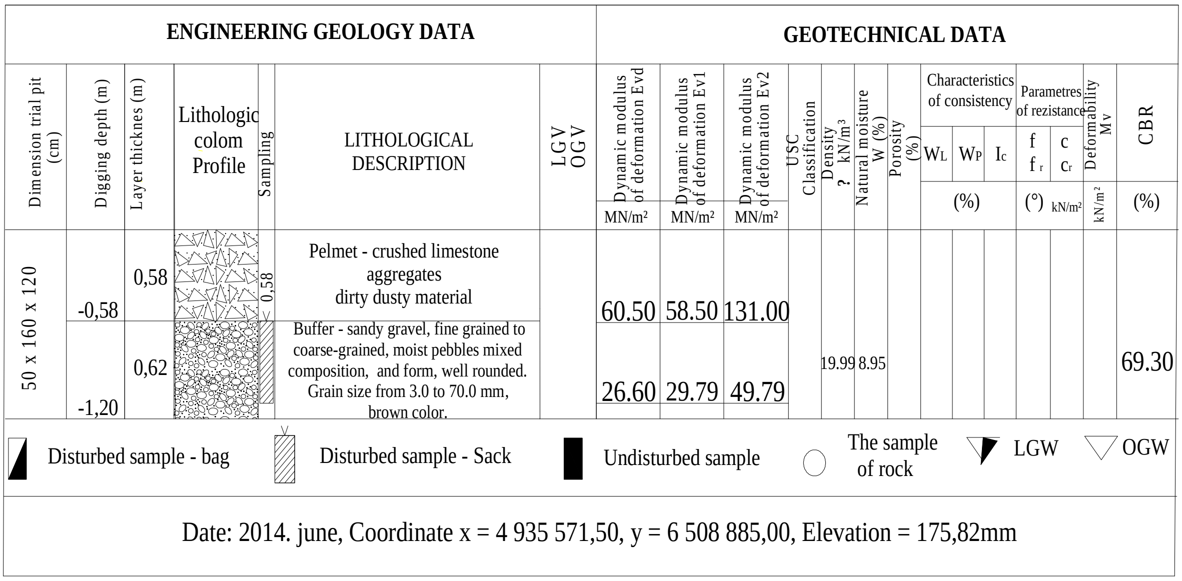

Figure 2b. Characteristic trench profile IJ – 7 on chainage km 105+450,00

In every trench by depth is made 1 - 4 experiments of dynamic circular plate Evd and of certain value Ev_1 i Ev_2, table 2

Table 2. The dynamic deformation modulus in research trenches

Exper. depth (m)	Total	Track		Between tracks	Station	The dynamic deformation modulus (MN/m^2)		
		Right	Left			Evd	Ev_1	Ev_2
< 0,5	34	8	9	13	4	20,03-76,27	19,29-75,50	45,66-140,00
0,5 - 1,0	47	12	15	12	8	19,15-82,50	10,50-63,16	18,00-136,80
1,0 - 1,5	10	3	2	3	2	14,40-64,30	11,00-62,30	19,10-138,60
1,5 - 2,0	3	-	1	1	1	14,90-47,07	11,23-42,84	19,70-104,00
> 2,0	10	1	3	5	1	<10-68,20	18,50-66,20	15,05-146,49
Total	104	24	30	34	16			

During the development of investigative trenches, sufficient number of samples from the superstructure, foundation and soil were taken, for defining the physical - mechanical characteristics of present lithological members, [8,9,10,17,18,19,20] . Those are the following:

- Identification - classification on 60 samples.
- Experiments of deformability on 6 samples.
- Experiment of direct shearing on 6 samples.
- Proctor and CBR's experiments on 52 samples.

DISCUSSION

Conducted research were performed on control parts of the existing railway and included analysis and synthesis of the results of terrain research and laboratory tests. They are sufficient for understanding the geological structure of the terrain, engineering-geological characteristics of represented lithological members and characteristics of railway on individual chainages. Separated chainages along the railway, towards its characteristics are as follows:
Characteristics of the terrain along the route of railway towards slope and stability conditions,

- chainage km 103+511 – km 103+796, railway placed through the tunnel „Orline“
- chainage km 103+800 – 104+100, km 104+950 – km 105+750 railway along steep slopes that are on the left side

- chainage km 108+614 – km 108+900 railway along steep slope that is on the right side of the railway
- chainage km 108+755 right track is placed through tunnel „Sikola 1“
- chainage km 104+100 – km 104+950 and km 106+100 – km 106+250 are gentle slopes on the left side of the railway
- chainage km 105+750 – km 106+100 and chainage km 106+250 – km 108+614, over relatively flat terrain, on the railway section are derived concrete plate and reduced culverts that allow surface waters to flow off, also were derived underpasses, overpasses and bridges, which are in good structural condition
- chainage km 104+480 – km 104+630, characterized by the appearance of planar (surface) erosion
- chainage km 104+630 – km 104+845 has one fossil landslide from sources of drinking water to the stream Parnica
- chainage km 104+845 do km 104+920 km on the left side of the railway are two (2) active landslides
- chainage km 105+400 to km 105+500, present landslide, extending from the stream Parnica,

Required maintenance of the stability of slopes and landslide remediation.

Characteristics of channels for surface water drainage,

- chainage km 103+511 – km 103+796, notable fallout of rock fragments behind the retaining wall into drainage channel, which is partly covered with fragments
- chainage km 103+794 – km 104+280, notable surface erosion of the slope, ie lower rockslides of small fragments, culverts and canals in poor condition
- chainage km 104+280 - km 104+300, drainage channels are in bad condition
- chainage km 104+300 – km 104+413, drainage channels are in bad condition
- chainage km 104+650 – km 104+810, drainage channels are not regulated
- chainage km 105+100 – km 105+250, drainage channels are unregulated
- chainage km 105+250 – km 105+400, drainage channels are not regulated
- chainage km 105+500 – km 105+750, drainage canals are unregulated
- chainage km 105+750 – km 105+807, drainage channels are not regulated
- chainage km 107+700 do km 108+000, drainage canals is unregulated
- chainage km 108+590 – km 108+614, drainage channels are not regulated.

Required regulation and maintenance of channels.

Characteristics of embankments along the railway are variable depending on the morphology of the terrain. Mostly, the route is placed in the embankment <1.0 m, where have been done the most research trenches, table 3. The depth of the trench is 0.2 - 0.3 m below the embankment in primary rock.Other sections are placed at zero level, ie a very small embankment, which can be classified in embankment < 1.0 m.

Tabela 3. Display chainages according to depth of embankment and number of exploratory trenches

Embankment (m)	Chainage	Number of trenches	Total	
			chain. (m)	trenches
< 1,0	chainage km 103+794 – km 104+280	2	1941	21
	chainage km 104+280 – km 104+300	1		
	chainage km 104+810 – km 104+845	1		
	chainage km 105+100 – km 105+250	2		
	chainage km 106+000 – km 106+350	3		
	chainage km 108+000 – km 108+590	9		
	chainage km 108+590 – km 108+614	1		
	chainage km 108+614 – km 108+900	2		
1,0 - 2,0	chainage km 105+250 – km 105+400	1	1064	15
	chainage km 105+400 – km 105+500	1		
	chainage km 105+500 – km 105+750	3		

	chainage km 105+852 – km 106+000	1		
	chainage km 107+400 – km 108+000	9		
> 2,0	chainage km 104+450 – km 104+810		1097	7
	chainage km 105+750 – km 105+807			
	chainage km 106+350 – km 106+620	1		
	chainage km 106+790 – km 107+112	3		
	chainage km 107+112 – km 107+400	3		
		Total:	4102	43

Exploratory trenches were carried out along the entire route mostly at a depth of 0.7 – 1.5 m, figure 3. If we keep in mind that the depth of the trench was 0.2 - 0.3 m below the embankment, it can be concluded that the embankment thickness is ranging from 0.5 – 1.2 m. It is important to emphasize that the right track on the same chainages is characterized by deeper embankment, because the regulations from 1978, were more demanding.

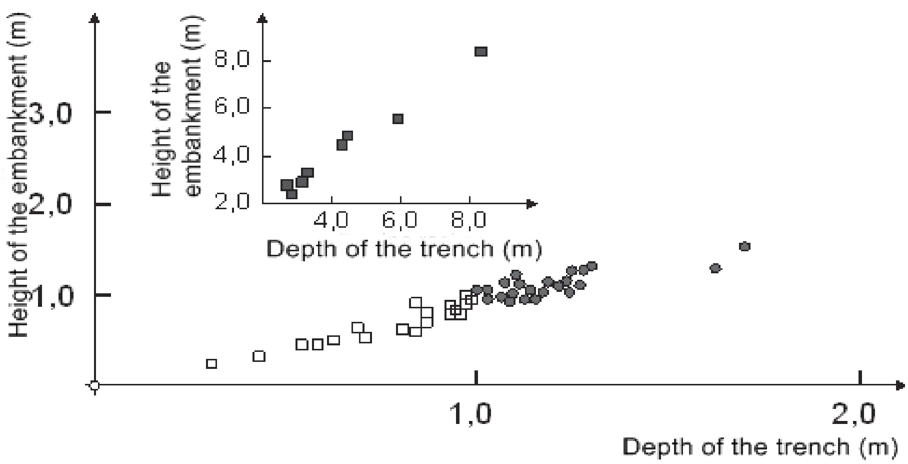

Figure 3. Chart of relations of height of embarkment and depth of trenches along the railroad

Experiment values Evd determined in trenches by depth during their manufacture, are different in a wide range from < 10 to > 100 MN/m^2. It is characteristic to note that deeper parts of the embankment are worse and are related to the chainage that are singled out as those of poor quality according to certain characteristics, primarily disordered circumferential channels.

Conducted research on the terrain and laboratory tests gave an overview of the data from which is defined the position of the railway route according to the engineering geological characteristics of sediment and conditions of stability, table 4.

Table 4. Characteristics of sediments according to the conditions of stability

Sediments	Natural stability (existing condition)			Stability in terms of construction		
	S	U	N	U	US	N
Embankment	+					
Contemporary riverbed sediments (a) and alluvial sediments of the river Bosna (al)	+			+	+[1]	
Proluvial sediments (pr)	+				+[1]	+[1]
Sediments of slopes (dl)	+[2]	+[3]	+[3]		+[1]	+[1]
Neogene-Miocene dacites (M)	+			+[1]		
Sandstone and sandy clay with rock fragments (J,K)	+	+			+[1]	+[1]
Igneous rocks of Jurassic volcano-sedimentary formation ($J_{2,3}$)	+	+	+	+[4]	+[2]	

1 – for large loads and deeper cuts, 2 – gentle slopes, 3- steep slopes, 4 - landslide

The research results showed that in general railway on the entire route is in poor condition, but it is important to define the type of reconstruction or remediation. Along the entire route of the railway should be removed old buffer which consists of upper and lower part, and is built from limestone crushed stone. New regulations of installation buffer layer are more demanding, [5,8,18,19]. Geotechnical conditions for the reconstruction of railway are as follows:

- railway planum – buffer of gravel for the required thickness compact to a value $E_{vd} \geq 55$ MN/m^2,
- railway planum – transitional (improved) must be made of materials for the embankment construction, which should be installed in a layer thickness of 30.00 cm with a compression of layer, to achieve dynamic modulus of deformation, ie until it reaches values of $E_{vd} \geq 40$ MN/m^2,
- embankment hull – gravel for the required thickness thicken until achieve value of $E_{vd} \geq 25 – 30$ MN/m^2 and
- subsoil – natural terrain both in zone of cuts as well as low embankments prepare to achieve the dynamic module deformation $E_{vd} \geq 25 – 30$ MN/m^2.

On separated chainages according to certain characteristics, it is necessary to harmonize the construction of embankments with the characteristics of the terrain.

ACKNOWLEDGEMENT

This paper was realized within „ European Union's 2008 IPA Programmed for Albania, Bosnia and Herzegovina, Croatia, The Former Yugoslav Republic of Makedonia, Montenegro, Serbia, Kosovo, Turkey and Iceland" - Infrastructure Projects Facility Technical Assistance Window (IPF TA) Western Balkans, Europe Aid/128073/CSER/MULTI. Project: WB5-BiH-TRA-14.*

(Received August 2017, accepted December 2017)

LITERATURE

[1] Laušević M., Jovanović Č., Mojičević M. (1980). Osnovna geološka karta SFRJ, list Doboj, R 1:100000, i Tumač OGK. Savezni Geološki Zavod, Beograd.

[2] Ćulibrk S. R. (1996). Geotehnički radovi u niskogradnji. Građevinski fakultet, Rudarsko-geološki fakultet. Subotica, Beograd.

[3] Đurić N. (2011). Hidrogeološka i inženjerskogeološka istraživanja. Građevinski fakultet, Subotica, Tehnički institut, Bijeljina.

[4] Grupa autora (2012). Program inženjerskogeoloških, hidrogeoloških i geotehničkih istražnih radova za trasu autoputa koridor Vc, Doboj Jug. IPSA Sarajevo. Fond stručnih dokumenata IPSA Sarajevo, Tehnički institut Bijeljina.

[5] Grupa autora (2013). Projekat: WB5-BiH-TRA-14.Glavna opravka pruge dionica Doboj – Maglaj i Jelina – Zenica na Koridoru Vc. FAZA II: Glavni Projekat, Dionica km 103+500 – Maglaj. Knjiga 4. Geološko – geomehanički elaborat. Tehnički institut Bijeljina.

[6] Benedetto, A, Benedetto, F, Tosti, F.2013. GPR applications for geotechnical stability of transportation infrastructures. *Nondestruct Test Eval,* 27(3),pp.253–262. CrossRefGoogle Scholar

[7] N. Đurić, et al., Coridor Vc, Motorway, Main Desing, Section Svilaj-Doboj South (Karuše), around 63 km long. Library of the Technical Institute, document No. 35–A/2012, (2012).

[8] Đukić D. (2004). Geotehničke klasifikacije za površinske radove u rudarstvu i građevinarstvu. Tuzla, Rudarski institut.

[9] Najdanović N., Obradović R. (1979): Mehanika tla u inženjerskoj praksi. Beograd, Rudarski institut.

[10] Đurić N. (2014). Geological characteristic of the terrain on the highwaycorridor Vc, Section Johovac - Doboj Jug, stac. km 10+754 - 15+820. Bijeljina. Arhiv za tehničke nauke br. 11, str. 17-23. http://dx.doi.org/10.7251/afts.2014.0611.017D

[11] Forlati, F., Lancellotta, R., Scavia, C., Simeoni, L. 1998. Swelling processes in sliding marly layers in the Langhe region, Italy. In: *Evangelista E, Picarelli L (eds) The geotechnics of hard soils-soft rocks*. Balkema, Rotterdam, pp 1089–1099.

[12] Graziani, A., Rotonda, T., Tommasi, P., 2009. Stability and deformation mode of a rock slide along interbeds reactivated by rainfall. Proc. of the 1st Italian Workshop on Landslides, Napoli, 8th-10th June 2009, 1, pp. 62–71.

[13] Pierson, T. C. 1980. Erosion and deposition by debris flows at Mt. Thomas, North Canterbury, New Zeland: *Earth SurfaceProcesses*, Vol. 5, pp. 227-247.
[14] Rokić, LJ.,2011., Fizička geologija Ljubomir Rokić. Sarajevo.
[15] Đurić, N., 2010. Some examples of research and rehabilitation characteristic landslide in the Republic of Srpska. *Arhive for Technical Sciences*, N^0 3, pp. 52-64.
[16] Đujić, A., Đurić, N., Mitrović, P. (2009). Klizište na pruzi Tuzla – Zvornik. Zbornik radova Arhiv za tehničke nauke, 1, 9-15.
[17] Bowles, J. (1997). Fondation analysis and design. Exoloration, sampling and in situ soil measurements. Fifth edition. McGraw Hill Higher Education.
[18] Eurocode 7 (1997). Geotechnical desing – Part 2: Desing assisted by laboratory testing, and Part 3: Desing assisted by fieldtesting. European Commitete for standarization. Brussels.
[19] ISO 22476-2, Geotechnical investigation and testing, Field Testing, Part 2: Dynamic probing. Case postal 56, CH-1211 Geneva 20, (2005).
[20] British Standards Institution, Code of Practice For Site Investigations, (1999), BS 5930, pp. 1-12.