**REPUBLIC OF SERBIA**
**CENTER FOR INVESTIGATION OF ACCIDENTS IN TRANSPORT**
**SECTOR FOR INVESTIGATION OF ACCIDENTS IN RAILWAY TRAFFIC**
**NEMANJINA 11, 11000 BELGRADE**

**No.: ŽS - 03/20**

**No.: 340-00-2/2020-02-1-53**

**Date: 17.11.2021.**

# FINAL REPORT ON INVESTIGATION OF AN ACCIDENT

| | |
|---|---|
| Accident type: | Train derailment |
| Train No.: | 45022 |
| Place: | Municipality of Jagodina,<br>open track between the stations Jagodina and Bagrdan |
| Date: | 28.11.2020. |
| Time: | 19:27 |

This report presents the results of investigation of an accident, derailment of the train No. 45022, which occured on 28.11.2020. at 19:27 on the main arterial line 102: Belgrade Center - Junction "G" - Rakovica - Mladenovac - Lapovo - Niš - Preševo - state border - (Tabanovce), between the stations Bagrdan and Jagodina, on the left track of the two-track railway line between km 123+600 and km 123+670.

The Working Group for investigation of this accident was formed by the Director of the Center for Investigation of Accidents in Transport RS, by Decision No. 340-00-2/2020-02-1-8 of 04.12.2020.

In accordance with the Article 33 of the Law on Investigation of Accidents in Air, Railway and Waterborne Traffic ("Official Gazette of RS" No. 66/15 and 83/18) and the Article 23 of the Directive 2004/49/EC of the European Parliament and of the Council of EU (Railway Safety Directive), the Center for Investigation of Accidents in Transport (hereinafter referred to as: CINS) drafted and published this Final Report.

In this report, all sizes and measurements are expressed in accordance with the International System of Units (SI).

The meaning of abbreviations used in the text is explained in the Glossary.

CINS has been established in accordance with the Law on Investigation of Accidents in Air, Railway and Waterborne Traffic ("Official Gazette of RS" No. 66/15). The founder is the Republic of Serbia and the holder of founding rights is the Government of the Republic of Serbia.

Sector for Investigation of Railway Traffic Accidents carries out tasks within the competence of CINS in relation to rail traffic with the aim of possible improvement of safety on the railway by issuing safety recommendations. The investigative procedure in the field of railway traffic is conducted on the basis of the provisions of the Law on Investigation of Accidents in Air, Railway and Waterborne Traffic ("Official Gazette of RS" No. 66/15 and 83/18).

CINS conducts investigations following the serious accidents on the railway system with a view to possible improvement of railway safety and the prevention of new accidents caused by the same or similar causes. Serious accident in railway traffic means any train collision or derailment of trains, resulting in the death of at least one person or serious injuries to five or more persons or extensive damage to rolling stock, the infrastructure or the environment, and any other similar accident with an obvious impact on railway safety regulation or the management of safety.

In addition to serious accidents, CINS may also investigate other accidents and incidents that could lead to a serious accident, including the technical failure of structural subsystems or interoperability constituents.

CINS has the discretion to decide whether to open an investigation of other accidents and incidents.

**CINS is independent in its work and performs independent accident investigations. The aim of an investigation is to identify the causes and the possibility of improving safety on the railway and to prevent accidents by issuing safety recommendations.**

**Professional activities related to safety investigations are independent of judicial inquiry or any other parallel investigations which objective is to determine responsibility or the degree of guilt.**

**Glossary:**

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|---|---|
| CINS | Center for Investigation of Accidents in Transport |
| RS | Republic of Serbia |
| MUP | Ministry of Interior |
| JP | Public Enterprise |
| IŽS | Serbian Railways Infrastructure |
| a.d. | Joint Stock Company |
| d.o.o. | Ltd. |
| ŽS | Railways of Serbia |
| JŽ | Yugoslav Railways |
| ZJŽ | Community of Yugoslav Railways |
| OC | Organizational Unit |
| ZOP | For track maintenance |
| KM | Contact network, catenary |
| TKP | Technical wagon affairs |
| TT | Telephone-telegraph |
| SS | Safety signalling |
| DTŠ | Continuous welded rail |
| APB | Automatic track block |
| TMD | Heavy motor vehicle |
| ECM | Entity in Charge of Maintenance |

# C O N T E N T:

# 1. Summary

## 1.1. Short description of the accident

On 28.11.2020. at 19:27 between km 123+600 and km 123+670 of the main arterial line 102: Belgrade Center - Junction "G" - Rakovica - Mladenovac -Lapovo - Niš - Preševo - state border - (Tabanovce), between the stations Bagrdan and Jagodina, on the left track of the two-track railway line, it came to derailment of the train No. 45022 (railway undertaking "Srbija Kargo"a.d.). From the train composition it derailed 8 wagon-tanks of Z series loaded with sulphuric acid (RID 80/1830, OM 5912/20). Viewed from the direction of locomotive 193-916, there derailed: fifth wagon-tank of series Zacs-z No. 33 72 7867 810-3 with two axles of the second bogie (they remained on their wheels in the track zone), seventh wagon-tank of series Zacs-z No. 33 72 7865 013-8 with all axles (they overturned on its side, seen in the direction of the train movement), eighth wagon-tank of series Zacs-z No. 33 72 7867 853-3 with all axles (overturned on its side to the left, seen in the direction of the train movement), ninth wagon-tank of series Zacs-z No. 33 72 7867 846-7 with all axles (overturned on its side to the right, seen in the direction of the train movement), tenth wagon-tank of series Zacs-z No. 33 72 7865 005-4 with all axles (remained upright, on its wheels, in the track zone, rotated), eleventh wagon-tank of Zacs-z series No. 33 72 7865 009-6 with all axles (tilted to the left and rotated to the right relative to the longitudinal axis of the track, viewed in the direction of train movement), twelfth wagon-tank of series Zacs-z No. 33 72 7865 010-4 with all axles (tilted to the left and rotated to the left relative to the longitudinal axis of the track, viewed in the direction of train movement) and thirteenth wagon-tank of the series Zacs No. 33 87 7868 736-2 with two axles of the second bogie (they remained on their wheels in the track zone). There were no fatally injured nor injured in the accident. Sulfuric acid leaked from some of the wagon-tanks. Material damage was caused to infrastructure, railway vehicles and goods.

## 1.2. The causes of accident determined by investigation

Based on the facts and evidence determined during on-site investigation by the Working Group of CINS and data submitted, the probable direct and immediate cause of the accident is decoupling of the track which was not maintained in accordance with Articles 74 and 76 of the Rulebook on technical conditions and maintenance of the superstructure of railways ("Official Gazette of RS" No. 39/16 and 74/16). Taking into account the available facts on the condition of the track (item 4.2.7), records from track inspection runs (item 4.2.8), on the action of horizontal longitudinal forces in the direction of the track axis which influence the tendency of rails movement, as well as the fact that the temperature of the rail at the time of the accident most likely caused tensile stresses in the rails ($t_{air}$ = - 0.4 ° C≈ $t_{rail}$ <$t_p$) and that due to the braking of the train there was additional tensile stresses in the rails, it is likely that, during the passage of the train, the track ruptured due to the fracture of the connecting screws in the insulated joint on the left rail at km 123+660.80 in the direction of increasing stationing, that is, the right rail in the direction of train No. 45022 movement and the rupture of the right rail at km 123+660.20 in the direction of increasing stationing, that is, left rail in the direction of train No. 45022 movement.

The maintenance of the railway line on the observed section was not performed in accordance with the Rulebook on technical conditions and maintenance of the superstructure of railways ("Official Gazette of RS" No. 39/16 and 74/16) having in mind the years of the last railway repairs, as well as insufficient number of executors, machinery and tools (see section 4.2.7).

## 1.3. Main recommendations and information on subjects to which the Report is submitted

Aiming to improve safety on the railway and prevent occurrence of the new accidents, CINS has issued the following safety recommendations:

**To the Directorate for Railways recommendations SR_12/21, SR_13/21, SR_14/21, SR_15/21, SR_16/21, SR_17/21, SR_18/21, SR_19/21, SR_20/21 and SR_21/21 are issued:**

**SR_12/21** Directorate for Railways, to consider the justification of the abolition of Paragraph 9 of Article 8 of the Rulebook on technical conditions and maintenance of railway lines superstructure ("Official Gazette of RS", No. 36/16), which reads: "Alternate (mixed) installation of wooden and concrete sleepers is not allowed" and justification to return via amendments to the stated Article ("Official Gazette of RS", No. 36/16 and 74/16) the aforementioned Paragraph of the Rulebook on technical conditions and maintenance of railway lines superstructure (see item 4.3.4.).

**SR_13/21** **"**IŽS"a.d., to conduct the risk assessment of train traffic on the main arterial line 102: Belgrade Center - Junction "G"- Rakovica - Mladenovac - Lapovo - Niš - Preševo - state border - (Tabanovce), left track, from Markovac station (exclusively) km 101+057 to Jagodina station (inclusive) km 136+000, given the inadequate maintenance and condition of tracks, sleepers and fasteners and the insufficient number of executors for maintenance from the construction industry; and take measures to reduce the risk to an acceptable level (see points 3.4.2 and 4.2.7.).

**SR_14/21** "IŽS"a.d., in the Rulebook on organization and work positions systematization of "IŽS"a.d., Belgrade, to consider the adequacy of the existing ones and consider the possibility to predict the appropriate number of executors in the construction industry both on the section of the railway on which the accident occurred and on the entire network in order to ensure the safe conduct of railway traffic. In accordance with the appropriate number of executors to plan the procurement of the necessary machinery and tools, all in order to ensure the safe conduct of railway traffic (see point 4.2.7.).

**SR_15/21** Elixir Zorka Mineralna đubriva d.o.o**.** Šabac**,** to establish maintenance procedures with a list of instructions that must be an integral part of the maintenance file with a detailed list of scope of work in regular repairs of wagon-tanks for transportation of sulfuric acid (see item 4.2.2.1.).

**SR_16/21** Elixir Zorka Mineralna đubriva d.o.o. Šabac, to establish maintenance procedures, in accordance with the requirements of the Rulebook on maintenance of railway vehicles ("Official Gazette of RS" No. 144/2020), where the maintenance of bogies must be performed according to the manufacturer's instructions, and the procedures must be

harmonized with that instruction, considering that wagons with worn inserts of the center bowl and side bearers represent a significant risk of derailment in curves (see item 4.2.2.1.) and in which the documentation of the characteristics of the buffer after repair and comparison with the characteristic given by the manufacturer will be defined, i.e. for newer and reconstructed wagons in accordance with the required characteristic according to EN 15551 for the corresponding type of buffer (see item 4.2.2.2.).

**SR_17/21** Elixir Group d.o.o. Šabac, as the holder for whose needs the transport is performed, it is necessary to provide procedures for proper closing of tank lids in accordance with the manufacturer's instructions, which include: checking the cleanliness and flatness of adjacent surfaces, use of undamaged prescribed seals, closing the opening with the projected number of screws with a torque wrench with the torque prescribed by the manufacturer. If this information is not known from the manufacturer, the tightening torque must be prescribed according to the general technical standards for pressure vessels (see item 4.2.6.).

**SR_18/21** Elixir Group d.o.o. Šabac, as the holder for whose needs the transport is performed, should require that staff be trained at all loading and unloading points to properly close the lids and carry it out according to the adopted procedure (see item 4.2.6.).

**SR_19/21** Elixir Group d.o.o. Šabac, as the holder of the wagons which did not have individual licenses (see items 2.2.2 and 3.4.4), to prescribe in its acts the verification of the existence of an individual license for use, before using the wagon and to conduct additional training of its staff on this issue (see item 4.2.6.).

**SR_20/21** "Srbija Kargo"a.d., to train the staff to carry out the measure at the reception points, that if it is possible to establish the lack of screws on the tank lids by visual inspection, to refuse the transport of improperly closed tanks (see item 4.2.6.).

**SR_21/21** "Srbija Kargo"a.d., to train the staff that wagons due to defects (as stated in item 4.2.2.3, in one tank it was determined that the GP gearbox was defective when the handle could turn without resistance and without arrest in the end positions and said gearbox has been fixed with wire in position P) must be labelled and sent for repair (see item 4.2.6.).

**To the Ministry of Construction, Traffic and Infrastructure SR_22/21, SR_23/21 and SR_24/21 are issued:**

**SR_22/21** Ministry of Construction, Transport and Infrastructure, Sector for Inspection Supervision, Department for Railway Traffic Inspection Affairs, to perform an extraordinary inspection of the condition of the railway infrastructure on the main arterial line 102: Belgrade Center - Junction "G" - Rakovica - Mladenovac - Lapovo

- Niš - Preševo - state border - (Tabanovce), left track, from the station Markovac (exclusively) km 101+057 to the station Jagodina (inclusive) km 136+000 and take measures within its competence (see items 3.4.2, 4.2.7. and 4.2.8.).

**SR_23/21** Ministry of Construction, Transport and Infrastructure, Sector for Inspection Supervision, Department for Railway Traffic Inspection Affairs, to perform an extraordinary inspection of Elixir Group d.o.o. Šabac which used railway vehicles that do not have a type license and without an individual license for use (see items 2.2.2. and 3.4.4.) and take measures within its competence.

**SR_24/21** The Ministry of Construction, Transport and Infrastructure, Sector for Railways and Intermodal Transport, to consider possible amendments in the existing legislation in order to facilitate the procedure of issuing type licenses and licenses for use only for existing vehicles in long-term operation in RS for which, due to current legal regulations, licenses cannot be issued by the Railway Directorate (see item 3.4.4.).

**To *Autorité française de sécurité ferroviaire* SR_25/21 is issued:**

**SR_25/21** Atir-Rail SA, to prescribe in maintenance procedures the control of the condition and wear of wearing inserts of center bowls and side bearers (see item 4.2.2.1.) as well as other elements that can reach the limit measures between the two repairs and define the documentation of buffer characteristics after repair and comparison with the characteristic given by the manufacturer (see item 4.2.2.2.).

# 2. Direct facts on the accident

## 2.1. Basic data on the accident

### 2.1.1. Date, time and location of the accident

On 28.11.2020. at 19:27 in the area of the municipality of Jagodina, on the main arterial line 102: Belgrade Center - Junction "G" - Rakovica - Mladenovac -Lapovo - Niš - Preševo - state border - (Tabanovce), between the stations Bagrdan and Jagodina, on the open section located in the direct vicinity of the state road IA rank, marking A1. On that section, the line is parallel with the state road.

The place of occurrence of the accident in question is approximately 35 m away from the state road IA rank, marking A1 (highway Belgrade - Niš). Next to the mentioned state road (next to the road lane for the direction from Niš to Belgrade) there is a gas station "Gazprom", approximately 300 m away from the place of the accident in question. In the vicinity of the place of occurrence of the accident in question, on the other side of the mentioned state road, there is the river Velika Morava, approximately 500 m away from the place of occurrence of the accident in question. There are no residential buildings near the accident site.

The view of the area of the accident site taken from the satellite is shown in Figure 2.1.1.1.

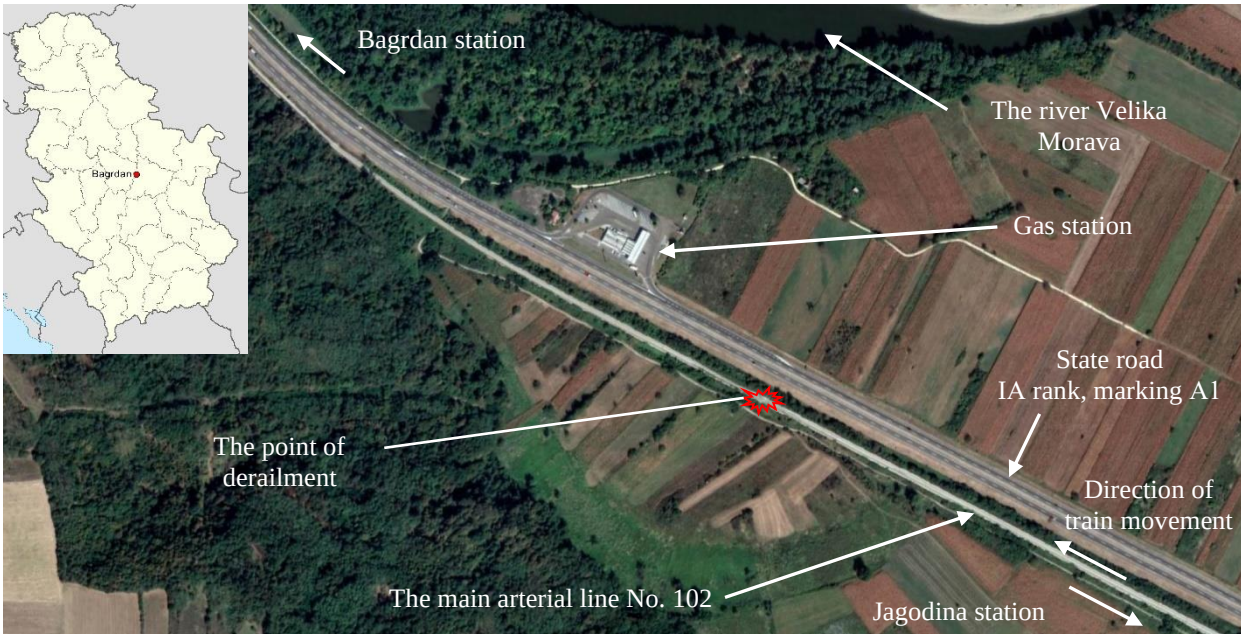



**Figure 2.1.1.1:** Satellite image of the area of the accident site (*Google maps*)

### 2.1.2. Description of the accident and the accident site and work of rescue and emergency services

On the main arterial line 102: Belgrade Center - Junction "G" - Rakovica - Mladenovac - Lapovo - Niš - Preševo - state border - (Tabanovce), while driving in the direction from the station Jagodina to the station Bagrdan, on the open line between km 123+600 and km 123+670 at train No. 45022, eight wagons of the Z series derailed.

Viewed from the direction of locomotive 193-916, there derailed: fifth wagon-tank of series Zacs-z No. 33 72 7867 810-3 with two axles of the second bogie (they remained on their wheels in the track zone), seventh wagon-tank of series Zacs-z No. 33 72 7865 013-8 with all axles (they overturned on its side, seen in the direction of the train movement), eighth wagon-tank of series Zacs-z No. 33 72 7867 853-3 with all axles (overturned on its side to the left, seen in the direction of the train movement), ninth wagon-tank of series Zacs-z No. 33 72 7867 846-7 with all axles (overturned on its side to the right, seen in the direction of the train movement), tenth wagon-tank of series Zacs-z No. 33 72 7865 005-4 with all axles (remained upright, on its wheels, in the track zone, rotated by approximately 30° to the left with respect to the longitudinal axis of the track), eleventh wagon-tank of series Zacs-z No. 33 72 7865 009-6 with all axles (tilted to the left for approximately 50° with respect to the vertical axis of the track and rotated to the right for approximately 20° with respect to the longitudinal axis of the track, viewed in the direction of train movement), twelfth wagon-tank of series Zacs-z No. 33 72 7865 010-4 with all axles (tilted to the left for approximately 40° with respect to the vertical axis of the track and rotated to the left for approximately 20° with respect to the longitudinal axis of the track, viewed in the direction of train movement) and thirteenth wagon-tank of the Zacs series No. 33 87 7868 736-2 with two axles of the second bogie (they remained on their wheels in the track zone).

After derailment, train No. 45022 crossed for another 110 m, after which it stopped (the exact distance could not be determined due to damage to the railway line and railway vehicles). After derailing, and before stopping, train No. 45022 decoupled in place between the eight wagon of the Zacs-z series No. 33 72 7867 853-3 and the ninth wagon of the Zacs-z series No. 33 72 7867 846-7, so that after stopping the train, the distance between the end of the eighth and the beginning of the ninth wagon was 27.5 m.

The view of the accident site (the point of derailment) is shown in Figure No. 2.1.2.1.

**Figure 2.1.2.1:** The view of the accident site (the point of derailment)

In Figure No. 2.1.2.2. a schematic representation of the mutual position of the vehicles in the train after the accident is shown.

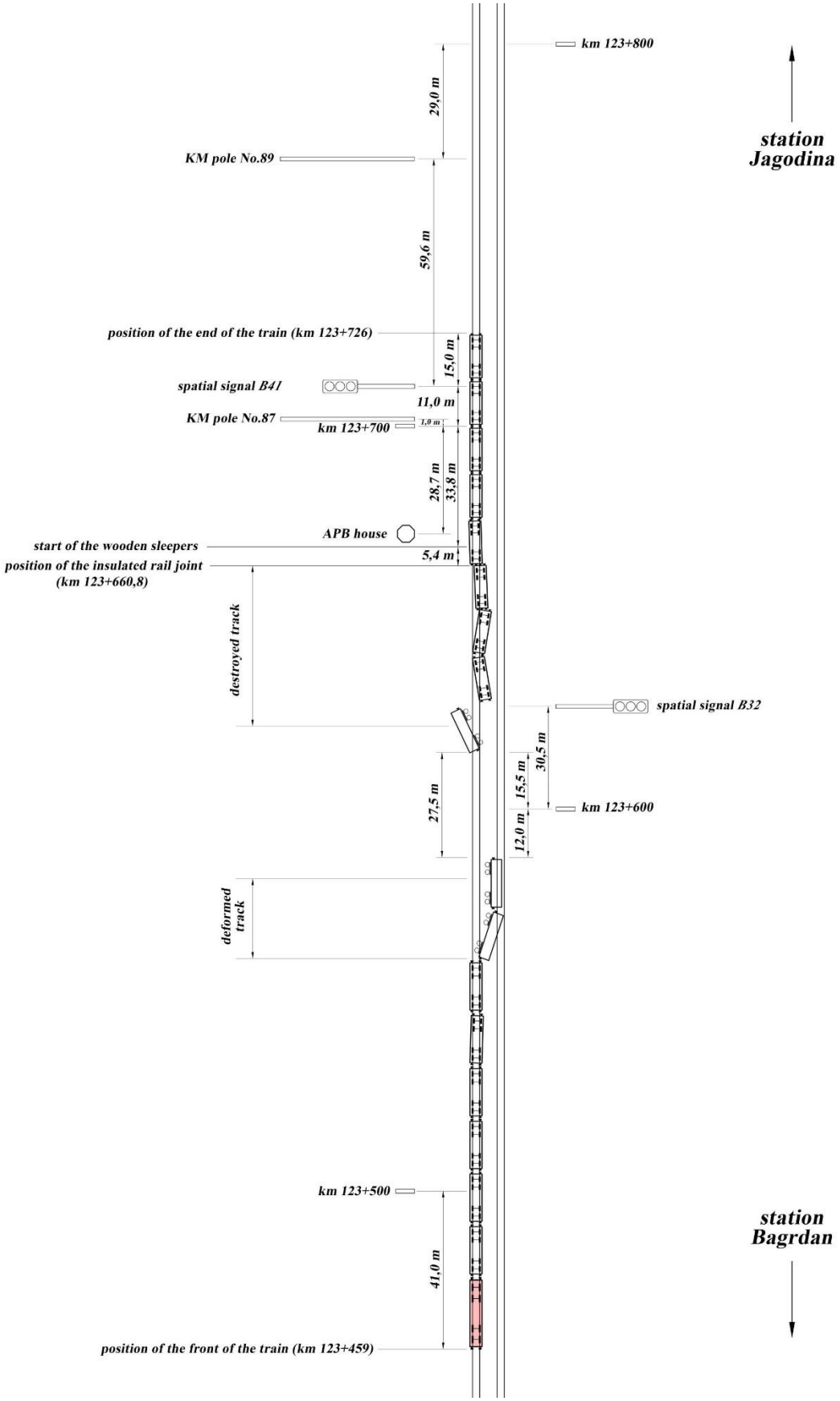



**Figure 2.1.2.2:** Accident site sketch (CINS)

Due to leakage of sulfuric acid (a substance that can endanger human health and is dangerous for the environment during uncontrolled release), members of the police and the fire and rescue brigade came to the accident site upon invitation.

Since there were no fatally injured nor injured people in this accident, there was no need to hire an emergency medical service.

Remediation of the consequences of this accident was performed by engaging professional services and resources of "IŽS"a.d. and "Srbija Kargo"a.d. with the assistance of members of the fire and rescue service.

Due to this accident, the railway traffic between the stations Bagrdan and Jagodina on both tracks of the two-track railway was interrupted. The traffic interruption lasted until 01.12.2020. at 22:00 when the railway was open for train traffic (the right track of the double-track railway was open for traffic and the traffic between the stations Bagrdan and Jagodina was organized in one track, on the right track).

### 2.1.3. Decision to launch investigation, the investigative team composition and conducting the investigation

CINS has been informed immediately upon the occurrence of this accident. Main Investigator for Railway Traffic received the first notification of the accident occurred on 28.11.2020. at 20:00 via telephone by the Main Wagon Dispatcher of "Srbija Kargo"a.d., and then also via telephone at 20:54 by the Head of Operations Department of "IŽS"a.d.

Based on the information received and the facts that the investigative team of CINS determined by on-site investigation of the accident on 29.11.2020. and on 01.12.2020., and also on 01.12.2020. at the station Bagrdan, CINS has launched the investigation of the accident in question in accordance with the Law on Investigation of Accidents in Air, Railway and Waterborne Traffic ("Official Gazette of RS" No. 66/15 and 83/18).

Composition of the Working group for investigation of the accident is determined by Decision No. 340-00-2/2020-02-1-8 of 04.12.2020. of the Director of CINS based on the Articles 6 and 32 of the Law on Investigation of Accidents in Air, Railway and Waterborne Traffic ("Official Gazette of RS" No. 66/15 and 83/18).

## 2.2. The accident background

### 2.2.1. Involved railway staff, contractors, other persons and witnesses

The train driver of the train No. 45022, employed at the railway undertaking "Srbija Kargo"a.d. participated in the accident in question.

The infrastructure manager "IŽS"a.d. staff did not participate in this accident, nor did the contractors, other persons and witnesses participate the accident in question.

### 2.2.2. The trains involved in this accident and their composition

In the accident in question, train No. 45022 was involved. The train operated on the route Dimitrovgrad - Šabac. The train consisted of a locomotive series 193-916, owned by the railway

undertaking “Srbija Kargo”a.d. and 17 (seventeen) wagon tanks of the Z series, with a total length of 253 m (72 axles) and a total gross weight of 1322 t. All wagon tanks that were part of train No. 45022 were loaded with sulfuric acid (RID 80/1830, OM 5912/20). According to the data obtained from the railway undertaking “Srbija Kargo”a.d. (consignment note for the consignment delivered in the attachment to the letter No. 1/2021-666 of 08.02.2021), the net weight of the entire consignments of sulfuric acid was 876,350 kg.

The table 2.2.2.1. gives overview of the wagons that were in the train No. 45022 composition.

**Table 2.2.2.1**: Overview of wagons of the train No. 45022 (viewed from the locomotive 193-916)

| Wagon Ordinal No. | Letter marking of the wagon series | Individual wagon No. | Owner | Holder | *ECM* |
|---|---|---|---|---|---|
| 1 | Zacs | 33 87 7864 174-0 | ATIR-RAIL | ATIR-RAIL | ATIR-RAIL |
| 2 | Zacs | 33 87 7866 951-9 | ATIR-RAIL | ATIR-RAIL | ATIR-RAIL |
| 3 | Zacs-z | 31 72 7865 006-2 | ELIXIR GROUP d.o.o. | ELIXIR GROUP d.o.o. | Elixir Zorka Mineralna đubriva Šabac |
| 4 | Zacs-z | 31 72 7865 011-2 | ELIXIR GROUP d.o.o. | ELIXIR GROUP d.o.o. | Elixir Zorka Mineralna đubriva Šabac |
| 5 | Zacs-z | 33 72 7867 810-3 | - | - | - |
| 6 | Zacs | 33 87 7866 749-7 | ATIR-RAIL | ATIR-RAIL | ATIR-RAIL |
| 7 | Zacs-z | 31 72 7865 013-8 | ELIXIR GROUP d.o.o. | ELIXIR GROUP d.o.o. | Elixir Zorka Mineralna đubriva Šabac |
| 8 | Zacs-z | 33 72 7867 853-3 | - | - | - |
| 9 | Zacs-z | 33 72 7867 846-7 | - | - | - |
| 10 | Zacs-z | 31 72 7865 005-4 | ELIXIR GROUP d.o.o. | ELIXIR GROUP d.o.o. | Elixir Zorka Mineralna đubriva Šabac |
| 11 | Zacs-z | 31 72 7865 009-6 | ELIXIR GROUP d.o.o. | ELIXIR GROUP d.o.o. | Elixir Zorka Mineralna đubriva Šabac |
| 12 | Zacs-z | 31 72 7865 010-4 | ELIXIR GROUP d.o.o. | ELIXIR GROUP d.o.o. | Elixir Zorka Mineralna đubriva Šabac |
| 13 | Zacs | 33 87 7868 736-2 | CFPM | ATIR-RAIL | ATIR-RAIL |
| 14 | Zacs | 33 87 7839 023-1 | ATIR-RAIL | ATIR-RAIL | ATIR-RAIL |
| 15 | Zacs | 33 87 7868 731-3 | CFPM | ATIR-RAIL | ATIR-RAIL |
| 16 | Zacs-z | 33 87 7866 801-6 | ATIR-RAIL | ATIR-RAIL | ATIR-RAIL |
| 17 | Zacs-z | 33 87 7864 462-9 | ATIR-RAIL | ATIR-RAIL | ATIR-RAIL |

Note: In Table 2.2.2.1. for wagons from train No 45022 composition, data based on excerpts from the European Virtual Vehicle Register (VVR) and the National Vehicle Register (NVR) of the Republic of Serbia are presented. No data were presented for the three cars whose individual numbers start with 33 72 because the cars were not registered in the National Vehicle Register (NVR) of the Republic of Serbia.

For three wagons that are not registered in the National Register of Vehicles (NVR) of the Republic of Serbia, and according to the data submitted by Elixir Group d.o.o., based on the Agreement on the purchase and sale of technical sulfuric acid concluded between Serbia Zijin Copper d.o.o. Bor (as a seller) and Elixir Group d.o.o. Sabac (as a buyer) on 31.12.2019. with a validity period until 31.12.2029. (serial Nos. 10327 and 334/1), Serbia Zijin Copper d.o.o. Bor the owner of the wagon for the transport of sulfuric acid has given them to Elixir Group d.o.o. Šabac in lease during the term of the Agreement.

A total of 8 (eight) wagon tanks of the Z series derailed out of the train composition.

The view of the Zacs wagon tanks that derailed in the accident in question is shown in Figure 2.2.2.1.


**Figure 2.2.2.1:** Appearance of Zacs series wagon that derailed in the accident in question

The wagons of the series *Za* that participated in the accident in question are four-axle special closed wagons for the transport of sulfuric acid with appropriate filling and dispensing systems.

### 2.2.3. Infrastructure and SS system

The main arterial line 102: Belgrade Center - Junction "G" - Rakovica - Mladenovac - Lapovo - Niš - Preševo - state border - (Tabanovce), between the stations Bagrdan and Jagodina, is a two track electrified line with monophase system 25 *kV* 50 *Hz*. According to its characteristics, the railway in question is mostly flat. The designed axle load is 225 kN and the axle load per meter is 80 kN/m. The curtain is made of gravel of limestone origin. The track is welded in DTŠ. On the left track on the respective part of the line, the projected speed is 120 km/h, the minimum radius of curvature is R = 800 m and the maximum slope is -4.8 ‰ (from km 122+900 to km 123+320 fall 4.8 ‰, viewed in the direction of increasing stationing).

The track was repaired in 1986 and 49E1 type rails were installed, which were welded in DTŠ. On the left track between the stations Bagrdan and Jagodina, sleepers have been installed according to the following:

- from km 120+701.45 to km 125+295 sleepers JŽ70, distance 60 cm, 1986., accessories SKL 2;
- from km 125+295 to km 126+864 sleepers ИМ2, distance 65 cm, 1973., accessories SKL 2;
- from km 126+864 to km 128+500 wooden sleepers, distance 65 cm, 1973., accessories K;
- from km 128+500 to km 130+300 wooden sleepers JŽ70, distance 65 cm, 2005., accessories K;
- from km 130+300 to km 135+692.55 wooden sleepers, distance 65 cm, 1982., accessories K.

Single and double insulated joints are installed on wooden sleepers.

On the left track, anti-travel devices are installed according to the following:

- from km 120+019 to km 120+071.25 type "MATHEE", 74 pieces installed;

- from km 120+553.17 to km 120+607.80 type “MATHEE”, 74 pieces installed;
- from km 120+921 to km 120+971 type “MATHEE”, 74 pieces installed;
- from km 134+594 to km 134+645.55 type “MATHEE”, 72 pieces installed;
- from km 134+725.80 to km 134+777 type “MATHEE”, 74 pieces installed;
- from km 134+989.37 to km 135+041.90 type “MATHEE”, 72 pieces installed.

According to the timetable booklet 9.1 - 9.2 (which was valid at the time of the accident in question), on the section of the line between the stations Bagrdan and Jagodina, the maximum allowed speed on the left track of the two-track line was 100 km/h. According to the same timetable booklet, at the distance between stations Lapovo - Jagodina, on the left track of the two-track line, there was one limited speed (from km 117+100 to km 120+900 with 30 km/h due to poor terrain; it also includes the area of the station Bagrdan), and at the distance between stations Bagrdan - Jagodina, on the left track of the two-track railway, there were two limited speeds: from km 120+900 to km 125+100 with 70 km/h (due to weak terrain) and from km 130+400 to km 134+692 with 50 km/h (due to weak terrain).

On the section of the line between the stations Bagrdan (km 120+300) and Jagodina (km 135+236) on the left track of the two-track line, there were two restricted speed runnings: from km 126+800 to km 128+100 with 70 km/h (introduced on 12.08.2020 by telegram “IŽS”a.d. No. 51 from 12.08.2020, due to rotten sleepers) and from km 130+400 to km 133+300 with 30 km/h (introduced by telegram “IŽS”a.d. No. 114 of 20.11.2020 due to rotten sleepers and poor track geometry).

Bagrdan station is an official point located at km 120+300 of the main line No. 102, and the station Jagodina is an official point located at km 135+236 of the main line No. 102. In terms of regulating the train traffic, these are intermediate stations that regulate the traffic of opposite and consecutive trains (crossing, overtaking and tracking trains).

The distance between the stations Bagrdan - Jagodina is provided by the SS system type SpDrS 64 of Siemens manufacturer. Traffic of trains between Bagrdan and Jagodina stations is regulated in the APB regime in block spatial sections according to the provisions of the Rulebook on types of signals, aspect of signals and markings on the line (“Official Gazette of RS” No. 51/20) and the Traffic Rulebook (“Official Gazette of ZJŽ”, No. 3/94, 4/94, 5/94, 4/96 and 6/03). The block spatial sections are equipped with APB and the traffic of successive trains is regulated by automatic placement of spatial signals by the train. The entrance and exit signals are operated by the train dispatcher of the official point to which these signals belong. On the double-track line, train traffic between Bagrdan and Jagodina stations is operated regularly on the correct track, namely trains from the direction Belgrade - Niš on the correct right track, and trains from the direction Niš - Belgrade on the correct left track. When the need arises, trains can also run on the wrong track. The traffic on the irregular track (train driving in the direction Belgrade - Niš on the left and Niš - Belgrade on the right track) takes place in the distance between the stations with the issuance of a drive order (there are no spatial signals nor entrance signals for driving on an irregular track). Track occupancy control is performed through insulated sections with two-rail isolation, with eight APB sections (associated relay and power supply devices, spatial signals, track chokes and track parts of autostop devices). At the distance between the stations Bagrdan - Jagodina, there are also three automatic level crossings RVV-1 (block 1 of the station Bagrdan), RVV-2 (Lanište) and RVV-3 (Bukovče) secured with half-barriers and road light signals of the Siemens system.

Marking for the railway line was taken according to the Regulation on the categorization of railways belonging to the public railway infrastructure (“Official Gazette of RS”, No. 92 of 29.06.2020).

The description of the railway and facilities is given according to the data obtained from "IŽS"a.d. (Letters of the Sector for Traffic Affairs No. 15/2021-21 dated 11.01.2021, the Sector for Construction Affairs No. 20/2021-97 dated 19.01.2021 and the Sector for Electrical Affairs No. 21/2021-24 dated 11.01.2021, submitted in the attachment to the letter "IŽS"a.d. No. 1/2021-169 from 28.01.2021).

### 2.2.4. Communication tools

The Bagrdan station is equipped with a forty-five-part telephone telecommunication (TT) desk manufactured by Siemens-EI, and the station Jagodina is equipped with an eighty-part telephone telecommunication (TT) desk manufactured by "Temax" in which all telephone connections for the respective track are equipped, which are handled in accordance with the Instructions for the use of telecommunication dispatching, station and rail telephone systems manufactured by "Siemens-EI" and "Temax", registration No. 100, record No. 20/2013-1139 from 19.06.2013. of the Directorate of Infrastructure.

During the regulation of train traffic between the neighboring stations Bagrdan and Jagodina, mutual agreement of train dispatchers in stations Bagrdan and Jagodina (requesting and giving permits, advising train departures, giving check-outs and other related to train traffic) is done on the line of OV Lapovo - Stalać. The recording of conversations on this line is done bilaterally, in the stations Lapovo and Stalać. In addition to the train dispatchers of the Bagrdan and Jagodina stations, the train dispatchers of the stations Lapovo, Ćuprija, Paraćin and Stalać are also connected to this line.

Communication between the staff that regulates the traffic (train dispatcher) in the stations Bagrdan and Jagodina with the staff of traction vehicles (train drivers) is done on the line of GV Lapovo - Stalać. The recording of conversations on this line is done bilaterally, in the stations Lapovo and Stalać. Communication between the staff regulating the traffic (train dispatcher) with the staff of traction vehicles (train drivers) can also be achieved through track telephones that are installed next to the entrance and spatial signals. This line is not connected to the recording device, but the conversations are conducted in the presence of witnesses (train dispatchers of the neighboring station), so that this way of communication is considered evidence-based communication.

In case of stopping of working (recording) of the recording devices, the stations where the recording devices are located (Lapovo and Stalać) are obliged to inform the train dispatchers of all stations by phonogram. In that case, the regulation of train traffic is done by communication in the presence of witnesses in accordance with Article 14 of Rulebook 2, Traffic Rulebook ("Official Gazette of ZJŽ" No. 3/94, 4/94, 5/94, 4/96 and 6/03).

The description of the means of communication is given according to the data obtained from "IŽS"a.d. (Letters of the Sector for Traffic Affairs No. 15/2021-21 dated 11.01.2021 and the Sector for Electrical Affairs No. 21/2021-24 dated 11.01.2021, submitted as an attachment to the letter "IŽS"a.d. No. 1/2021-169 from 28.01.2021).

### 2.2.5. Works performed on or near the accident site

In the vicinity of this accident site no works were performed.

### 2.2.6. Activation of the emergency plan on the railway and sequence of events

The railway undertaking "Srbija Kargo"a.d. has, immediately after the occurrence of the accident in question, informed CINS, that is, the Main Investigator for Railway Traffic, and then the same was done by the infrastructure manager "IŽS"a.d. The infrastructure manager "IŽS"a.d. and the railway undertaking "Srbija Kargo"a.d. have formed a joint investigative committee which conducted investigation of the accident in accordance with applicable regulations. Upon conclusion of the Draft Final Report of the investigation by CINS, no Report on investigation by the joint investigative committee of the infrastructure manager and the railway undertaking has been submitted.

According to the data submitted in attachment of the Letter from "IŽS"a.d. (Letter of the Sector for Traffic Affairs No. 15/2021-21 од 11.01.2021.), immediately upon occurrence of the accident in question, section of the main arterial line 102: Belgrade Center - Junction "G" - Rakovica - Mladenovac -Lapovo - Niš - Preševo - state border - (Tabanovce), between the stations Bagrdan and Jagodina was closed for the traffic of trains (on 28.11.2020. at 19:27 left and right track were closed). Lifting of the derailed wagons and their removal from the accident site was done by hiring breakdown trains "IŽS"a.d., the Center for breakdown train affairs, namely OJ for breakdown train affairs Kraljevo and OJ for breakdown train affairs Niš. After removing the derailed and overturned wagons from the right track of the two-track track and creating a free profile, on 01.12.2020. at 22:00 the right track of the double-track railway between Bagrdan and Jagodina stations was open for train traffic. In the period from 23.12.2020. at 04:00 to 24.12.2020. at 23:01, a continuous closure of the right track between Bagrdan and Jagodina stations was held, during which, by engaging the equipment and manpower of breakdown trains, overturned and derailed wagons and parts were lifted and loaded on other Rgs and Eas series wagons and transferred to Jagodina station, after which the members of the Sector for Construction Affairs took measures to organize the repair of the damage caused to the left track of the two-track railway between the stations Bagrdan and Jagodina. The works on the reconstruction and preparation of the left track for traffic were completed on 31.12. 2021. at 16:00, when the left track of the two-track railway between the stations Bagrdan and Jagodina was open for train traffic with the introduction of restricted speed running from 20 km/h, from km 123+450 to km 123+800.

### 2.2.7. Activation of the emergency plans of public rescue services, police and medical services and sequence of events

Due to this accident, members of MUP RS, the Police Directorate, the Police Administration in Jagodina, Traffic Police Department Jagodina, the Traffic Police Office on the state road IA rank, members of MUP RS, the Police Directorate, Sector for Emergency Situations, Emergency Situations Department in Jagodina and member of MUP RS, the Police Directorate, the Police Administration in Jagodina, Criminal Police Department, Economic Crime Sector.

By the letter of MUP RS, the Police Directorate, he Police Administration in Jagodina, Traffic Police Department Jagodina, the Traffic Police Office on the state road IA rank 03/21/4/3 No. 221-7040/21 of 11.03.2021., data were submitted that the on-duty service of the Traffic Police Office Jagodina received a notification from the on-duty service of the police station Lapovo that it came to derailment of wagon-tanks from the arterial line near the Bagrdan strait. A patrol of the Traffic Police Office on the state road of the IA rank (one official vehicle with police markings and one police officer) was sent to the accident site, which determined that the territory covered

by the Traffic Police Office on the state road of the IA rank was not endangered for traffic. The patrol remained on the site to provide assistance and security to the Jagodina Fire Brigade because they were operating from the direction of the state road IA rank No. 1. Also, the JP "Putevi Srbije" was informed, which sent to the scene its on-duty team for securing with barriers.

By the letter of MUP RS, Sector for Emergency Situations 09 No. 217-260/21 of 18.02.2021., data were submitted that on 28.11.2020. at 19:56, the on-duty service of the Police Administration in Jagodina reported to the duty service of the Fire and Rescue Company Jagodina that on the main arterial line, direction Niš - Belgrade, between the railway stations Jagodina and Lapovo, on the territory of the Bagrdan strait, there occurred a derailment of the wagon tanks loaded with sulfuric acid. Three vehicles with seven firefighters were sent to the intervention from the Fire and Rescue Company of Jagodina, and in regional cooperation, one vehicle with three firefighters and rescuers were sent from the Fire and Rescue Department of Batočina. At 20:50, a total of ten members of the fire and rescue unit with four fire trucks, a police patrol and the train driver of the train No. 45022 were on the site. At the time of arrival at the scene, the traffic police patrol was securing the scene (fire trucks were stopped in the stop lane of the highway) until the arrival of the team of JP "Putevi Srbije", which secured the stopped fire vehicles with light signals and cones. The traffic on the highway was not interrupted. On the spot, the team of the fire and rescue unit, equipped with adequate protective equipment, performed a closer scouting. On that occasion, it was determined that six wagon tanks had derailed, two of which were on wheels, and four overturned on their sides. A small amount of sulfuric acid leaked from the three overturned tanks, while the leak was more extensive from one tank.

It was not possible to seal the leak with the equipment owned by the fire and rescue company. At approximately 21:30, representatives of the railway arrived at the scene and, with the technical assistance of members of the fire and rescue unit, toured the scene of the accident. In agreement with the representatives of the railway, at 22:30 a part of the members of the fire and rescue team was withdrawn from the scene. One fire truck with two rescue firefighters was left at the scene to be on duty. The permanent duty lasted until 01.12.2020. at 16:30. The on-site inspection was held on 28.11.2020. in the period from 21:40 to 22:30, performed by the inspector of the Criminal Police Department in Jagodina, Economic Crime Sector, forensic technician, employee of the Police Administration in Jagodina and inspector of the Department for Emergency Situations in Jagodina.

## 2.3. Dead, injured and material damage

### 2.3.1. Passengers, third parties and the railway staff including contractors

In the accident in question, there were no fatally injured nor injured.

### 2.3.2. Goods, luggage and other assets

In this accident due to leakage from the damaged wagon tanks, it came to loss of the part of goods (sulfuric acid). After reloading the goods (sulfuric acid) from the derailed wagons, the lack of goods was determined according to the following:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| from wagon No. | 33 72 7867 810-3 | missing | 2.16 t | in the amount of | 16.20 | EUR |
| from wagon No. | 31 72 7865 013-8 | missing | 2.04 t | in the amount of | 15.30 | EUR |
| from wagon No. | 33 72 7867 853-3 | missing | 5.28 t | in the amount of | 39.60 | EUR |
| from wagon No. | 33 72 7867 846-7 | missing | 28.00 t | in the amount of | 210.00 | EUR |
| from wagon No. | 31 72 7865 005-4 | missing | 2.09 t | in the amount of | 15.67 | EUR |
| from wagon No. | 31 72 7865 009-6 | missing | 1.75 t | in the amount of | 13.13 | EUR |
| from wagon No. | 31 72 7865 010-4 | missing | 51.65 t | in the amount of | 387.38 | EUR |
| from wagon No. | 33 87 7868 736-2 | missing | 4.00 t | in the amount of | 30.00 | EUR |
| | | **missing in total** | **96.97 t** | **in the amount of** | **727.28** | **EUR** |

The mass of goods (sulfuric acid) lost due to leaks from the damaged wagon tanks is stated according to the document Notice on the performed reloading of the wagons damaged in the accident on 28.11.2020. on the open railway Jagodina - Bagrdan No. 34-6-4/2020-589 of 30.12.2020. of the station Lapovo Marshalling Yard, Organizational unit for traffic and transport Požarevac, Sector for traffic and transport, "Srbija Kargo"a.d.

The amount of material damage caused by the loss of goods (sulfuric acid) is shown on the basis of data provided by "Srbija Kargo"a.d. submitted on 02.06.2021. by e-mail as well as Elixir Group d.o.o. Šabac by e-mail from 01.07.2021. The damage is expressed in euros (EUR).

According to the official middle exchange rate of the National Bank of Serbia on 28.11.2020., which amounted to 1 EUR (Euro) = 117.5834 RSD (Dinar), the total material damage to the goods (sulfuric acid) caused by the accident in the amounts to 85 516.06 dinars (RSD).

### 2.3.3. Railway vehicles, infrastructure and the environment

In the accident in question the railway vehicles and infrastructure have been damaged. On the property of the third parties, no material damage has been caused.

The material damage structure is given according to the following:

| | | |
|---|---|---|
| Damage to the railway vehicles (wagons in train composition): | 18 162 952.29 | RSD |
| Total costs of lifting of derailed wagons: | 16 968 002.00 | RSD |
| On the railway line (superstructure and substructure): | 6 498 932.00 | RSD |
| On KM facilities: | 1 968 872.00 | RSD |
| **Total direct material damage:** | **43 598 758.29** | RSD |

There was no damage to SS facilities and means of communication

The damage is stated in the official currency of the RS (Dinar - *RSD*).

According to the official middle exchange rate of the National Bank of Serbia on 28.11.2020., which amounted to 1 EUR (Euro) = 117.5834 RSD (Dinar), the total material damage to the infrastructure and the railway vehicles in the accident in question amounts to 370 790.08 EUR.

The material damage in this report is presented on the basis of invoices, estimates, ie documents confirming the stated amounts of damage submitted by "IŽS"a.d. and "Srbija Kargo"a.d.

### 2.3.4. External conditions - weather conditions and geographical characteristics

The place of occurrence of the accident in question is located in the area of the municipality of Jagodina, in the unpopulated area. The configuration of the terrain near the place of the accident is plain.

The geographical coordinates of the accident site are: 44° 03' 41,4" *N* and 21° 12' 28,6" *E*.

The area where the accident in question occurred is not populated (there are no residential buildings near the place of the accident).

The scene of the accident is approximately 35 m from the state road IA rank, marking A1 and approximately 300 m from the gas station "Gazprom" (which is located next to the mentioned state road). On the other side of the mentioned state road, there is the river Velika Morava, approximately 500 m away from the site where the accident in question occurred.

The section of the line on which the accident took place is in the direction and on a slope of 0.3‰ (ascent, seen in the direction of train movement, ie, in the direction of decreasing stationing).

By the letter of the Republic Hydrometeorological Institute No. 925-1-391/2020 of 29.12.2020., data were submitted that on 28.11.2020. in the area between the stations Bagrdan and Jagodina, the maximum air temperature was 0.3°C, the minimum -0.8°C, and the minimum air temperature at 5 cm from the ground -1.1°C. There was no precipitation during the day, nor were meteorological phenomena observed. The ground was moist throughout the day, and the meteorological visibility was from 1 to 10 km (meteorological visibility is the transparency of the atmosphere expressed by the greatest distance at which the observer of normal vision can recognize familiar objects in the environment, when observing during the day, and light sources at observation at night). A light wind was blowing with a maximum gust of 3.4 to 5.4 m/s. It was cloudy all day long.

At 18:00 the air temperature was -0.4°C, air pressure 1006.6 mbar, relative humidity 98% and visibility 1.0 km. The middle wind speed was 0.5 m/s, the middle wind direction was northwest, the maximum wind speed was 1.6 m/s and the maximum wind direction was west-north-west.

At 19:00 the air temperature was -0.4°C, air pressure 1006.3 mbar, relative humidity 98% and visibility 1.0 km. The middle wind speed was 0.5 m/s, the middle wind direction was northwest, the maximum wind speed was 1.8 m/s and the maximum wind direction was west-north-west.

At 20:00 the air temperature was -0.1°C, air pressure 1006.4 mbar, relative humidity 96% and visibility 2.0 km. The middle wind speed was 0.5 m/s, the mean wind direction was west, the maximum wind speed was 1.5 m/s and the maximum wind direction was west-north-west.

The data were issued on the basis of measurements and observations at the Meteorological Station Ćuprija, which is climatologically representative of the requested area.

At the time of the investigation of the accident in question on 29.11.2020. by the CINS investigative team, it was a day. The weather was cloudy, with no wind. Visibility was good. Occasionally it rained lightly. The ground was moist. The air temperature was approximately 0°C.

# 3. Minutes on the investigation and examination

Data, facts and evidence regarding the occurrence of the serious accident in question were collected and determined on the basis of:

- On-site investigation by the investigative team of CINS;
- wagons examination done in the workshop;
- materials submitted by infrastructure manager "IŽS"a.d.;
- materials submitted by railway undertaking "Srbija Kargo"a.d.;
- materials submitted by "Elixir Group" d.o.o. Šabac;
- materials submitted by "ATIR RAIL" и
- materials submitted by "Serbia Zijin Copper" d.o.o. Bor.

For the accident in question, on-site investigation and investigation were conducted by the joint investigative committee, composed of the infrastructure manager "IŽS"a.d. and the railway undertaking "Srbija Kargo"a.d.

## 3.1. Summary of testimonies

The CINS working group on 19.02.2021. interrogated the train driver who was operating at the train No. 45022 and who was employed at the railway undertaking "Srbija Kargo"a.d. at the time of this accident; at CINS' premises.

The Minutes on hearing of the employee who was operating the train No. 45022 (the train driver) and the Report on irregularities during operation of the traction vehicle staff (EV-38) of 28.11.2020. was submitted by "Srbija Kargo"a.d.

From "IŽS"a.d. the Report of the train dispatcher on irregularities during operation (SP-9) No. 0744 of 28.11.2020. issued by the train dispatcher of the station Jagodina and Report of the train dispatcher on irregularities during operation (SP-9) No. 0670 of 28.11.2020. issued by the train dispatcher of the station Bagrdan, who were on duty at the time of occurrence of the accident in question.

Summary of testimonies for the train driver who was on duty at the train No. 45022 was given according to the hearing conducted by the Working Group of CINS.

### 3.1.1. The railway staff

The train driver stated that the train drive from the station Crveni Krst departure station proceeded normally without unusual jerks when starting or stopping the tanks train. He noted that he had restricted speed running at 70 km/h on the section of the railway near the Lanište stop and that he continued at that speed until the spatial signal B-41, when at a distance of approximately 30 m he noticed that the rails were moved on that section of the railway, approximately 50 cm to the right in the length of 60 to 100 cm and that the deformation was behind the spatial signal B-41, probably in front of the house but certainly near the house of the SS device. He had not noticed the deformation before because it was already dark and he was driving with a reflector. The passage of the locomotive over the deformation threw him first to the right, then to the left, he only managed to activate both handles for air and electric braking, after a few seconds he felt a great longitudinal jerk and loss of voltage. He noted that at that moment he did not feel any collapse or bouncing of the locomotive, only transversal jerks. On the presented data from the

register devices of the locomotive that there was an interruption of fast braking by the train driver for a few seconds, he stated that at the time of the jerk, he was holding the brake valve handles, but he does not remember whether he moved them during the jerk.

### 3.1.2. Other witnesses

There were no witnesses of this accident.

## 3.2. Safety management system

### 3.2.1. Organizational frame and manner of issuing and executing orders

In accordance with the applicable Rulebook of Safety Management System, "IŽS"a.d. has informed CINS on the accident occurred.

In accordance with the applicable Safety Management System Manual (SMS), "Srbija Kargo"a.d. has informed CINS on the accident occurred.

The infrastructure manager "IŽS"a.d. and the railway undertaking "Srbija Kargo"a.d. have, in accordance with the Law on Railway Traffic Safety ("Official Gazette RS" No. 41/2008), formed the joint investigative committee which conducted the investigation of the accident in question. By completion of the draft Report on investigation by CINS, no Report on investigation of the joint investigative committee of infrastructure manager and the railway undertaking has been submitted.

### 3.2.2. Requirements to be fulfilled by the railway staff and the manner they are applied

"Srbija Kargo"a.d. has, through the established Safety Management System Manual (SMS), secured competence management, that is, of the processes, that all the employees directly involved in the performance of the railway traffic, be trained and competent, as well as planning of the workload.

Regarding the accident in question in which the train driver was involved, employee of "Srbija Kargo"a.d., all activities related to professional training, competence and working time planning were carried out in accordance with applicable regulations.

"IŽS"a.d. as the infrastructure manager has through the Rulebook of the safety management system (SMS) secured competence management, that is, of the processes, that all the employees directly involved in the performance of the railway traffic, be trained and competent, as well as planning of the workload.

### 3.2.3. Procedures for internal audits and controls and their results

"IŽS"a.d. as the infrastructure manager has established Rulebook of the safety management system. The safety management system includes the organization and all procedures and processes established in "IŽS"a.d. for the safe operation of railway traffic.

Risk control related to the maintenance of railway infrastructure (subsystems infrastructure, energy, control, management and signaling - railway part) and railway vehicles that is used by

"IŽS"a.d. for maintenance, is based on the implementation of defined activities of regular and corrective maintenance and their monitoring and control. Regular and corrective maintenance includes constant supervision, controls, inspections, fixings and repairs.

Requirements, standards and procedures for maintenance of "IŽS"a.d. are determined on the basis of legal regulations, general and individual acts of the company, manufacturer's instructions and standards.

Regarding the accident in question, regular and corrective maintenance of the track was not performed in accordance with the applicable regulations.

## 3.3. Relevant international and national regulations

### 3.3.1. Law on Railway ("Official Gazette of RS" No. 41/2018)

II Railway infrastructure

...

1. Management of public railway infrastructure

...

Obligations of the infrastructure manager

Article 10 (excerpt)

The infrastructure manager is obliged to ensure safe and uninterrupted organization, regulation and management of railway traffic, uninterrupted access and use of public railway infrastructure and access to service facilities entrusted to him for management and services he provides in these facilities to all interested applicants for infrastructure capacity allocation, under equal, non - discriminatory and transparent conditions, as well as permanent, uninterrupted and quality maintenance and protection of railway infrastructure.

...

7. Maintenance of public railway infrastructure

Article 55 (excerpt)

Public railway infrastructure must be maintained in a condition that ensures safe and uninterrupted railway traffic, as well as quality and orderly transport, in accordance with the regulations governing safety in railway traffic and technical regulations and standards. Maintenance of public railway infrastructure includes regular maintenance and corrective maintenance. The technological unit for maintenance consists of all elements of the public railway infrastructure. Maintenance intervenes on certain elements, which thus bring them into a condition that does not reduce the technological function of the railway and prevents the creation of bottlenecks on the railway. The infrastructure manager by a special act approves the introduction of any restricted speed running or permanent speed limit in relation to the projected parameters of the railway, with an explanation of the reasons for reducing traffic speeds and reducing the capacity of the railway, prescribing technical measures for their reconstruction, as well as the planned deadline, which he submits to the Republic Inspector for Railway Traffic.

Article 56

Works on regular maintenance are in particular: maintenance and replacement of elements of the superstructure of the railway (switches, tracks and track connections), with the same or other type by which the parameters of the railway are maintained at the designed level; works on the substructure of the railway line (drainage and arrangement of slopes); removal of trees, bushes and shrubs from the railway belt, replacement and renovation with the same or other materials of culverts and bridges up to 10 m in length, if their opening is not changed; replacement and supplementation of elements of signaling - safety and telecommunication devices and plants; replacement and supplementation of elements of stable electric traction plants, as well as other plants for transformation and transmission of electricity for train traction; adaptation and repair of buildings of railway official positions and other facilities at railway official places which are in the function of railway traffic which do not change their construction and external appearance; cleaning of snow and ice from tracks, plants and surfaces on station platforms, stops, etc.

...

### 3.3.2. Law on Railway Traffic Safety ("Official Gazette of RS" No. 41/2018)

III. RAILWAY SAFETY MANAGEMENT IN RAILWAY TRAFFIC

1. Guaranteeing safety in railway traffic

Article 5.

The Ministry in charge of transport affairs (hereinafter: the Ministry), the Directorate, the Center for Investigation of Accidents in Transport (hereinafter: the Center), the infrastructure manager (hereinafter: the manager) and the railway undertaking, each in accordance with the tasks it performs, provide: 1) that the safety of railway traffic in the railway system is preserved, and where practicable, constantly improved, with priority being given to accident prevention; 2) that safety regulations and safety are applied transparently and non-discriminatory; 3) to accelerate the development of a unified railway system. The manager and the railway undertaking are responsible for the safe operation of the railway system and the control of risks associated with it, by implementing the necessary risk control measures, in cooperation with each other, applying national safety regulations and standards and establishing safety management systems in accordance with this law.

…

V. INFRASTRUCTURE SUBSYSTEM

…

Maintenance of infrastructure subsystems

Article 28

The manager is obliged to maintain the super and substructure of the railways in a condition that ensures safe and regular railway traffic.

…

IX. RAILWAY VEHICLES

…

2. Vehicles maintenance

Person in charge of maintenance

Article 53. (excerpt)

The holder of the vehicle is obliged to appoint a person in charge of its maintenance for each vehicle he uses. The person in charge of maintenance can also be a railway undertaking, manager or vehicle owner. The person in charge of maintenance is registered in the National Register of Railway Vehicles. The vehicle cannot be used unless a person has been designated to maintain it. In addition to the responsibility of the railway undertaking and the manager for the safe operation of trains, the person in charge of maintenance, through the maintenance system, is responsible for ensuring that the vehicles in charge of maintenance are in a condition that allows them to move safely.

…

Certification of the person in charge of maintenance of freight wagons

Article 54 (excerpt)

The person in charge of maintaining the trucks must be certified in accordance with the regulations issued by OTIF. The Directorate or other accredited certification body from the Republic of Serbia, the OTIF Contracting States or the States of the European Union shall issue a certificate to the person in charge of maintenance of freight wagons on the form prescribed by OTIF. The certificate referred to in paragraph 2 of this Article shall be issued with a validity period not exceeding five years.

…

Vehicle maintenance

Article 55.

Vehicles must be maintained in a condition that ensures safe railway traffic.

### 3.3.3. Law on Railway System Interoperability (“Official Gazette of RS” No. 41 of 31.05.2018)

III License for use

...

Vehicle type license

Article 22 (excerpt)

The types of all vehicles registered in the Republic of Serbia, of any manufacturer, must be approved.

The license for the type of vehicle is issued by the Directorate on the prescribed form and in the form of a decision

...

Vehicles conforming to an approved type must obtain individual licenses for use issued on the basis of a procedure to verify compliance with the approved type and a declaration of conformity to the vehicle type.

...

VI Penalty provisions

Article 36 (excerpt)

A fine of 700,000 to 2,000,000 dinars shall be imposed on a company, other legal entity or a responsible person in a legal entity for a misdemeanour if:

...

7) uses railway vehicles that do not have a type license (Article 22, paragraph 1);

8) uses vehicles without an individual license for use (Article 22, paragraph 7);

### 3.3.4. Rulebook on rolling stock maintenance ("Official Gazette of RS", No. 101/2015, 24/2016 and 36/2017)

**Note:** At the time of occurrence the accident in question, this Rulebook was applicable.

Article 5. (excerpt)

Maintenance of traction-buffer equipment

...

12.As part of the regular maintenance of buffer equipment, the following is performed:
1) checking the identity of the buffer at the front of the vehicle;
2) check the fixation of the buffer for the front carrier;
3) buffer stroke check;
4) check the height of the buffer axis above the upper edge of the rail;
5) lubrication of the buffer plate, buffer casing and plunger;
6) checking for damage, cracks, fractures and deformations of the buffer.

13. On regular repairs, except for works performed and on periodic inspections, the buffer devices are disassembled, worn or damaged parts are repaired or replaced with correct ones, and complete anti-corrosion protection is performed.

...

Annex 6. (excerpt)

1. Maintenance of bogies

The deadlines for periodic inspections and regular repairs of the bogie take place according to the maintenance cycles of the railway vehicle prescribed by the manufacturer.

...

### 3.3.5. Instruction on unique criteria for Control of Railway Conditions on the Railway Network JŽ, Instruction 339 ("Official Gazette ZJŽ" No. 2/2001 and 4/2004)

**Note:** By the decision of "IŽS"a.d. No. 4/2015-51-17 of 29.12.2015. on the takeover of regulations issued by the ZJŽ as its internal acts, this Instruction was taken over and is still in force on "IŽS"a.d.

Article 2. (excerpt)

...

6. The record should contain the following basic elements: what is being examined and by what, the date of recording the track and the stationing of the recorded track or section, a diskette with a **graphic and analytical presentation of the technical condition of the measured track or section of the track.**

---

**Important note:**

1. The emphasized part of the text in item 2, under 6, with the amendments from 2004, replaced the text from the previous edition of Instruction 339 (2001), which read:

The record should contain the following basic elements: what is being examined and by what, the date of recording the track and the stationing of the recorded track or section, r**egistered places that directly endanger the safety of railway traffic.**

2. In item 7 of the valid edition of Instruction 339, the text under 5 from the previous edition of Instruction 339 (1989), is missing from Article 7, which read as follows:

**Registered errors that directly endanger traffic safety must be rectified on the same day after the passing of the track inspection coaches. If this is not possible, appropriate safety measures should be taken.**

---

Item 9, sub-item 3 (excerpt) of the valid Instruction 339 from 2001/2004:

- "*B* - errors due to which it is necessary to plan works for their elimination"
- "*C* - errors that are above the operating limits **and that require urgent elimination or reduction of speeds"**

---

**Important note:**

The emphasized part of the text in item 9, under 3 replaced the text of the earlier edition of Instruction 339 (1989), which read:

**"And which must be removed immediately because they endanger traffic safety."**

---

Item 9 (excerpt) of the valid Instruction 339 from 2001/2004:

The condition of the track is assessed on the basis of the total length of errors in groups "B" and "C" at a length of one kilometer.

The condition of 1km of the track is:

- Satisfactory, up to 250 m errors in group B and up to 25 m errors in group C, ie ≤250/25 (B/C).
- Unsatisfactory, over 250 m errors in group B and over 25 m errors in group C, ie >250/25 (B/C).

---

**Important note:** Instruction 339 was amended in 2001. when the last paragraph from item 9 was deleted, which in the previous edition of Instruction 339 (1989) read:

**Immediately after the track inspection coach run, works are undertaken on all kilometers where the length of errors greater than 200/20 appears, and it must be determined in the Minutes how this situation occurred. After determining the reasons for the occurrence of errors and their location, the plan for improving the condition of the observed kilometer is immediately developed.**

---

### 3.3.6. Rulebook on technical conditions and maintenance of railway lines superstructure No.: 340-201-2/2016 ("Official Gazette of RS" No. 39/16)

**Note:** Rulebook on Amendments to the Rulebook on technical conditions and maintenance of railway lines superstructure ("Official Gazette of the RS", No. 74/16) amended this Rulebook.

3. Sleepers

Type and use of sleepers

Article 8.

Sleepers made of prestressed concrete and wooden sleepers are installed on the tracks.

Concrete sleepers must be in accordance with SRPS EN 13230, and wooden sleepers in accordance with SRPS EN 13145.

Concrete sleepers must have an electrical resistance in the dry state of at least 6000 Ω and 3000 Ω in the wet state.

Used wooden sleepers are installed during the individual replacement of sleepers.

Switches are mounted on wooden and concrete sleepers.

For new, renovated or upgraded main arterial lines, 2.60 m long concrete sleepers are installed for the 60E1 rail and elastic fastening accessories with a slope of leaning surface of 1: 40.

Concrete sleepers 2.40 m and 2.50 m long can be installed on regional and local railways.

Concrete sleepers are not installed on rail joint and on a length of 30 m in front of and behind the bridge with an open track.

Alternate (mixed) installation of wooden and concrete sleepers is not allowed.

The transition from the section with built-in wooden sleepers to the section with concrete sleepers, and vice versa, must be at least 10 m away from the rail joint.

If on the section of track with concrete sleepers, level crossings are made on wooden sleepers, it is necessary to install 30 wooden sleepers in front of and behind the level crossing.

Concrete sleepers can also be installed at road crossings.

### 3.3.7. Rulebook on Amendments to the Rulebook on technical conditions and maintenance of railway lines superstructure ("Official Gazette of RS", No. 74/16)

Article 4.

In Article 8, paragraph 1, after the word: “prestressed”, the word: “reinforced” is added.

In paragraph 2, after the No.: “13230”, the words: “(part of 1-5)” are added.

After paragraph 3, new paragraphs are added 4-7, which read: “Hardwood sleepers (oak and beech) can be installed everywhere, primarily in tunnels, on insulating sections of the railway, at level crossings, in curves with a radius of less than 250 m, on platform tracks, in the case of track connections up to 150 m in length, if these tracks are with wooden sleepers, as well as in parts of the railway where the earthen body is in motion.

Soft wood sleepers (pine, chestnut, larch) can be installed only in the track in the direction, with lightly loaded rails and tracks.

All wooden sleepers must be labelled with a hammer for receiving raw sleepers, secured against splashing, impregnated, with a numerator marked with the year of impregnation, which also indicates the year of their installation. If the sleepers are installed later, the year of installation is marked with a special numerator.

Wooden sleepers cannot be completely drilled in places where tyrphons or nails come in.”

Previous paragraphs 4-8. become 8-12.

The previous paragraph 9, which becomes paragraph 13, is amended to read as follows:

“Concrete sleepers shall not be installed on unstable substructure, on rail assemblies, 30 m in front of and behind open road bridges and on bridges without curtain.”

The previous paragraphs 10-12. become 14-16.

### 3.3.8. Rulebook on technical conditions and maintenance of railway lines superstructure No.: 340-201-2/2016 (“Official Gazette RS” No. 39/16 and 74/16)

3. Sleepers

Type and use of sleepers

Article 8.

Sleepers made of prestressed reinforced concrete and wooden sleepers are installed on the tracks.

Concrete sleepers must be in accordance with SRPS EN 13230, and wooden sleepers in accordance with SRPS EN 13145.

Concrete sleepers must have an electrical resistance in the dry state of at least 6000 Ω and 3000 Ω in the wet state.

Hardwood sleepers (oak and beech) can be installed everywhere, primarily in tunnels, on insulating sections of the railway, at level crossings, in curves with a radius of less than 250 m, on platform tracks, in the case of track connections up to 150 m in length, if these tracks are with wooden sleepers, as well as in parts of the railway where the earthen body is in motion.

Soft wood sleepers (pine, chestnut, larch) can be installed only in the track in the direction, with lightly loaded rails and tracks.

All wooden sleepers must be labelled with a hammer for receiving raw sleepers, secured against splashing, impregnated, with a numerator marked with the year of impregnation, which also indicates the year of their installation. If the sleepers are installed later, the year of installation is marked with a special numerator.

Wooden sleepers cannot be completely drilled in places where tyrphons or nails come in.

Used wooden sleepers are installed during the individual replacement of sleepers.

Switches are mounted on wooden and concrete sleepers.

For new, renovated or upgraded main arterial lines, 2.60 m long concrete sleepers are installed for the 60E1 rail and elastic fastening accessories with a slope of leaning surface of 1: 40.

Concrete sleepers 2.40 m and 2.50 m long can be installed on regional and local railways.

Concrete sleepers are not installed on rail joint and on a length of 30 m in front of and behind the bridge with an open track.

Concrete sleepers shall not be installed on unstable substructure, on rail assemblies, 30 m in front of and behind open road bridges and on bridges without curtain.

The transition from the section with built-in wooden sleepers to the section with concrete sleepers, and vice versa, must be at least 10 m away from the rail joint.

If on the section of track with concrete sleepers, level crossings are made on wooden sleepers, it is necessary to install 30 wooden sleepers in front of and behind the level crossing.

Concrete sleepers can also be installed at road crossings.

III Method and deadlines for maintenance of the superstructure

Types of superstructure maintenance

Article 66.

Superstructure maintenance can be:
1) regular;
2) extraordinary.

Regular maintenance includes:
1) current maintenance;
2) medium repairs;
3) main repairs;
4) inspections and controls.

Extraordinary maintenance includes:
1) unforeseen works;
2) reconstructions.

Maintenance of the track welded in DTŠ

Article 74. (excerpt)

Conditions and temperature interval for performing certain works on the track welded in DTŠ are:

1) adjustment of the direction and level of the track with packing of sleepers, if the track does not rise more than 30 mm and when the track axle is in exploitation tolerances, it can be done in the interval $t_p = \pm 15°C$;

2) lifting of tracks from 30 to 50 mm with packing of sleepers of sleepers can be performed in the interval $t_p = \pm 10°C$;

3) when a larger lifting or moving of the track axle over the exploitation tolerances is required, the work can be performed in the interval $t_p = \pm 15°C$;

4) works that require lateral and longitudinal movement of the track, removal of the curtain or release of rails from the sleepers - even on a slight length of the track, such as: sieving, partial replacement and addition of the curtain, individual replacement of sleepers, partial replacement of track accessories, etc., can be performed up to temperature $t_p = \pm 15°C$;

…

7) if due to cutting or fracture of the rail there is a disturbance of DTŠ, which is formed at the required temperature, or the rail is cut at a temperature higher than +35ºC, the adjacent parallel rail must be cut.

If, after performing the works referred to in paragraph 1 of this Article, the curtain between the sleepers fronts does not compact mechanically, and a temperature increase of more than tp+20°C is expected, the train speed should be reduced in the section where the works were performed.

…

The procedure referred to in paragraph 7 of this Article shall be applied only when all remnants of the previous weld have been previously removed from the rail profile. All work on cutting and installation of insulated assemblies is performed in the interval $t_p$ or, when this is not possible, the final regulation of the insulated assembly and the switch should be performed at $t_p$, as in the case of final welding.

The correctness of the position against the longitudinal travel of the rails (which were installed on the connecting rails, intermediate rails, around the insulated assemblies and in the welded track in DTŠ behind and in front of the switches) is checked when greater heat or cold occurs, as well as any sudden temperature change.

Installation of new or correction of the position of existing devices is performed only in the interval tp ± 5 °C.

Inspection and control of the track welded in DTŠ

Article 76 (excerpt)

Inspection and control of the track welded in DTŠ is performed quarterly, based on the documentation on DTŠ.

…

When inspecting and measuring the mentioned places and phenomena, the temperature in the rails is recorded at the same time.

At constant points - benchmarks, the measurement or movement of DTŠ is performed.

…

special attention should be paid to:

1) on sections on which works have been performed in the last two to three weeks that disturb the stability of the track;

2) on sections with a higher percentage of contaminated curtain, weaker fastening accessories with “player” sleepers, with horizontal and vertical deformations of the track, with rails on which defects were found, with corrugated and wrinkled rails, etc.;

…

6) on sections where normal (regular) speed has been introduced, and no release of rails from internal stresses has been performed;

7) on all parts of the railway on which the deformation of the track has already been repaired;

8) on all parts of the railway that are considered to be capable of deforming the railway trunk, embankments, cuts and structures.

…

DTŠ disturbances, as well as observed changes (due to force majeure or other reasons) on the track, expansion joints, switches and railway trunk pose a danger to traffic safety, and accordingly, train speeds are reduced or traffic is suspended, with urgent remedial measures.

Track inspection, control and measurement

Article 80 (excerpt)

…

Testing the correctness of the installed wooden sleepers is performed by a systematic inspection, with special attention paid to visible damage to the sleepers and the condition of the plugs, especially if the plugs are wooden. Observed cracks and damages to the concrete sleepers are protected from water penetration and damage to the reinforcement. In case of major damage, the sleepers are replaced.

Article 81. (excerpt)

The technical condition of all types of track accessories and accessories as a whole must be such as to provide a firm connection between the rails, the rail with the sleeper and to prevent loosening of the accessories and the connection.

Damaged, worn or missing elements of track accessories should be replaced or supplemented, loose accessories should be tightened, and if necessary, individual elements should be lubricated.

...

Review and control of insulated joint

Article 83 (excerpt)

…

A detailed inspection of the correctness of the insulated section and the insulated joint is performed by the responsible workers of construction and electrical activities, at least once during four months.

A detailed spring inspection is performed until the end of March, and autumn until the end of November.

Detailed examinations are also performed when extreme temperatures appear.

### 3.3.9. 314 Rulebook on maintenance of Yugoslav railway lines superstructure ("Official Gazette ZJŽ" No. 3/71, 2/75, 5/76)

**Note:** At the time when the last overhaul of the section of the railway on which the accident in question occurred was performed, this Rulebook was applicable. By the decision of "IŽS"a.d. No. 4/2015-51-17 of 29.12.2015. on taking over regulations issued by ZJŽ as its internal acts in accordance with Article 152 of the Law on Railway Safety and Interoperability ("Official Gazette of RS" No. 104/2013, 66/2015 - other law and 92/2015), this Rulebook with amendments published in the "Official Gazette of the ZJŽ" No. 8/89, 2/90 and 8-9/91, which do not refer to items 2, 10 and 11 of Article 21) was taken over and was in application on "IŽS"a.d. until the entry into force of the Rulebook on technical conditions and maintenance of the railway lines superstructure No.: 340-201-2/2016 ("Official Gazette of RS" No. 39/16 and 74/16).

Article 21. (excerpt)

...

2. Hardwood sleepers (oak and beech) can be installed everywhere, primarily in tunnels, **on insulated sections of track**, at level crossings, in curves with a radius of less than 250 m at normal gauge railways, at curves with a radius of less than 200 m at narrow gauge railway, on platform tracks, at track connections up to 150 m in length if these tracks are with wooden sleepers, as well as at sections of the railway where the earthen body is in motion.

...

10. Mixed installation of wooden and concrete sleepers is prohibited.

The transition from the section of track where wooden sleepers are installed to the section with concrete sleepers, and vice versa, must be at least 10 m away from the rail joint.

...

11. Exceptionally, reinforced concrete and prestressed concrete sleepers may be installed in insulated sections of railways if they meet certain electrical conductivity requirements prescribed by the Technical Conditions for the manufacture and acceptance of reinforced and prestressed concrete sleepers.

...

## 3.4. Functioning of the railway vehicles and technical installations

### 3.4.1. Control, command and signalling

At the time of occurrence of the accident, between the stations Jagodina and Bagrdan, the control, command and signaling devices were correct and operational.

No faults or malfunctions have been recorded on the control, command and signaling devices.

### 3.4.2. Infrastructure

From letter No. 1/2021-169 of 28.01.2021. "IŽS"a.d., according to the submitted data on inspections of the railway performed in the period before the accident performed by the activities for maintenance of the railway "IŽS"a.d., OC ZOP Paraćin, which are out of date and incomplete or do not exist (control of DTŠ - measurement of longitudinal and transversal displacement of the track), with the explanation **"that due to TMD failure, lack of fuel and priority tasks on the order of the Head of OC ZOP Paraćin were not performed",** the factual situation given in the following text was determined.

At the place where the train No. 45022 derailed, rails of type 49E1 (ZENICA 86 UIC 49) were installed, welded in DTŠ. The view of the rails is shown in Figure 3.4.2.1.

**Figure 3.4.2.1:** The view of rails type "*49E1*" *ZENICA 86 UIC 49*

Between the stations Bagrdan and Jagodina on the left track, sleepers with fastening track accessories have been installed, as follows:

- 1986, from km 120+701.45 to km 125+295.00 reinforced concrete prestressed sleepers JŽ70, spacing 60 cm, with fastening accessories "SKL 2", appearance shown in Figure 3.4.2.2. a),

- in 1973, from km 125+295.00 to km 126+864.00 reinforced concrete prestressed sleepers IM 2, spacing 65 cm, with fastening accessories "SKL 2",

- 1973, from km 126+864.00 to km 128+500.00 wooden sleepers, spacing 65 cm, with fastening accessories "K",

- 2005, from km 128+500.00 to km 130+300.00 reinforced concrete prestressed sleepers JŽ70, spacing 65 cm, with fastening accessories "K", appearance shown in Figure 3.4.2.2. b),

- 1982, from km 130+300.00 to km 135+692.55 wooden sleepers, distance 65 cm, with fastening accessories "K", appearance shown in Figure 3.4.2.2. c).

*a)* *b)* *c)*

**Figure 3.4.2.2:** The view of fastening track accessories

The track grid is covered with curtain made of gravel. The appearance of the track grid is shown in Figure 3.4.2.3

**Figure 3.4.2.3:** Curtain made of gravel of limestone origin

The designed specific axle load is 225 kN, and the special axle load per meter is 80 kN/m.

Insulated joint at km 123+660.80 is installed on wooden sleepers, which is in accordance with item 2 of Article 21. 314 of the Rulebook on maintenance of the Yugoslav Railway lines superstructure ("Official Gazette ZJŽ" No. 3/71, 2/75, 5/76, 8/89, 2/90 и 8-9/91), which was in application at time of its installation. Having in mind the place of installation of the insulated joint (km 123+660.80) and the place of installation of the first concrete sleeper (after wooden sleepers) at km 123+666.20 it can be stated that it is not in accordance with item 10 of Article 21 of the aforementioned Rulebook, which requires that the transition from the section with built-in wooden

sleepers to the section with concrete sleepers, and vice versa, must be at least 10 m away from the rail joint. The appearance of the insulated joint in km 123+660.80 is shown in Figure 3.4.2.4.

**Figure 3.4.2.4:** Insulated joint at km 123+660,80

Devices against the travel of rails (longitudinal movement) on the left track are installed according to the following:

- from km 120+019.00 to km 120+071.25, type “MATHEE”, 74 pieces,
- from km 120+553.17 to km 120+607.80, type “MATHEE”, 74 pieces,
- from km 120+921.00 to km 120+971.00, type “MATHEE”, 74 pieces,
- from km 134+594.00 to km 134+645.55, type “MATHEE”, 72 pieces,
- from km 134+725.80 to km 134+777.00, type “MATHEE”, 74 pieces,
- from km 134+989.37 to km 135+041.90, type “MATHEE”, 72 pieces.

An illustrative method of installing devices against rail travel is shown in Figure 3.4.2.5.

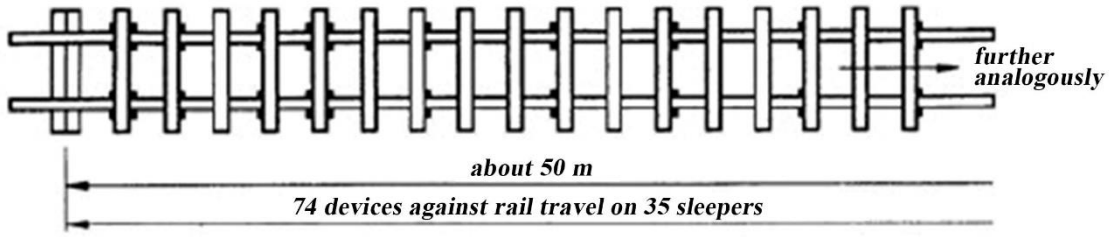



**Figure 3.4.2.5**: Method of installing devices against rail travel

At the place where the train No. 45022 derailed, the track was observed to decrease in the direction of increasing stationing, i.e. to rise 0.30 ‰ in the direction of train No. 45022 movement, in the direction and on the embankment.

The geometry of the track is very poor and is manifested by a disturbed level in the longitudinal and transversal direction, which caused a reduction in speed and the introduction of restricted speed runnings.

Due to the poor condition of the substructure of the railway **(weak terrain**), from km 120+900 to km 125+100 on the railway, the speed limit is 70 km/h on the left track.

Overview of restricted speed runnings:

- Bagrdan - Jagodina, left track, from km 117+000 to km 125+315 with Vmax = 30 km/h. Introduced 18.09.2017., by telegram "IŽS"a.d. No. 117 from 18.09.2017., due to the alienation of the supporting rope on the catenary **and rotten sleepers**.

  Canceled 05.10.2017., by telegram "IŽS" a.d. No. 123 from 05.10.2017.;

- Bagrdan - Jagodina, left track, from km 122+200 to km 125+100 with Vmax = 70 km/h, introduced on 04.05.2018., by telegram "IŽS"a.d. No. 20 from 07.05.2018., due to **disturbance of track direction.**

  Canceled on 03.07.2018. by telegram "IŽS"a.d. No 12 from 03.07.2018.;

- Bagrdan - Jagodina, left track, from km 120+900 to km 125+100 with Vmax = 70 km/h, introduced on 03.07.2018., by telegram "IŽS"a.d. No. 12 of 03.07.2018., **due to poor leveling and track direction.**

  Canceled on 09.10.2018. by telegram "IŽS"a.d. No 58 from 09.10.2018.;

- Bagrdan - Jagodina, left track, from km 120+900 to km 125+400 with Vmax = 50 km/h, introduced on 09.10. 2018., by telegram "IŽS"a.d. No. 58 of 09.10. 2018., due to poor **leveling and track direction.**

  Cancelled on 03.12. 2018. by telegram "IŽS"a.d. No. 5 from 03.12.2018.;

- Bagrdan - Jagodina, left track, from km 120+900 to km 125+100 with Vmax = 70 km/h, introduced on 03.12.2018., by telegram "IŽS"a.d. No. 5 from 03.12.2018., **due to the poor condition of the substructure.**

  Converted to limited speed by the Timetable Booklet for 2018/2019.;

- Bagrdan - Jagodina, left track, from km 123+650 to km 123+700 with Vmax = 30 km/h, introduced on 17.09.2019., by telegram "IŽS"a.d. No. 114 of 18.09.2019., **due to a cracked rail on the insulated joint at km 120+680 and the poor condition of the substructure**.

  Canceled 30.09.2019. year, by telegram "IŽS"a.d. No. 188 of 30.09.2019.

During the on-site investigation by the joint investigative committee by "IŽS"a.d. and "Srbija Kargo"a.d., in the presence of representatives of CINS, on 29.11.2020. the track gauge was measured in the zone where the first traces of derailment were observed.

The measurement was performed with a track scale meter of the Robel brand, owned by "IŽS"a.d. The measured values are shown in Table 3.4.2.1.

The sleepers are marked in the direction of the decreasing stationing, i.e. in the direction of train No. 45022 movement. The distance between the adjacent sleepers is 0.60 m.

**Table 3.4.2.1:** Track gauge measured immediately upon the occurrence of the accident

| Ordinal number of measu-rement | Place of measurement (sleeper No.) | Deviation from the prescribed gauge (mm) | Cross-level (mm) | *km* position |
|---|---|---|---|---|
| Start of measurement from the pole KM No. 91 - approximately 112 m distance from the end of the last (17) wagon in train No. 45022 **(measured at every third sleeper)** | | | | |
| 1. | Zero sleeper | -3 | +1 | 123+837.67 |
| 2. | 3 | -3 | +2 | +835.87 |
| 3. | 6 | 0 | +2 | +834.07 |
| 4. | 9 | -2 | +2 | +832.27 |
| 5. | 12 | -4 | +3 | +830.47 |
| 6. | 15 | -4 | +3 | +828.67 |
| 7. | 18 | -3 | 0 | +826.87 |
| 8. | 21 | -2 | +2 | +825.07 |
| 9. | 24 | -3 | +1 | +823.27 |
| 10. | 27 | -3 | +3 | +821.47 |
| 11. | 30 | -3 | +2 | +819.67 |
| 12. | 33 | -4 | +3 | +817.87 |
| 13. | 36 | -5 | +3 | +816.07 |
| 14. | 39 | -4 | +1 | +814.27 |
| 15. | 42 | -3 | +2 | +812.47 |
| 16. | 45 | -2 | +3 | +810.67 |
| 17. | 48 | -2 | +3 | +808.87 |
| 18. | 51 | -3 | +1 | +807.07 |
| 19. | 54 | -2 | +2 | +805.27 |
| 20. | 57 | -5 | +3 | +803.47 |
| 21. | 60 | -4 | +2 | +801.67 |
| 22. | 63 | -3 | +2 | +799.87 |
| 23. | 66 | -3 | +1 | +798.07 |
| 24. | 69 | -3 | 0 | +796.27 |
| 25. | 73 | -2 | +1 | +794.47 |
| 26. | 76 | -3 | 0 | +792.67 |
| 27. | 79 | -3 | +2 | +790.87 |
| 28. | 82 | -2 | 0 | +789.07 |
| 29. | 85 | -2 | +1 | +787.27 |
| 30. | 88 | -2 | +3 | +785.47 |
| 31. | 91 | -2 | +4 | +783.67 |
| 32. | 94 | -3 | +3 | +781.87 |
| 33. | 97 | -3 | +3 | +780.07 |
| 34. | 100 | -2 | +3 | +778.27 |
| 35. | 103 | -3 | +4 | +776.47 |
| 36. | 106 | -2 | +5 | +774.67 |
| 37. | 109 | -2 | +3 | +772.87 |
| 38. | 112 | -5 | +4 | +771.07 |
| 39. | 115 | -4 | +6 | 123+769.27 |
| The KM pole No. 89 approximately 41 *m* distance from the end of the last (17) wagon in train No. 45022 (**measured at every second sleeper**) | | | | |
| 40. | 117 | -4 | +5 | 123+767.47 |
| 41. | 119 | -3 | +6 | +766.27 |
| 42. | 121 | -3 | +5 | +765.07 |
| 43. | 123 | -2 | +5 | +763.87 |

| | | | | |
|---|---|---|---|---|
| 44. | 125 | -2 | +4 | +762.67 |
| 45. | 127 | -2 | +3 | +761.47 |
| 46. | 129 | -2 | +4 | +760.27 |
| 47. | 131 | -2 | +3 | +759.07 |
| 48. | 133 | -2 | +3 | +757.87 |
| 49. | 135 | -2 | +4 | +756.67 |
| 50. | 137 | -2 | +4 | +755.47 |
| 51. | 139 | -2 | +4 | +754.27 |
| 52. | 141 | -2 | +4 | +753.07 |
| 53. | 143 | -1 | +5 | +751.87 |
| 54. | 145 | -1 | +5 | +750.67 |
| 55. | 147 | -3 | +4 | +749.47 |
| 56. | 149 | -3 | +3 | +748.27 |
| 57. | 151 | -3 | +3 | +747.07 |
| 58. | 153 | -3 | +3 | +745.87 |
| 59. | 155 | -3 | +3 | +744.67 |
| 60. | 157 | -3 | +3 | +743.47 |
| 61. | 159 | -3 | +3 | +742.27 |
| 62. | 161 | -3 | +3 | +741.07 |
| 63. | 163 | -3 | +2 | +739.87 |
| 64. | 165 | -4 | +2 | +738.67 |
| 65. | 167 | -4 | +2 | +737.47 |
| 66. | 169 | -4 | +3 | +736.27 |
| 67. | 171 | -5 | +2 | +735.07 |
| 68. | 173 | -3 | +3 | +733.87 |
| 69. | 175 | -3 | +1 | +732.67 |
| 70. | 177 | -2 | +1 | +731.47 |
| 71. | 179 | -2 | +3 | +730.27 |
| 72. | 181 | -3 | +3 | +729.07 |
| 73. | 183 | -6 | +3 | +727.87 |
| 74. | 185 | -10 | +3 | 123+726.67 |
| **The end of the last wagon (17th) in train No. 45022 (measured at one end of the wagon, the middle of the wagon and at the other end of the wagon, for a total of four wagons (17, 16, 15 and 14)** | | | | |
| 75. | End of 17. wagon | -8 | +3 | 123+725.47 |
| 76. | Middle of 17. wagon | -3 | +2 | +718.97 |
| 77. | Between 17. and 16. | -5 | +3 | +712.47 |
| 78. | Middle of the 16. wagon | -3 | +2 | +705.97 |
| 79. | Between 16. and 15. | -2 | +4 | +699.47 |
| 80. | Middle of the 15. wagon | -6 | +7 | +692.97 |
| 81. | Between 15. and 14. | -5 | +5 | +686.47 |
| 82. | Middle of the 14. wagon, **(the point where concrete sleepers end and where wooden sleepers start)** | -2 | +5 | +679.97 |
| 83. | Between 14. and 13. **approximately 1 *m* after the first trace of derailment (the first trace is four sleepers away from the point of sleepers separation)** | -2 | +1 | 123+673.47 |
| **13. wagon derailed** | | | | |

In Table 3.4.2.2. the track gauge measured 05.08.2020 is shown, after mechanical regulation of the track in the direction and level (OC ZOP Paraćin).

**Table 3.4.2.2:** The track gauge measured on 05.08.2020. after mechanical regulation of the track in the direction and level (OC ZOP Paraćin)

| Ordinal number of measu-rement | Place of measurement (*km* position) | Deviation from the prescribed gauge (mm) | Cross-level (mm) |
|---|---|---|---|
| As geometric surveying of track with track inspection coach EM-80L was not performed in 2020, the Sector for Construction Affairs sent a letter No. 20/2020-1811 of 01.10.2020., ordered to perform measurements with manual meters | | | |
| 1. | 123+830.00 | 3 | 3 |
| 2. | 123+820.00 | 3 | 3 |
| 3. | 123+810.00 | 3 | 3 |
| 4. | 123+800.00 | 3 | 3 |
| 5. | 123+790.00 | 3 | 4 |
| 6. | 123+780.00 | 4 | 4 |
| 7. | 123+770.00 | 4 | 3 |
| 8. | 123+760.00 | 3 | 3 |
| 9. | 123+750.00 | 3 | 2 |
| 10. | 123+740.00 | 2 | 2 |
| 11. | 123+730.00 | 2 | 2 |
| 12. | 123+720.00 | 2 | 3 |
| 13. | 123+710.00 | 3 | 0 |
| 14. | 123+700.00 | 0 | 0 |
| 15. | 123+690.00 | 0 | 1 |
| 16. | 123+680.00 | 1 | 0 |
| 17. | 123+670.00 | 0 | 0 |

On the chart 3.4.2.1. the ratio of the track gauge measured immediately after the accident and the track gauge measured on 05.08.2020 is shown and after the mechanical regulation of the track in the direction and level (OC ZOP Paraćin).

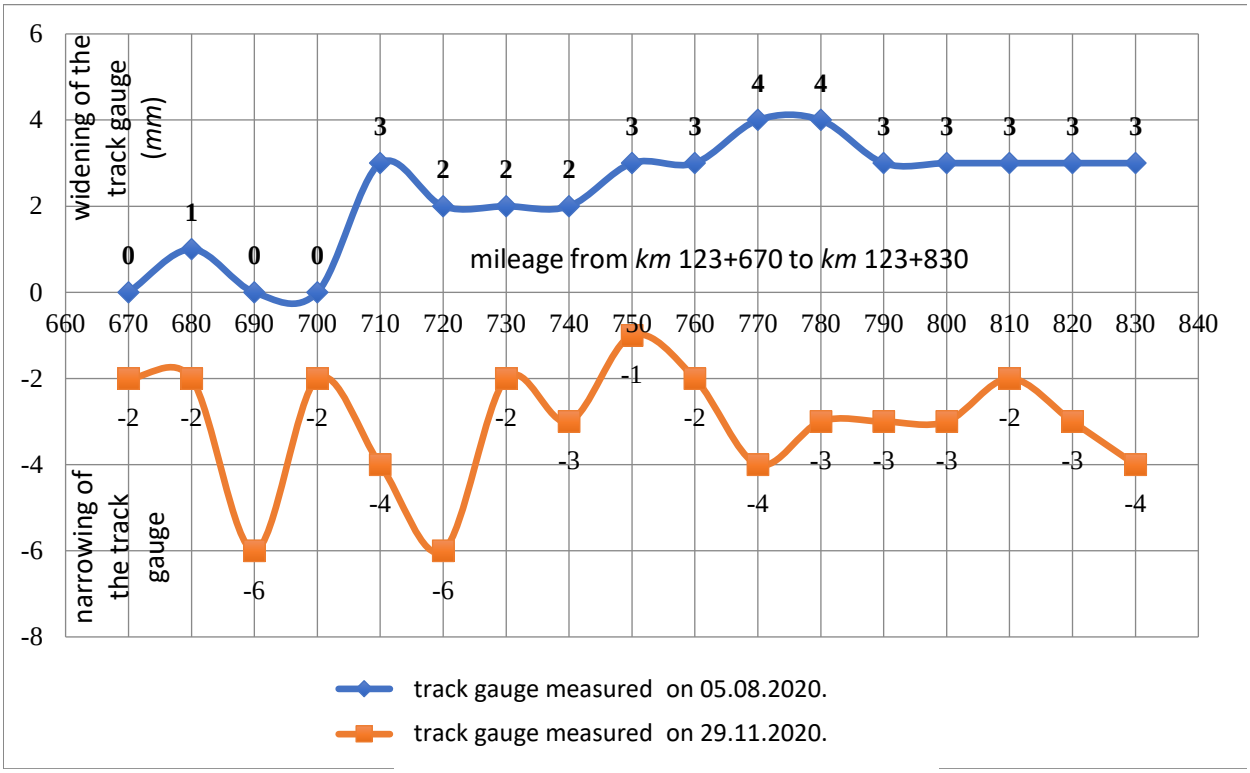



**Chart 3.4.2.1:** The ratio of the track gauge measured immediately after the accident and the track gauge measured on 05.08.2020 after the mechanical regulation of the track in the direction and level (OC ZOP Paraćin)

In the event that the rail brakes, which occurs at high cold speeds, the two parts of the rail disengage until a balance is established between the longitudinal tensile forces in the rails and the longitudinal resistance that exists between the rail and the sleeper or between the sleeper and its base (curtain). The magnitude of the longitudinal displacement may or may not be symmetrical on the left and right sides of the rail fracture.

Due to the action of the fastening accessories and the existence of resistance to the longitudinal movement of the sleeper in the curtain, the track is stiff at some distance from the fracture and there is no longer movement. At the place of the rail fracture and in the zone of the ends at the fracture of the rail, the diagram of longitudinal resistance and the diagram of longitudinal displacement (shortening) of the newly created ends of the rail are shown in Figure 3.4.2.6.

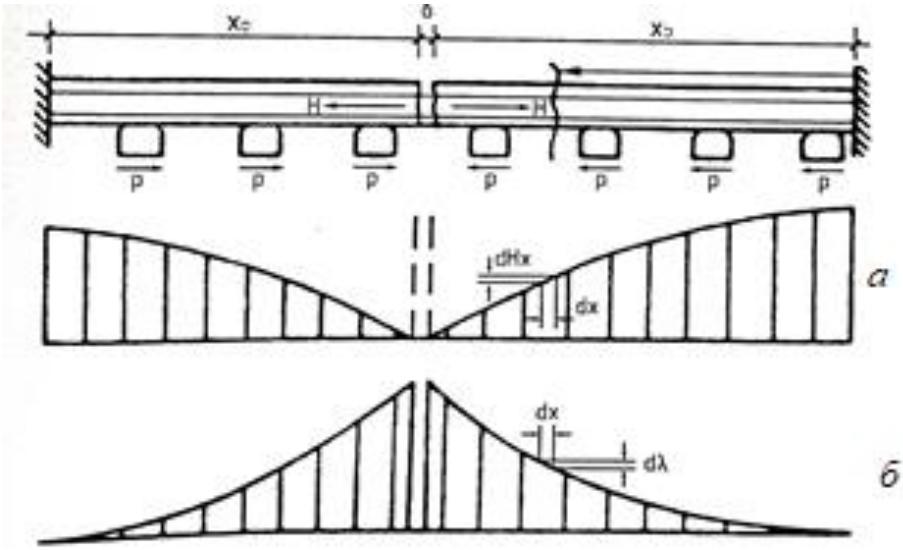



**Figure 3.4.2.6:** Diagram of longitudinal resistance (a) and the diagram of longitudinal displacement (b)

Based on the above, as well as the visual inspection of the track in the derailment zone performed on 29.11. and 01.12.2020. by the representatives of CINS, it can be concluded that the narrowing of the track occurred due to inadequate maintenance of the track welded in DTŠ for which there is no record of longitudinal and transversal movement of the track, which was stated on the basis of letter No. 20/2021-97 of 19.01. 2021 of the Sector for Construction Affairs, which was submitted as an attachment to letter No. 1/2021-169 of 28 .01.2021. of "IŽS"a.d., and as a consequence of the accident. In this section of the track, the speed is limited due to the poor condition of the substructure, which is reflected in the direction and level of the track.

Due to the bursting of the rails, there came to an uneven longitudinal movement of the rails (longitudinal movement of the rails is shown in Figure 3.4.2.7.) and thus narrowing of the track. Poor rail-sleeper connection (compression and lack of rubber inserts whose appearance is shown in Figure 3.4.2.8.), as well as the condition of the fastening accessories that are not lubricated, loose and missing (the appearance of the fastening accessories is shown in Figure 3.4.2.9.), caused the bevel and damage of the sleepers (the appearance of bevel and damage of the sleeper is shown in Figure 3.4.2.10.), and thus narrowing of the track.

**Figure 3.4.2.7**: The view of longitudinal movement of rails

**Figure 3.4.2.8**: The view of rubber inserts

**Figure 3.4.2.9**: The view of fastening accessories

**Figure 3.4.2.10**: The view of sleepers after the accident

### 3.4.3. Means of communication

At the time of the accident in question, on the section of the railway between the stations of Jagodina and Bagrdan, the means of communication were correct and operational.

No disturbances or malfunctions were recorded on the means of communication.

### 3.4.4. Railway vehicles

At the time of the accident, train No. 45022 was moving in the direction from the Jagodina station to the Bagrdan station (from the end to the beginning of the line, in the direction of the decreasing stationing).

During the drive of train No. 45022, a total of 8 (eight) wagon tanks of the Z series derailed. The fifth, seventh, eighth, ninth, tenth, eleventh, twelfth and thirteenth wagon derailed out of the train, viewed from the locomotive 193-916.

On the spot, locomotive 193-916 and all wagon tanks from train No. 45022 were found.

An overview of derailed wagons, seen from locomotive 193-916, is given in Table 3.4.4.1.

**Table 3.4.4.1:** The view of derailed wagons

| **wagon** | | **description:** |
|---|---|---|
| **series:** | **No.:** | |
| *Zacs-z* | 33 72 7867 810-3 | fifth wagon-tank with two axles of the second bogie, they remained on their wheels in the track zone |
| *Zacs-z* | 31 72 7865 013-8 | seventh wagon-tank with all axles, found on the right track, they overturned on its side, seen in the direction of the train movement, on the tank lids there was sulfuric acid |
| *Zacs-z* | 33 72 7867 853-3 | eighth wagon-tank derailed with all axles, found on the right track, overturned on its side to the left, seen in the direction of the train movement, on the tank lids there was sulfuric acid |
| *Zacs-z* | 33 72 7867 846-7 | ninth wagon-tank derailed with all axles, found on the left track, overturned on its side to the right, seen in the direction of the train movement |
| *Zacs-z* | 31 72 7865 005-4 | tenth wagon-tank with all axles, remained upright, on its wheels, in the track zone, rotated by approximately 30° to the left with respect to the longitudinal axis of the track, seen in the direction of the train movement |
| *Zacs-z* | 31 72 7865 009-6 | eleventh wagon-tank with all axles, found tilted to the left for approximately 50° with respect to the vertical axis of the track and rotated to the right for approximately 20° with respect to the longitudinal axis of the track, viewed in the direction of train movement |
| *Zacs-z* | 31 72 7865 010-4 | twelfth wagon-tank of series Zacs-z No. 33 72 7865 010-4 with all axles, found tilted to the left for approximately 40° with respect to the vertical axis of the track and rotated to the left for approximately 20° with respect to the longitudinal axis of the track, viewed in the direction of train movement |
| *Zacs* | 33 87 7868 736-2 | thirteenth wagon-tank with two axles of the second bogie, they remained on their wheels in the track zone |

The view of derailed wagons is shown in Figures 3.4.4.1, 3.4.4.2. and 3.4.4.3.

**Figure 3.4.4.1:** The view of derailed and overturned wagons

**Figure 3.4.4.2:** The view of derailed and overturned wagons


**Figure 3.4.4.3:** The view of derailed and overturned wagons and parts of derailed wagons

According to the data submitted from "Srbija Kargo"a.d. by e-mail from 14.12.2020., which were received by the Directorate for Railways, it was determined that the wagons with individual Nos. 33 72 7867 810-3, 33 72 7867 853-3 and 33 72 7867 846-7 were not included in the National Register of Vehicles (NVR) of Republic of Serbia, and these wagons have been in operation for many years. Having in mind that these three wagons are part of a series of a larger number of

wagons that were once numbered, it can be assumed that they have a type license and individual licenses from a former ZJŽ. Later, the Directorate for Railways was formed, which is responsible for issuing licenses. Having in mind that the Directorate for Railways does not have the documentation for the mentioned wagons, they could not be included in the National Register of Vehicles (NVR) of the Republic of Serbia. Also, according to the data submitted by Elixir Group d.o.o, based on the Agreement on the purchase and sale of technical sulfuric acid concluded between Serbia Zijin Copper d.o.o. Bor (as a seller) and Elixir Group d.o.o. Šabac (as a buyer) 12/20/2019 with a validity period until 31.12.2029. (serial Nos. 10327 and 334/1), Serbia Zijin Copper d.o.o. Bor, as the owner of the sulfuric acid transport wagon, gave wagons to Elixir Group d.o.o. Šabac in lease during the term of the agreement, but none of the contracting parties has the documentation for the said wagons.

According to the data submitted by "Srbija Kargo"a.d. by e-mail from 08.03.2021., the locomotives of 193 series do not have a built-in speedometer device as a special part of the equipment, but this function is realized by the devices PZB/LZB (which is an improved auto stop device) and ETCS (as a completely new safety system). All data on train movement are entered and stored in the TRU device, from where from data on locomotive speed and movement can be downloaded. For the PZB/LZB device installed on the locomotive 193-916, a certificate was issued on 22.10.2019. and for the ETCS device installed on the locomotive 193-916, a certificate was issued on 15.11.2019. Certificates issued are valid for two years. No special certificate is issued for the TRU device.

Data processing stored on 28.11.2020. in the device TRU type Alstom, installed on the locomotive 193-916 from the train No. 45022 was performed in "Srbija Kargo"a.d., Section for traction of trains and TKP Belgrade.

## 3.5. Traffic management and regulation

### 3.5.1. Actions taken by the staff that manages traffic regulation, control and signalling

The traffic of train No. 45022 on the route Jagodina - Bagrdan took place in the APB mode, that is, at a block distance. According to the entry in the Traffic Log of the Jagodina station, train No. 45022 passed the Jagodina station at 19:10, through the fourth track.

The train staff at the Crveni krst station, via the accompanying documents, received orders and notifications on the traffic of train No. 45022 on that section of the line.

### 3.5.2. Exchange of voice messages in relation to the accident

Immediately before and during the occurrence of the accident in question, there was no communication between the driver and the staff regulating the traffic. The last communication between the train driver and the staff regulating the traffic was realized at the Crveni Krst station, where the staff was changed, the locomotives were changed, the short brake test was performed and the train driver was submitted by a train dispatcher a General Order I No. 7 (S-20) on 28.11.2020., with notifications on introduced restricted speed runnings, switched-off faulty track balises and unsecured road crossings. For the section of the railway that refers to the left track between the stations Jagodina and Bagrdan, in General Order I No. 7 (S-20) from 28.11.2020., a restricted speed run of 70 km/h from km 128+100 to km 126+800 was stated.

Communication between the staff regulating the traffic and the driver was re-established after the accident in order to inform about the accident occurred, so that the train driver of the train No. 45022, via radio-dispatching connection and later again via mobile operator, informed the dispatcher of the telecommand in Niš and the train dispatcher of the Bagrdan station.

### 3.5.3. Measures taken to protect and secure the place of the accident

After the accident, section of the main arterial line Belgrade Center - Junction "G" - Rakovica - Mladenovac - Lapovo - Niš - Preševo - state border - (Tabanovce) between the stations Jagodina and Bagrdan (left and right track of the two-track railway), was closed for traffic.

Given the facts regarding train No. 45022 after the accident in question and the place where it stopped, there was no need to take special measures to secure the train from self-starting.

Considering that the train No. 45022 contained a substance that in case of uncontrolled release from the wagon tanks can endanger human health and is potentially dangerous for the environment, the MUP RS was informed about the accident in question.

No other measures have been taken to secure the scene of the accident.

## 3.6. Interface between men, machine and organisation

### 3.6.1. Working hours of the staff involved

From the railway undertaking "Srbija Kargo"a.d. the Traction staff Sheet (form EV-1) No. 402, Section for traction and rolling stock maintenance Lapovo, was submitted as the attachment to the Letter No. 1/2021-666 of 08.02.2021. from which it can be seen that the train driver with registration No. 112 in shift on 28.11.2020., from the beginning of the shift until the occurrence of the accident in question, while driving a traction vehicle series 193-916 spent a total of 10 hours and 27 minutes.

According to the data submitted by "Srbija Kargo"a.d. by letter No. 1/2021-666 of 08.02.2021. and electronically from 02.06.2021., it can be stated that the extension of the driving time of the traction vehicle occurred in accordance with Article 87 of the Law on Safety in Railway Traffic ("Official Gazette of RS" No. 41/18).

### 3.6.2. Health-related and personal circumstances that have effects on the serious accident, including the presence of physical or mental stress

For the railway staff, data were delivered from which it can be seen that the train driver that was in service at train No. 45022 was professionally trained and medically fit to perform the work. The train driver of the train No. 45022 has a License for operating a traction vehicle No. RS 71 2017 1056 issued by the Directorate for Railways on 23.12.2016. with a validity period until 23.12.2026. Joint investigative committee made of representatives of "IŽS"a.d. and "Srbija Kargo"a.d. did not perform alcotesting of the train driver of the train No. 45022.

Immediately after the accident, having in mind that he did not have any physical injuries, the train driver did not ask for medical help and it was not given to him. He felt the presence of

psychological stress a little later, seeing the consequences of the accident and getting information about the acid leak.

### 3.6.3. Design of the equipment that has an influence on the interface between the user and the machine

Section of the main arterial line Belgrade Center - Junction "G" - Rakovica - Mladenovac - Lapovo - Nis - Preševo - state border - (Tabanovce) between the stations Jagodina (km 135+236) and Bagrdan (km 120+300) (left track of the two-track railway), is designed for speeds up to 120 km/h and maximum loads of 22.5 t/axle (225 kN/axle).

Due to the condition of the railway, the projected speed was reduced to 70 km/h for all trains on the left track of the two-track railway.

According to the designed condition, the traffic on the line in question is regulated in the APB mode at a block distance.

The locomotive is controlled by the driver through commands from the driver's cab, designed during the production of the locomotive. With locomotive 193-916, no objections or deficiencies were registered on the control systems and devices.

No objections or deficiencies were registered in the designed technical - operational characteristics of the Za series wagons.

## 3.7. Previous accidents of similar character

Based on the data obtained by "IŽS"a.d. for the period from 01.01.2009. to 28.11.2020. on the main arterial line Belgrade Center - Junction "G" - Rakovica - Mladenovac - Lapovo - Nis - Preševo - state border - (Tabanovce) between the stations Jagodina and Bagrdan, there occurred 1 (one) accident, train derailment and review of the accident in question is given in Table No. 3.7.1.

**Table 3.7.1:** Review of the accidents made in the period from 01.01.2009. to 28.11.2020.

| Ordinal No. | Date | Time | Short description | Cause |
|---|---|---|---|---|
| 1 | 13.04.2020. | 15:25 | Between the stations Jagodina and Bagrdan, on the left track of the two track line, at km 122+015, the train derailment od the train No. 62940 (undertaking "Srbija Kargo"a.d.) with 7 *Za* wagons. | Improper maintenance of speed in the zone of restricted speed runs, oscillations in the speed of movement with occasional exceeding of the maximum allowed speed and irregularities in the composition of the train (the undertaking singled out the opinion, considering that the main cause is poor track condition). |

In the accident occurred there were no fatally injured nor injured.

# 4. Analysis and conclusions

## 4.1. Final review of the course of events and making conclusion on the event based on the facts determined during investigation and examination

On 28.11.2020., train No. 45022, composed of 17 (seventeen) wagon tanks loaded with 856 t of sulfuric acid, which was towed by locomotive No. 193-916, was moving from Jagodina station to Bagrdan station on the left track of the two-track railway line. According to the statement of the train driver and on the basis of the records registered by the recording device from locomotive on the movement of train, the train was, from the stop Lanište to the place of the accident, moving at a limited speed of 70 km/h.

At 19:26, immediately after the passage of the spatial signal B 41, on the section of the line that is in the direction and slope of 0.3 ‰, the train driver, according to his own statement, under the light of a reflector about 30 m in front of the locomotive, noticed a large deformation of the track, both rails deformed to the right about 50 cm. He introduced fast braking and felt first a strong lateral jerk, and then a longitudinal jerk, after which the train stopped with its forehead at km 123+459.

Eight wagon tanks derailed, five of which overturned, blocking the right track as well. The train decoupled between the eighth and ninth wagon. The tank of the twelfth wagon was breached and the complete content leaked out of it. On other overturned wagons, there was also a partial leak of sulfuric acid under the lids of the filling and emptying openings. Seven of the eight wagon tanks were severely damaged.

A total of approximately 97 t of sulfuric acid leaked.

The track was damaged over 100 m in length, out of which the superstructure was completely destroyed at over 50 m.

With the quick reaction of the train driver, who immediately after the accident informed the competent dispatchers, the traffic on both tracks between the stations Jagodina and Bagrdan was stopped in time.

## 4.2. Discussion - analysis of the facts established during the investigation and examination with the aim of drawing conclusions regarding the causes of the accident and the effect of the rescue services

### 4.2.1. Review of the derailed wagons at the scene

On 29.11.2020., representatives of CINS went to the scene of the accident. The 193-916 locomotive and the first four wagons were on track. The fifth wagon No. 33 72 7867 810-3 derailed with the rear bogie on the left side of the track in the direction of movement. On the adjacent track (right track of the two-track line), between the fifth and sixth wagons, there was a failed axle assembly of overturned seventh wagon (Figure 4.2.1.1).

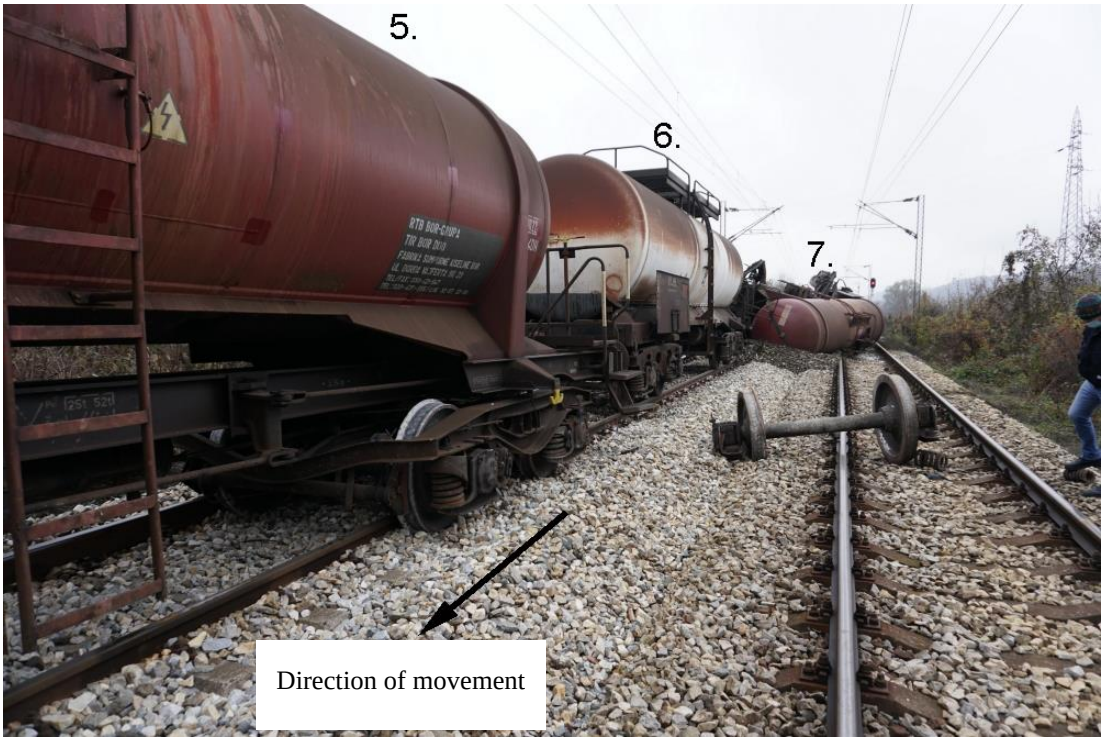



**Figure 4.2.1.1:** Fifth derailed wagon

The sixth wagon No. 33 87 7866 749-7 remained on the rails. The seventh wagon No. 31 72 7865 013-8 was overturned on the left side in the direction of movement, buried in the gravel (Figure 4.2.1.2) and partially on the adjacent track, but remained hooked to the sixth wagon. Two of the four screws were missing on one lid of the overturned seventh wagon and one of the four screws on the other lid. Sulfuric acid leakage occurred under the improperly closed lid (Figure 4.2.1.3).


**Figure 4.2.1.2:** Seventh derailed wagon No. 31 72 7865 013-8

**Figure 4.2.1.3:** Sulfuric acid leakage from the wagon No. 31 72 7865 013-8

The seventh and eighth wagon remained hooked. The connecting hoses of the main air line were found to be disassembled (Figure 4.2.1.4), and the end taps were open. This indicates that after the main air line was emptied by rapid braking due to impact forces during derailment and overturning, the air brake couplings became detached.

The eighth wagon No. 33 72 7867 853-3 was also overturned on the left side, partly on the adjacent track. On this wagon also, one of the four screws was missing on one lid and there was a minor leak of sulfuric acid. (Figure 4.2.1.4).

In the zone of overturning of the eighth wagon, the complete track was deformed to the left, obviously under the influence of large lateral forces while overturning the seventh and eighth wagons to the left in the direction of movement (Figure 4.2.1.5). The first three axle assemblies of the seventh wagon were separated from the frames of the bogies. One axle assembly flew over the seventh wagon and stopped on the adjacent track (Figure 4.2.1.1). Several concrete sleepers at that place were cut in the zone between the rails.

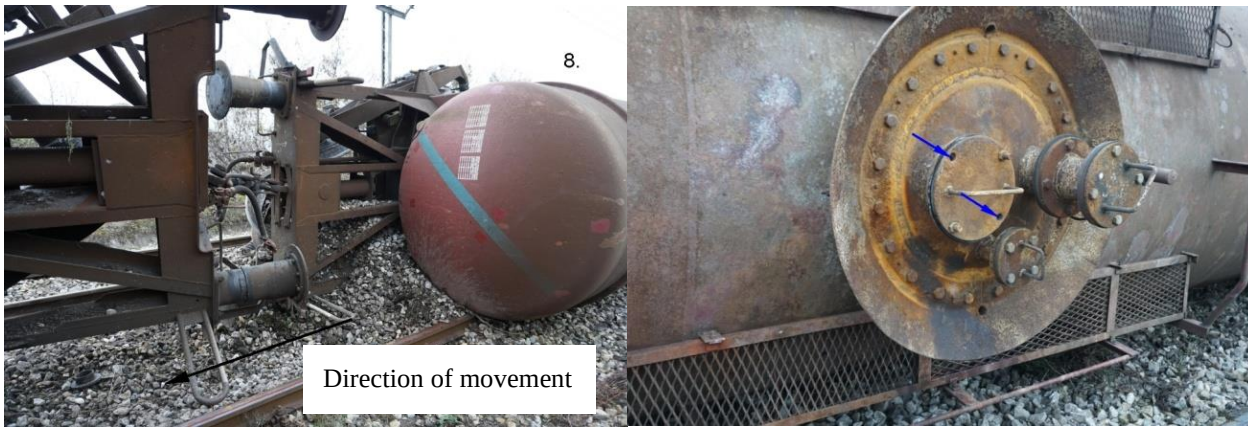



**Figure 4.2.1.4:** Derailed eighth wagon No. 33 72 7867 853-3 and sulfuric acid leakage on the lid


**Figure 4.2.1.5:** Deformed left track

The first part of the train ends with the eighth wagon, which was separated from the second part of the train by approximately 27 m. All traction devices of the front part of the train were found in a tense state after the accident, which means that the seventh and eighth wagon have, after derailment and sinking into the superstructure of the railway, additionally braked that part of the train.


**Figure 4.2.1.6:** Undamaged traction devices at the end of the eighth wagon

Traction devices between the eight wagon, which form the end of the front part of the train, and the ninth wagon, which form the beginning of the second part of the separated train, had no signs of damage, which means that they were disengaged during derailment (Figure 4.2.1.6 and 4.2.1.7). This indicates that the wagons of the front part of the train were the first to derail and cause additional braking of the train during which the ninth wagon caught up with the eighth. At the same time, the eighth wagon rotated to the left around the longitudinal axis, due to overturning, during which the buffers of the eighth and ninth wagon passed each other, allowing the shackle link to be released and it's falling off the hook. In Figure 4.2.1.6. the broken fence and the trail on

the bridge of the eighth wagon can be seen, which most likely originates from the left buffer of the ninth wagon.

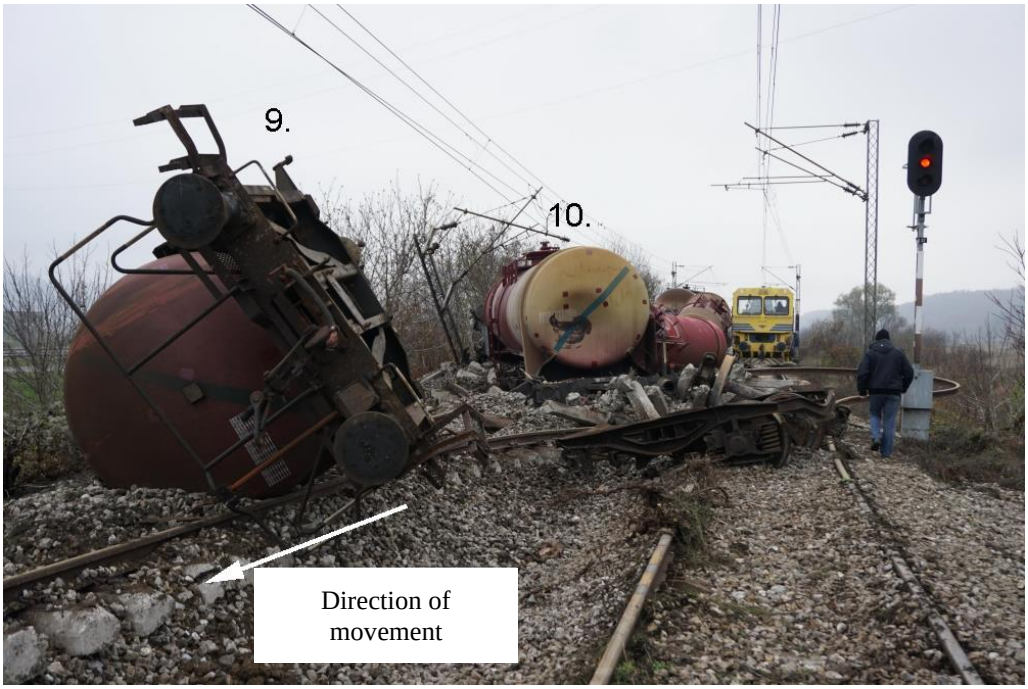
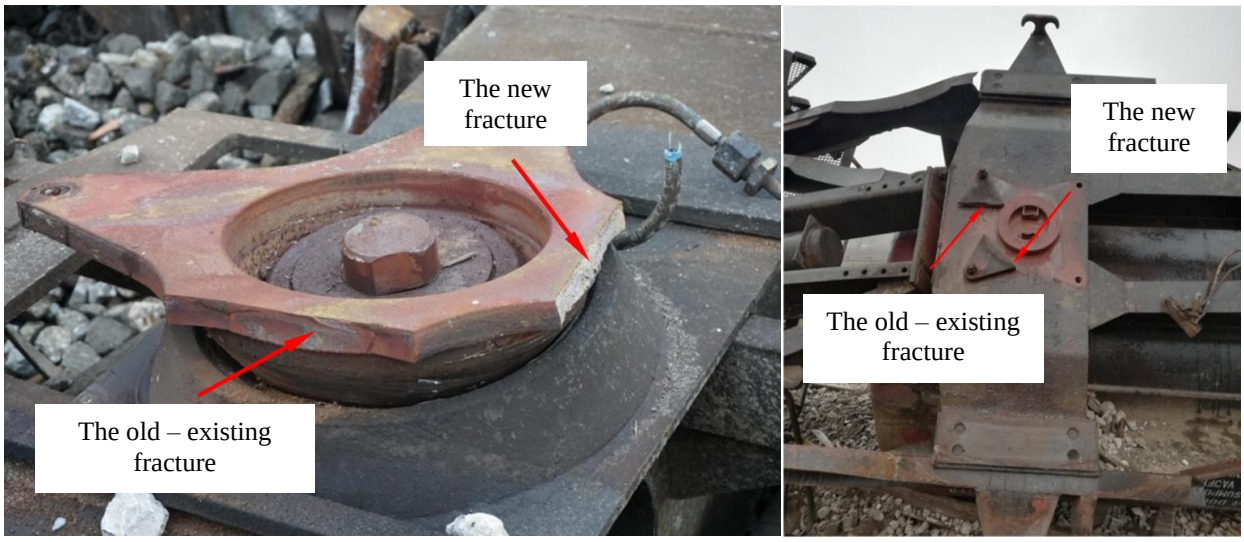



**Figure 4.2.1.7:** Overturned ninth wagon with undamaged traction devices

From the overturned ninth wagon, there was a larger leakage of sulfuric acid under the lids of the filling and emptying openings.

The front bogie of the ninth wagon detached from the wagon box during the derailment due to the cracking of the fastening screws and the fastening plate of the bogie's upper part. One axle detached from the frame of the bogie.




*а)* *б)*

**Figure 4.2.1.8:** Front flange center bowl fracture of the ninth wagon' front bogie No. 33 72 7867 846-7

In Figure 4.2.1.8. it can be seen that one arm of the flange plate of the upper cup had already been broken during earlier exploitation. According to the polished appearance of the part of the crack surface, it has the character of a fatigue fracture. Since the flange plate of the upper center bowl was fastened with four screws, it is most likely that this old fracture was a consequence of the previous loosening of one of the fastening screws.

The other broken arm of the flange plate is metallic shiny, coarse-grained cross-section and is obviously broken by a single action of very great force.

The braking force which can be transmitted by the center bowl and its connecting elements to the wagon box may not be greater than the adhesion force in contact of the four wheels of the bogie with the rail. During fast braking, the coefficient of adhesion does not exceed 0.12. If it were adopted that in the extreme case it was as high as 0.2, the extreme braking force could not exceed approximately 70 kN.

On the other hand, the area of the broken arm is more than 15 $cm^2$. For the assumed tensile strength of a cast steel from which the center bowl was made of only 400 N/mm2, the breaking force (if it originates from fast braking) should be at least 600 kN or at least 10 times greater than the realistically possible force during fast braking (without taking into account the force transmitted by the two remaining screws).

It can be concluded that the fracture of this arm and the tearing of the remaining two screws did not precede the derailment, but were caused as a result of the action of very large impact forces. Also, the old - existing fracture did not affect the occurrence of derailment, but it contributed to easier tearing of the other arm and the remaining screws at the time of the accident and more severe consequences of the accident.

According to the situation found, after the detachment that occurred during the derailment between the eighth and ninth wagons, the ninth wheels sank into the superstructure of the track and overturned on the right side in the direction of movement. Then the head of the tank of the tenth wagon collided with the buffer of the overturned ninth wagon, upon which it was not broken, but a large indent remained on it (Figure 4.2.1.9).


*a) After the accident*

*b) After clearing the tracks and cutting the rails*

**Figure 4.2.1.9:** Tenth wagon with a bent left rail nailed to the front part

In addition, the left rail, in the direction of movement, was found nailed to the front of the tenth wagon above the frame of the bogie (Figure 4.2.1.9. b). The length of the pinned and bent rail indicates that its broken beginning was approximately in the zone of the found twelve wagon, ie ten meters after the insulated joint, observed in the direction of movement. This indicates that when the tenth wagon approached that point, the track was already so destroyed that the rail was raised enough to be stuck above the frame of the bogie.

The front parts of the bogie between the tenth and eleventh wagon are completely compressed and deformed. The eleventh wagon overturned on the left side in the direction of movement (Figure 4.2.1.10. a).


*a) After the accident* *b) After removing the eleventh wagon*

**Figure 4.2.1.10:** Twelfth wagon with a punctured tank

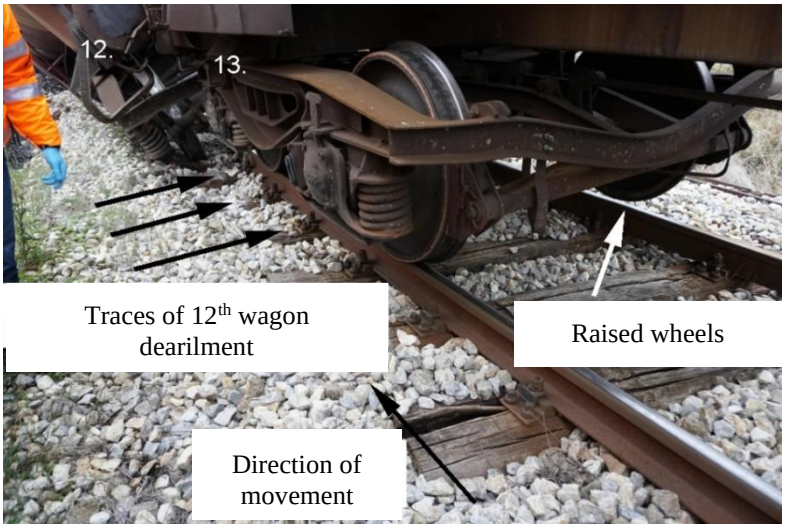
The twelfth wagon with a head of the tank collided against the buffer of the eleventh wagon, thus breaking the tank (Figure 4.2.1.10. b). The entire content of 51.7 t of sulfuric acid leaked from this tank.

**Figure 4.2.1.11:** Lack of screws on the lid of the twelfth wagon No. 31 72 7865 010-4

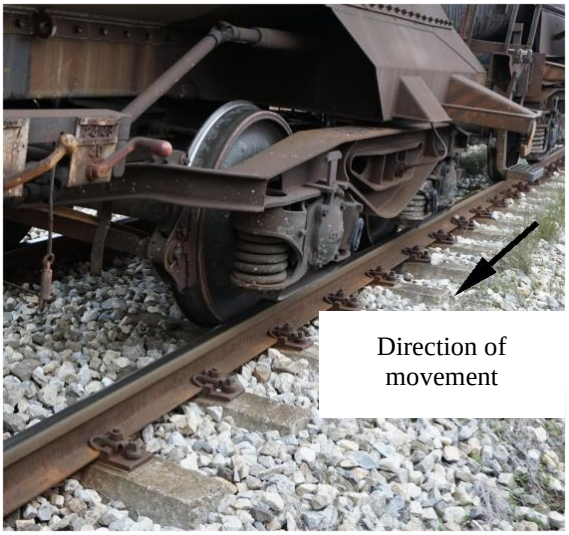
Defects of the part of the screws on the tank lids were also found on the twelfth wagon (Figure 4.2.1.11.).

In Figure 4.2.1.12. the beginning of the destroyed part of the track with an insulated joint is shown, seen in the direction of train movement. Thirteenth wagon collided with the buffer of twelfth wagon with the front of the tank (Figure 4.2.1.13. c). The left wheels of the front bogie in the direction of movement remained on the unbroken part of the track directly in front of the insulated joint. The right wheels of the front bogie were found to be up off the track (Figure 4.2.1.13. a), and the rear bogie derailed to the right in the direction of movement (Figure 4.2.1.13. b). The left wheels of the rear bogie had fallen on the inside of the track next to the rail, and the right ones remained next to the right rail in the air. Apparently, this happened under the influence of a collision on the twelfth wagon that overturned on the left side.


**Figure 4.2.1.12:** The beginning of the destroyed track at the insulated joint at km 123+660.80 and the zone of greatest acid leakage




*a) Front bogie of the 13th and rear bogie of the 12th wagon*




*b) The rear derailed bogie of the 13th wagon*

*c) Damage to the 13th wagon (recorded upon removal of the 12th wagon)*

**Figure 4.2.1.13:** Position and state of the 13th wagon

All the wagons behind the thirteen remained on the track. In all these wagons, the buffers were found in a compressed state due to a collision with a previously derailed wagon.

### 4.2.2. Inspection of wagons in the workshops and review of overhaul documentation

During the on-site inspection of the wagon, it was noticed that on some buffers, the trace on the lubricant indicates insufficient travel, which could contribute to the increase of the consequences of the accident. In the case of separate bogies, it has been noticed that the wear parts of the side bearers go beyond the exploitation tolerances. Therefore, in the station Bagrdan on 01.12.2020., the first six wagons from the train were inspected.

A broken wire was found on the first wagon in train No. 33 87 7864 174-0, by which the G-P brake mode switch was previously fixed in the P position (Figure 4.2.2.1). In order to check

whether any malfunction of the brake of these wagons could have had an impact on the occurrence of the accident, the wagons were sent to a repair workshop to check the correctness of the brake.

**Figure 4.2.2.1:** The wire that fixed the G-P gear handle

In order to check the indications that the buffers of certain wagons do not have sufficient travel, which would also have a partial impact on the consequences of the accident, on 04.12.2020., a test was made to compress six wagons from a train at the Bagrdan station. By observing the buffer travel, an indication was determined to check the characteristics of the buffer from wagon No. 31 72 7865 011-2 and wagon No. 33 87 7864 174-0 on the press in the repair workshop.

On 08.02.2021. in the repair workshop for freight wagons repair in Velika Plana (owned by "Srbija Kargo"a.d.), an inspection of all derailed wagons was performed.

In the workshop, a review and verification of the characteristic measures of the wheel and axle profiles was performed. Based on the Report on the detailed review submitted by "Srbija Kargo"a.d. (No. 18/21-318 of 10.02.2021) after the accident and review of the submitted documentation on the maintenance of derailed wagons during the previous regular repair, it was determined that the characteristic measures of all derailed wagons (eight wagons) relating to the height of the flange, flange thickness, measures $q_r$, internal wheel distance, external distance over wheel flange, rolling circle diameter, within prescribed limits. Based on the documentation submitted, all wagons were maintained in a timely manner in accordance with the applicable regulations.

#### 4.2.2.1. Wear of center bowl and side bearers

In the workshop "Srbija Kargo"a.d. in Velika Plana, damage and excessive wear of plastic inserts in center bowl s and on the side elastic slides of the fifth and thirteenth wagon in the train were noted. This wears and damages can significantly increase the swivel resistance of the bogies. This fact is not the direct cause of this accident, but it increases the swivel resistance when turning

in curves, which is reflected in the increase of lateral guiding forces on the wheels, which in certain situations can contribute to wagon derailment by climbing the wheel on the rail.

*a)*

b)

**Figure 4.2.2.1.1:** Condition of slides and lower center bowls of the wagon No. 33 87 7868 736-2

In Figure 4.2.2.1.1. the excessively worn slide inserts at the ends levelled with a metal support are shown and the worn and damaged insert of the center bowl of one bogie Y25 from the wagon No. 33 87 7868 736-2. Traces of scraping of metal parts of the cup can be seen on the rim of the center bowl from contact with the upper center bowl, which must not happen with the insert within the permitted wear limits.

In Figure 4.2.2.1.1. b shows a worn and deformed insert of the center bowl of the second bogie from the wagon No. 33 87 7868 736-2.

In Figure 4.2.2.1.2. shows the condition of the center bowls of both bogies Y25 from wagon No. 33 72 7867 810-3 which show traces originating from the metal-metal contact with the upper center bowls due to excessive wear of the plastic insert.

According to the data from the Instructions for operation and maintenance of bogies type Y25 and type Y27 adopted on the Yugoslav Railways ("Official Gazette of ZJŽ" No. 2/87), the average wear of the insert is 0.1 mm per 200,000 km travelled. Based on that, it is clear that the inserts should have been replaced in the previous revision, but that this was not done.

**Figure 4.2.2.1.2:** Center bowls of bogies from the wagon No. 33 72 7867 810-3

Figure 4.2.2.1.3. shows the worn insert of the side bearer from the wagon' bogie No. 33 72 7867 810-3, which was found at the place of derailment.

**Figure 4.2.2.1.3:** Non-metallic insert of the lower side bearer of the wagon No. 33 72 7867 846-7 bogie worn to the metal support

By reviewing the submitted documentation on the maintenance of the wagon of the holder Atir-Rail SA in the maintenance procedures, there is no explicitly prescribed control of the condition and wear of the wearing inserts of center bowls and side bearers. There is no information in the submitted documents on the performed maintenance procedures that these controls were performed.

By reviewing the submitted documentation on the maintenance of the wagon of the holder Elixir Group d.o.o. it was determined that it does not contain maintenance procedures from which a list of instructions that must be an integral part of the maintenance file could be seen, but only overhaul-technical documentation on the work performed on the wagons that participated in the derailment. In addition, a short list of the scope of work in the regular repairs of the wagon tanks for the transport of sulfuric acid was submitted by Elixir Group d.o.o., with a mark MIP-RŠV d.o.o. Ćuprija, without numeric marking and without date.

The scope of work includes an inspection and, if necessary, the replacement of worn inserts of the center bowl and side bearer. The entire submitted overhaul-technical documentation does not show that this was done on any wagon.

It is necessary to correct the maintenance procedures, ie to adopt the maintenance procedure and appropriate maintenance instructions, as well as the control of the performed works, considering that the wagons with worn inserts of the center bowl and side bearer represent a significant risk of derailment in curves. In accordance with the requirements of the Rulebook on the maintenance of railway vehicles, maintenance of the bogies must be performed according to the manufacturer's instructions, so the procedures must be harmonized with these instructions. Maintenance deadlines must ensure that parts between the two repairs do not wear out more than the operating limits specified by the manufacturer. If the original instructions are not available, valid technical documentation must be used as a basis, eg: 250 Instructions for operation and maintenance of bogies type Y 25 and type Y 27 adopted on the Yugoslav Railways (“Official Gazette of ZJŽ” No. 2/87).

#### 4.2.2.2. Buffer characteristics

In the Factory of Railway Vehicles Želvoz 026 Smederevo, on 24.02.2021. an inspection and testing of the buffers of wagon No. 31 72 7865 011-2 (owner Elixir Group d.o.o. Šabac) and wagon No. 33 87 7864 174-0 (owner Atir-Rail SA) was performed.

A visual inspection of the removed buffers and measurement of the external dimensions with a meter tape was performed. The dimensions of the buffers were within the prescribed limits. Traces of lubricant in the zone of the guide and baffle sleeve indicated that the travels of the buffer of the wagon No. 31 72 7865 011-2 are significantly smaller than 105 mm, so the recording of the force-stroke diagram on the press was performed.

The analysis of the recorded characteristics of four buffers showed that only one buffer has force-stroke characteristics in acceptable tolerances for the period between two revisions in relation to the prescribed limits for category A buffers, while the remaining three identified the following shortcomings:

- The buffer preload is too high so that the buffer compression starts at approximately 80 kN.
- The maximum force in the springs is reached at a stroke of 60 to 70 mm instead of the prescribed 100 to 105 mm for this category of buffers.
- There are no visible category markings on the buffers according to UIC regulations or EN 15551.

In the case of longitudinal disturbances in the train, which are a consequence of traction and braking, such buffers do not protect the bearing structure and the load to a sufficient extent. In the case of fast braking, they cause a jump in force and the formation of greater impulse forces and accelerations, which pose an additional risk. In the case under consideration, such buffer characteristics contributed to the more severe consequences of the accident.

When passing a wagon with such buffers through sharp curves, such a characteristic induces high tensile forces of the coupling and compression of the inner buffer, which creates a moment that increases the lateral force on the guide wheel and increases the risk of derailment by climbing the wheel on the rail.

From the recorded diagrams of wagon buffers No. 33 87 7864 174-0 of the owner of Atir-Rail SA it can be seen that the buffers have force-stroke characteristics within acceptable tolerances for the period between two revisions in relation to the prescribed limits for category A buffers. There is less subsidence of the elastomeric spring of the elastic-friction apparatus, ie the maximum force is reached at a slightly lower stroke than declared for this category of buffers. Compression stroke work and absorbed work are within the prescribed limits. There are appropriate visible markings on the buffers for category A buffers capable of irreversibly absorbing additional impact energy according to EN 15551.

Reviewing the submitted maintenance documentation for the wagons that derailed as well as for the two wagons that remained on the track, namely wagon No. 31 72 7865 011-2 and No. 33 87 7864 174-0, there are no records of force-stroke of the buffer in the maintenance files, after a major repair. It is not clear from the submitted documentation that the recording of the force-deflection diagram is required at all.

It is necessary to adopt or correct the existing instructions in which, in accordance with the requirements of the Rulebook on maintenance of railway vehicles, the documentation of buffer characteristics after repair will be defined and compared with the characteristics given by the manufacturer, ie for newer and reconstructed wagons in accordance with the required characteristics according to EN 15551 for the appropriate type of buffer.

#### 4.2.2.3. Brake of the wagon No. 33 87 7864 174-0

For wagon No. 33 87 7864 174-0 (which were the first to the locomotive 193-916), where a wire was found with which the GP gear handle was tied in position P, in the workshop Želvoz 026 Smederevo, an inspection was performed and braking diagrams were recorded. According to the submitted measuring list IB: 594 159-1 of 24.2.2021., the maximum pressure in the brake cylinder during fast braking in P mode was 4.05 bar, and in G mode 4.09 bar. These values are above the prescribed value of 3.8 ± 0.1 bar. In the accompanying minutes, it was stated that the distributor valve lacks a maximum pressure limiter (HBG) and that the G-P (passenger-cargo) mode switch switches without resistance. Other brake characteristics and parameters are within the permitted limits.

Based on that, it can be stated that the first wagon No. 33 87 7864 174-0 in the train achieved approximately 7% higher braking force than projected. The unwanted change of the G-P braking mode was also possible under the effect of longitudinal jerks.

### 4.2.3. Braking and loading of the train

Based on the submitted conductor's report for train No. 45022 from 28.11.2020. (Figure 4.2.3.1.), the mass of the train without a locomotive was 1233 t, and the total braking mass in braking mode was 856 t. The percentage of braking mass was 69%, which is above the minimum required 65% for a train up to 500 m long and a maximum speed of 100 km/h.

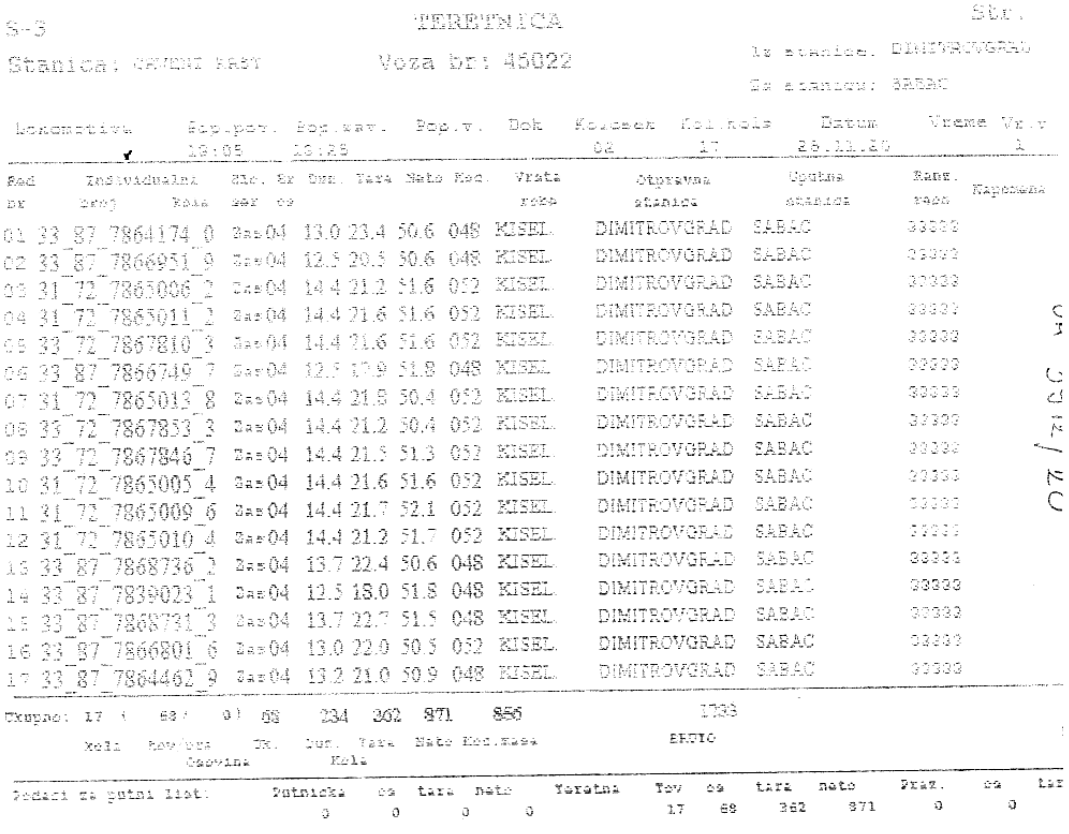
Based on the submitted records from the device for recording data on the movement of the locomotive, it can be concluded that the locomotive 193-916 braked in mode G. All wagons were braked in mode P, which was determined by on-site inspection.

According to UIC 421, for a train weighing from 800 t to 1200 t, the locomotive should brake in mode G, and the rest of the train in mode P.

For a train weighing over 1200 t, it is necessary for the locomotive and the first five wagons to be braked in mode G, and the rest of the train in mode P.

Formally, train No. 45022 exceeds a mass of 1200 t and the first five wagons had to be braked in mode G. Given that exceeding the limit mass is less than 3%, it can be considered that the train braking mode did not pose a significant risk that would could cause an accident.

For further analysis, it is necessary to keep in mind the time frames of operation of the pneumatic brake. During fast braking, the time of development of braking force in the locomotive in mode G is from 18 to 30 s (middle value 24 s), and in individual wagons in mode P, from 3 to 5 s (middle value 4 s). To this should be added an average of approximately 0.5 s delay from the moment of braking to the beginning of the development of pressure in the brake cylinder, as well as the breakthrough time (necessary for the pressure drop wave in the main air line to reach the end of the train) for the train of length 234 m is approximately 1 s. This practically means that the first wagon reaches approximately 50% of the braking force after approximately 2.5 s, the last after 3.5 s, and the locomotive after an average of 12 s. The first wagon reaches 95% of the braking force after approximately 4.5 s, the last after 5.5 s, and the locomotive after an average of 24 s, and certainly not before 18 s from the moment of placing the brake valve handles in the fast braking position.



S-3 TERETNICA Str.

Stanica: OPENIC RAST Voza br: 45022 Iz stanice: DIMITROVGRAD

Za stanicu: SABAC

| Lokomotiva | Bop.por. | Bop.nav. | Pop.v. | Dok | Kocnica | Kol.kola | Datum | Vreme | Vr.v |
|---|---|---|---|---|---|---|---|---|---|
| | 18:05 | 20:55 | | | 68 | 17 | 26.11.20 | | 1 |

| Red br | Individualna oznaka | Vlas. | Ser | Ex oz | Duz. | Tara | Neto | Kod. | Vrsta robe | Otpravna stanica | Ciljna stanica | Rang. voza | Napomena |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 | 33 87 7864174 0 | Zas | 04 | | 13.0 | 23.4 | 50.6 | 048 | KISEL. | DIMITROVGRAD | SABAC | 99999 | |
| 02 | 33 87 7866951 9 | Zas | 04 | | 12.5 | 20.5 | 50.6 | 048 | KISEL. | DIMITROVGRAD | SABAC | 99999 | |
| 03 | 31 72 7865006 2 | Zas | 04 | | 14.4 | 21.2 | 51.6 | 052 | KISEL. | DIMITROVGRAD | SABAC | 99999 | |
| 04 | 31 72 7865011 2 | Zas | 04 | | 14.4 | 21.6 | 51.6 | 052 | KISEL. | DIMITROVGRAD | SABAC | 99999 | |
| 05 | 33 72 7867810 3 | Zas | 04 | | 14.4 | 21.6 | 51.6 | 052 | KISEL. | DIMITROVGRAD | SABAC | 99999 | |
| 06 | 33 87 7866749 7 | Zas | 04 | | 12.5 | 17.9 | 51.8 | 048 | KISEL. | DIMITROVGRAD | SABAC | 99999 | |
| 07 | 31 72 7865013 8 | Zas | 04 | | 14.4 | 21.8 | 50.4 | 052 | KISEL. | DIMITROVGRAD | SABAC | 99999 | |
| 08 | 33 72 7867853 3 | Zas | 04 | | 14.4 | 21.2 | 50.4 | 052 | KISEL. | DIMITROVGRAD | SABAC | 99999 | |
| 09 | 33 72 7867846 7 | Zas | 04 | | 14.4 | 21.3 | 51.3 | 052 | KISEL. | DIMITROVGRAD | SABAC | 99999 | |
| 10 | 31 72 7865005 4 | Zas | 04 | | 14.4 | 21.6 | 51.6 | 052 | KISEL. | DIMITROVGRAD | SABAC | 99999 | |
| 11 | 31 72 7865009 6 | Zas | 04 | | 14.4 | 21.7 | 52.1 | 052 | KISEL. | DIMITROVGRAD | SABAC | 99999 | |
| 12 | 31 72 7865010 4 | Zas | 04 | | 14.4 | 21.2 | 51.7 | 052 | KISEL. | DIMITROVGRAD | SABAC | 99999 | |
| 13 | 33 87 7868736 2 | Zas | 04 | | 13.7 | 22.4 | 50.6 | 048 | KISEL. | DIMITROVGRAD | SABAC | 99999 | |
| 14 | 33 87 7839023 1 | Zas | 04 | | 12.5 | 18.0 | 51.8 | 048 | KISEL. | DIMITROVGRAD | SABAC | 99999 | |
| 15 | 33 87 7868731 3 | Zas | 04 | | 13.7 | 22.7 | 51.5 | 048 | KISEL. | DIMITROVGRAD | SABAC | 99999 | |
| 16 | 33 87 7866801 6 | Zas | 04 | | 13.0 | 22.0 | 50.5 | 052 | KISEL. | DIMITROVGRAD | SABAC | 99999 | |
| 17 | 33 87 7864462 9 | Zas | 04 | | 13.2 | 21.0 | 50.9 | 048 | KISEL. | DIMITROVGRAD | SABAC | 99999 | |

Ukupno: 17 ( 68 / 0) 68 234 362 871 886 1733

Kola Kol/vuc Osovina OK. Duz. Tara Neto Kod.Masa BRUTO

| Podaci za putni list: | Putnicka | os | tara | neto | Teretna | Tov | os | tara | neto | Praz. | os | Lic |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 0 | 0 | 0 | | 17 | 68 | 362 | 871 | 0 | 0 | |

**Figure 4.2.3.1:** Conductor's report No. 45022

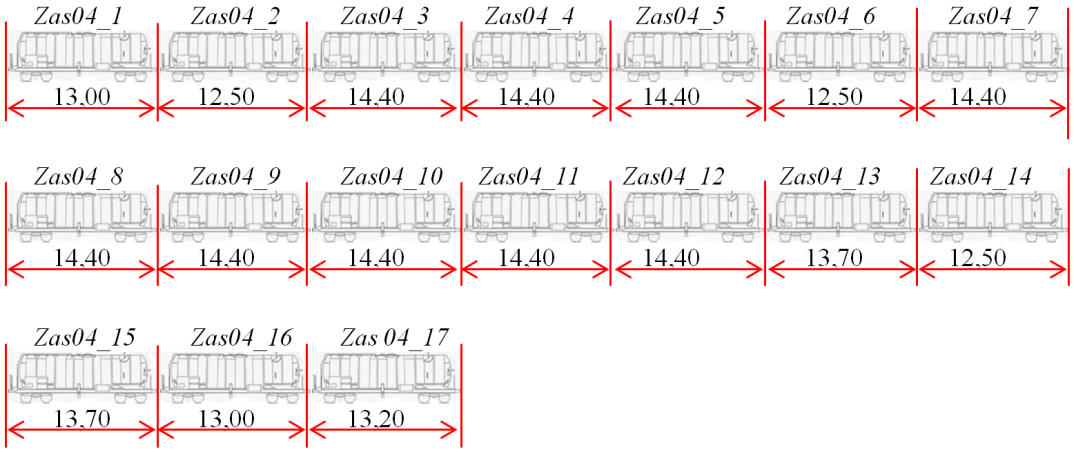



**Figure 4.2.3.2:** Train scheme No. 45022 with wagon lengths

The brake release process also has a similar start delay in relation to the given command and still develops much slower than the braking process (15-25 s for individual wagons of mass over 70 t in P mode).

Based on the conductor's report for train No. 45022, all wagons were loaded within the limits of carrying capacity for mode S. Due to the partial movement of wagons on lines with lower permissible axle load, all wagons were loaded for a nominal axle load of 18 t. Based on data on useful tank volumes and having in mind the density of sulfuric acid concentration of 95-98% from 1.84 kg/l, the degree of filling of tanks ranged from 53.9% to 83.3%, on average 73%.

In the case of tanks that are partially filled, especially under the action of longitudinal inertial forces, a ripple of liquid occurs, which causes additional oscillatory forces. The greatest oscillatory forces occur when the tanks are filled to 2/3 of the volume, since then there occurs the most unfavourable ratio of the mass of the load and the available space for ripples. During the ripple, alternating oscillatory load and unloading of the wheels of the front and rear end of the tank occurs. At the moment of unloading the wheels, the effect of the transversal unevenness of the track makes it much easier for the wheels to climb on the rail and derail. This is the reason why the frequency of derails and overturns is higher on trains with insufficiently filled tanks than on other cargoes. This is also the most probable reason that the fifth and thirteenth wheels derailed on the rear-unloaded bogie.

It can be stated that when using wagon tank on lines that have less permissible axle load than the projected axle load for tanks, there is an additional risk of derailment due to increased fluid ripple due to lower degree of filling.

### 4.2.4. The train driver’s statement

From “Srbija Kargo”a.d. for the train driver of the train No. 45022, the Minutes on the hearing of the employee and the Report of the staff of traction vehicle on irregularities during operation (Form EV-38) of 28.11.2020 were obtained.

For further clarification, in the premises of CINS on 19.02.2021., the train driver was questioned by the CINS Working Group.

In considering the train driver's statement, the CINS investigative team considered the following:

1. Such a large and short deformation, as described by the train driver, which includes 2 to 3 sleepers, would require the previous action of an extremely large concentrated transversal external force, but even in that case the resulting deformation would be longer. The investigative team believes that the appearance of such an external force before arrival of the train at the scene of the accident is practically unbelievable.

2. One can take into account the possibility that the train driver's observation under the spotlight was inaccurate and that the deformation was longer. Such deformation could occur on DTŠ in summer conditions at high temperatures when there is a thermal compressive stress in the rails. At the request of CINS, the Republic Hydrometeorological Institute submitted data on meteorological conditions in the accident zone (letter No. 925-1-391/2020 of 29.12.2020). According to the data from the Meteorological Station Ćuprija, which can be considered representative as the place of the accident, on 28.11.2020., the temperature was minimally of -0.8°C, and a maximum of 0.3°C. It was cloudy throughout the day and there was no precipitation. The ground was moist all day. A light wind was blowing with maximum gusts of 3.4 to 5.4 m/s.

Given the temperature data, it is unlikely that the track was ejected due to thermal compressive stresses. At a temperature of approximately 0°C in DTŠ, there was a tensile stress. Due to that, the rail could possibly burst, but it could not lead to such a large transversal ejection of both rails.

3. Approximately one hour before the accident, passenger train No. 2906 passed on the same track in the same direction, whose staff at the Bagrdan station did not report anything unusual.

4. Based on the analysis of records from the device for recording data on running on the locomotive 193-916, at the time of the introduction of fast braking, it was located with her front at a place approximately 0.8 m behind the insulated joint (Figure 4.2.5.3.). The driver stated that he started braking after crossing the deformed part of the track. This means that the deformed part of the track should be in the zone immediately before the insulated joint. That part of the track remained undamaged. An on-site examination revealed a deformation of 3 to 4 cm of the left and right rails on the left side observed in the direction of movement (Figure 4.2.5.4).

5. Based on the above, the CINS investigative team considers the train driver's observation about the size of the track deformation to be unlikely.

### 4.2.5. Analysis of locomotive 193-916 data

Based on the submitted analysis from the device for recording train movement data, the speed and position of the train in the characteristic moments of the accident can be determined.

In Figure 4.2.5.1. the position of the train front in relation to the hectometer mark for km 123+500 is shown. Having in mind the length of the locomotive (18.98 m), the first wagon (12.99 m) and the second wagon up to the third axle (12.54 m - 2.57 m - 0.9 m), the front of the train stopped at km 123 +459.


**Figure 4.2.5.1:** The position of the train front in relation to the hectometer pole

In Figure 4.2.5.2. an excerpt of the diagrams obtained from the locomotive 193-916 movement data recording device for the period of approximately 1.5 minutes before and during the accident is shown. The diagrams mark the characteristic moments:

1- the moment of introduction of fast braking by the train driver,

2- the moment of stopping of fast braking by the train driver,

3- approximate moment of train decoupling,

4- moment of stopping the locomotive with the front part of the train.

Based on detailed data from the device from the moment of introducing the fast braking to the moment of stopping, the locomotive crossed 201 m. Based on that, it follows that the train driver started fast braking at km 123+660, which is 0.8 m after crossing the insulated joint on the track at 19: 26: 54.90. This train position is schematically shown in Figure 4.2.5.3.

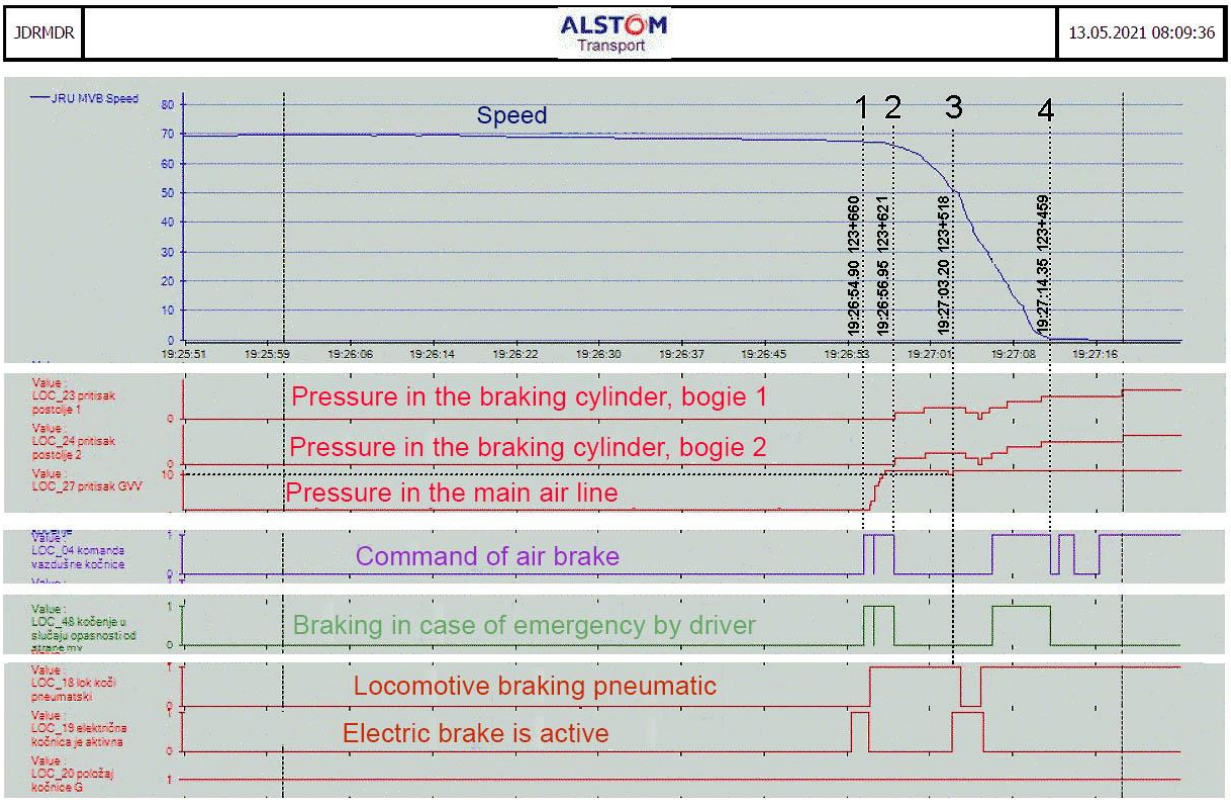



**Figure 4.2.5.2:** Excerpt of data from the locomotive data log device 193-916

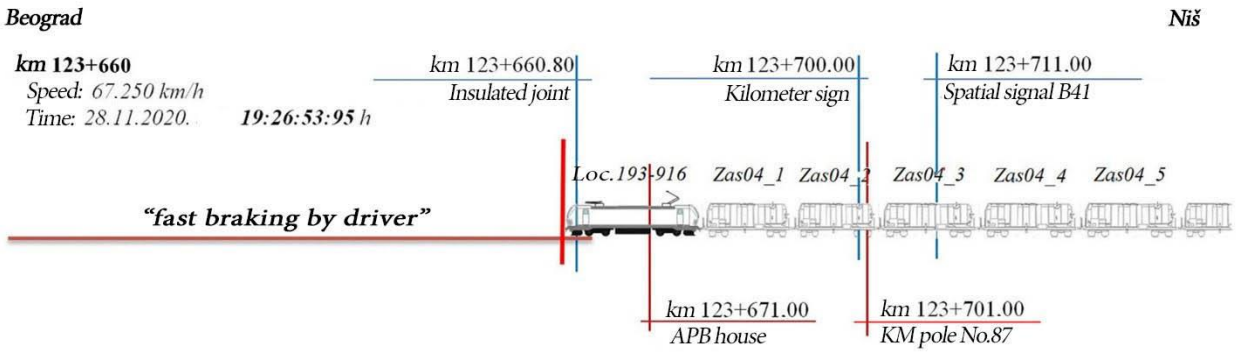


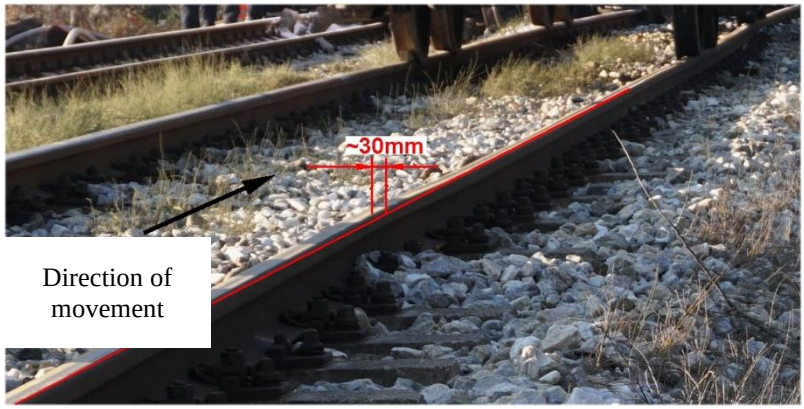

**Figure 4.2.5.3:** Position of the train at the moment of introducing the fast braking

According to the train driver's statement, he started the braking after overcoming a large deformation of both rails, which he had previously noticed. Having in mind the position of the train from Figure 4.2.5.3. and the train driver's statement, the deformation should be in the area around the APB house, and certainly in front of the insulated joint. That section of the track remained undamaged. It did not show a large deformation to the right side, as described by the train driver, or credible traces that there was such a large transversal movement of the track.

Viewed in the direction of train No. 45022 movement, in the zone of ten meters behind the hectometer mark at km 123+700, ie approximately 30 m before the insulated joint, a transversal deformation of both rails to the left side was observed. At the left rail, the deformation was approximately 35 mm, and at the right approximately 30 mm (Figure 4.2.5.4). The deformation is

at a length of 10 sleepers (approximately 6 m). According to standard EN 13848-5: 2017, the directional deviation limit that requires immediate intervention, for a speed of 80 km/h is 22 mm.


*a) left rail in direction of movement*




*b) right rail in direction of movement*

**Figure 4.2.5.4:** Observed deformation of the left and right rail

This deformation does not correspond to the deformation that the train driver stated in his statement, because it is significantly smaller and longer, and it extends to the left instead of to the right in relation to the direction of the train movement.

In general, such deformation of the left and right rail could initiate a derailment, especially having in mind the probable excitation of fluid ripples in the tanks.

Twenty meters further, in the direction of movement, near the APB house (at km 123+673), the first unambiguous trace of the impact of derailed wheels on the screws of the left rail fastening connection, from the inner side (Figure 4.2.5.5), which exist only on two screws at a distance of 1.8 m and corresponding to the position in which the second derailed bogie of the thirteenth wagon was found. There are no signs of derailment on the adjacent screws and sleepers or on the side of the opposite rail. Traces were taken after the wagons were removed from the place of the derailment.

**Figure 4.2.5.5:** The first trace of derailment from the thirteen derailed wagons

The following traces originate from the derailment of the twelfth wagon and are already shown in Figure 4.2.1.13. a). These are the only clear traces of derailment before the insulated joint.

Analyzing further recorded data from the locomotive (Figure 4.2.5.2.), after the introduction of fast braking, a pressure drop is observed in the main air line. This data has eleven levels. Level 0 indicates the nominal pressure in the main line (5 bar). Level 10 indicates a pressure of 3.5 bar, which corresponds to the set maximum braking. Level 11 indicates the pressure in the main line below 3.2 bar, which corresponds to fast braking or loss of pressure due to train decoupling.

The pressure in the brake cylinders of the front and rear bogie of the 193-916 locomotive is displayed in seven levels. Level 7 corresponds to the maximum pressure in the brake cylinder.

After 2.05 s from the introduction of fast braking, the braking interruption was noticed by the train driver. Based on the train driver's statement, it was not his conscious action and was most likely the result of a longitudinal jerk. The longitudinal jerk could not be caused by the action of the brake. From the pressure diagram in the brake cylinders of the locomotive, it can be seen that it did not even start to grow until that moment, that is, the locomotive did not start to brake. Having in mind the explanation given in chapter 4.2.3, up to that point the pressure in the brake cylinders of the first wagon could reach only approximately 35% of the maximum value, and for the last wagon a little over 10%. Accordingly, a drop in speed was recorded in the first 2.05 s for only 0.453 km/h.

Previously, it indicates that the jerk could have been a consequence of the beginning of the derailment. In Figure 4.2.5.6. the train position at that time is shown. Based on this position, having in mind very few traces of derailment in front of the insulated joint, which occurred in the final phase of derailment of the twelfth and thirteenth wagon, it can be assumed that the jerk could have occurred due to collision of locomotive wheels or the first two wagons on some kind of obstacle or broken rail in the zone of insulated joint or behind it.

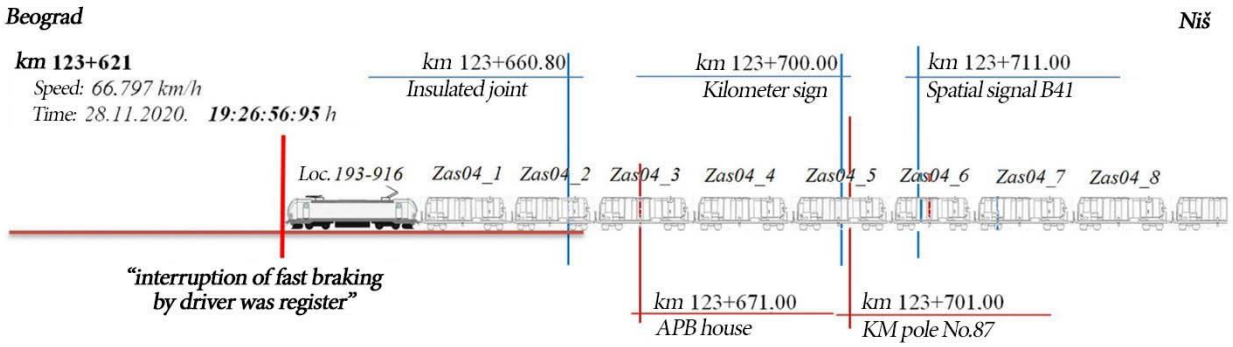



**Figure 4.2.5.6:** The train position at the moment of cessation of fast braking

Interruption of fast braking causes the main air line to be replenished with air. After 5.75 s, it can be seen that the pressure in the main line changes from level 11 to level 10. This means that due to the replenishment, the pressure in the main line increased over 3.5 bar and a short-term unlocking began, which can be seen by the signal "locomotive brakes pneumatically" which drops from 1 to 0. Brake release is also seen after a short-term pressure drop in the brake cylinders of the locomotive, which occurs with the usual delay in relation to changes in the main air line.

In the next half second, the pressure in the main line goes to level 11 again (the pressure drops - the main line empties) even though the position of the brake valve handles is still in the position of the fast braking interruption. This indicates that at that moment, the main air line was broken, most likely between the eighth and ninth wagon due to the overturning of the seventh and eighth wagons on the left side. The position of the train at that time is shown in Figure 4.2.5.7.

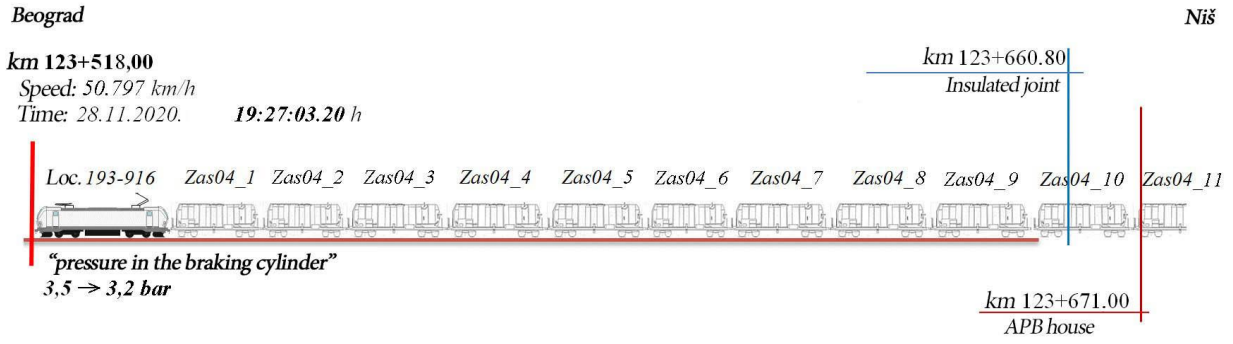



**Figure 4.2.5.7:** The train position at the moment of decoupling

It can be seen from the records that after the decoupling in the brake cylinders of the locomotive, the pressure rises again, the signal "locomotive brakes pneumatically" changes to position 1 (braking) even before the driver returns the brake valve handles to the fast braking position.

It can be further seen that by the time of stopping, the pressure in the brake cylinders of the locomotive reached level 5 out of 7, ie in accordance with the slow action of the G braking mode, it did not even reach the maximum braking force.

Figure 4.2.5.8. shows the train position after stopping upon derailment.

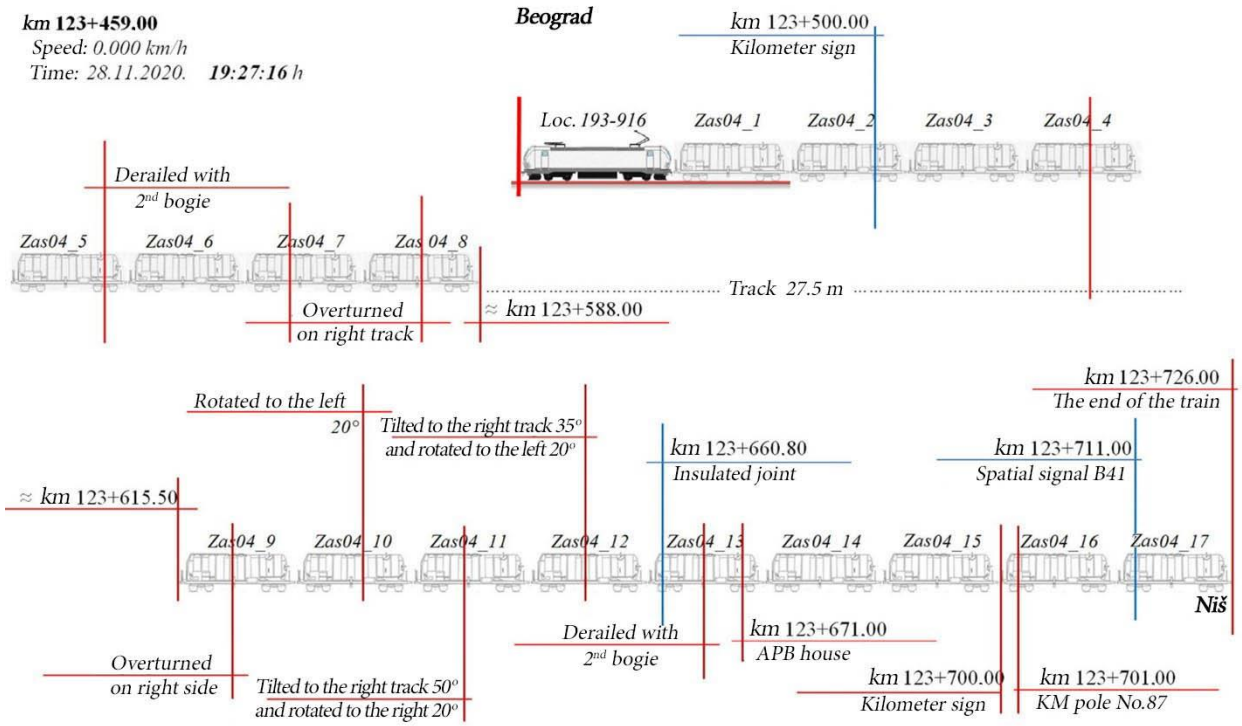



**Figure 4.2.5.8:** The train position after stopping upon derailment

### 4.2.6. Failures in train dispatch, receipt and inspection

As stated in section 4.2.1. on several tanks it was found that 1 or 2 of the 4 screws, on the lids for filling or emptying the tank, were missing. As a result, sulfuric acid leaked from several overturned tanks under improperly closed lids. The user for whose needs the transport is performed must provide procedures for proper closing of tank lids in accordance with the manufacturer's instructions, which include: checking the cleanliness and flatness of adjacent surfaces, use of undamaged prescribed seals, closing openings with projected number of screws with torque wrench with torque prescribed by the manufacturer. If this information is not known from the manufacturer, the tightening torque must be prescribed according to the general technical standards for pressure vessels.

The user should request that staff be trained at all loading and unloading points for closing the lids properly and carrying it out according to the adopted procedure.

If it is possible to establish by visual inspection the lack of screws on the tank lids, the undertaking should refuse the transport of improperly closed tanks. Reception staff should be trained to implement this measure.

As stated in point 4.2.2.3, in case of one tank, it was determined that the G-P gearbox was defective when the handle could be turned without resistance and without arrest in the end positions. The mentioned gearbox was fixed with a wire in position P. The undertaking must conduct additional training of its staff that the wagon due to such defects must be labeled for repair and instructed to repair.

According to the Law on Interoperability of the Railway System ("Official Gazette of RS" No. 41/18) (see point 3.3.3), the user of a vehicle without an individual license for use bears sanctions. It is necessary for the user of a vehicle that did not have individual licenses to prescribe in its acts a check of the existence of an individual license for use, before it starts using vehicles and to conduct additional training of its staff.

### 4.2.7. Analysis of the number of executors, mechanization and track condition

OC ZOP Paraćin maintains the railway lines on the network "IŽS"a.d., as follows:

- The main arterial line 102: Belgrade Center - Junction "G" - Rakovica - Mladenovac - Lapovo - Niš - Preševo - state border - (Tabanovce), two-track from the station Markovac (exclusively) km 101+057 to station Stalać (inclusively) km 176+737; one-track from the station Stalać (exclusively) km 176+737 to the station Đunis (inclusively) km 194+469 to km 233+943.
- The line No. 104: (Jagodina) - Junction Ćuprija - Ćuprija - Paraćin, one-track from Junction Ćuprija km 0+000 to the station Paraćin (exclusively) km 6+369.
- The line No. 124: Junction Lapovo Varoš - Lapovo Marshalling Yard - Lapovo two-track from km 0+000 to km 3+045.
- The line No. 404: Paraćin - Stari Popovac, one-track from the station Paraćin (exclusively) km 0+500 to the station Stari Popovac (inclusively) km 13+750.

OC ZOP Paraćin maintains in total 273,749 m of open track with transit tracks.

The railway section Jagodina - Lapovo maintains the railway lines on the network "IŽS"a.d. and, as follows:

- The main arterial line 102: Belgrade Center - Junction "G" - Rakovica - Mladenovac - Lapovo - Niš - Preševo - state border - (Tabanovce), two-track from the station Markovac (exclusively) km 101+057 to station Jagodina (inclusively) km 136+037.
- The line No. 124: Junction Lapovo Varoš - Lapovo Marshalling Yard - Lapovo, two-track from km 0+000 to km 3+045.

The railway section Jagodina - Lapovo maintains a total of 76,050 m of open track with transit tracks, 37,116.24 m of station tracks, 9 official points, 24 bridges, 86 culverts, 24 road crossings and 151 switch.

Out of a total of sixteen employees in the railway section Jagodina - Lapovo, the direct executors are thirteen (2 managers of track works, 2 blacksmith - locksmith mechanic, 8 operators of light railway machinery and **1 railway track worker**). When 2 track managers are excluded from the direct executors, eleven executors remain to perform the works.

By analyzing only one position of maintenance of the superstructure of the track in accordance with the Methodology for determining the required number of executors to perform the planned scope of work and Labor Force standards in construction - JŽTP "Belgrade", 1985, and also, for lubrication of fastening screws in the track with unscrewing and re-screwing for 1.0 km of track,

ie 1667 sleepers, with four fastening screws, twice a year, for the annual fund of hours 1840, the required number of workers is shown in Table 4.2.7.1.

**Table 4.2.7.1:** The required number of workers for the position of screws lubrication per km of the track

| Track length *(m)* | Distance between the sleepers (*m)* | Sleepers in total (*piece)* | No. of screws per sleeper (*piece)* | Screws in total (*piece)* | No. of lubrications during a year | In total sleepers/ (*piece)* | Norm time per a screw | Annual fund hours/worker | Required number of workers / kilometer |
|---|---|---|---|---|---|---|---|---|---|
| **1000.0** | **0.60** | **1667** | **4.0** | **6668** | **2** | **13336** | **0.09** | **1840** | **0.65** |

**Having in mind the required number of workers shown in Table 4.2.7.1. and considering the number of executors in the railway section Jagodina - Lapovo, only for the position of lubrication of screws, without other maintenance positions, with the existing number of executors (11) during one year, maintenance can be performed on approximately 17 km of the track.**

According to the norms I - IV of current maintenance of the superstructure of the standard track line per relevant kilometer (Sector for Construction Affairs, ŽTP Belgrade, 1998), for repaired lines older than 20 years (Standard III), the required number of workers per relevant kilometer is 0.526, which for a total of 113,166 km of tracks maintained by the Railway Section Jagodina - Lapovo, is approximately 60 workers.

The conducted analysis indicates an insufficient number of direct executors in the railway section Jagodina - Lapovo, on the maintenance of the superstructure of the railway lines in order to ensure safe and orderly railway traffic. Therefore, the number of direct executors is insufficient for the maintenance of the substructure of the railway lines.

Railway section Jagodina - Lapovo has the following machinery and tools: 2 machines for drilling rails, 2 machines for cutting rails, 2 chainsaws for cutting branches, 1 wagon 5.0 t, 1 wagon "Valter", 1 machine for wrapping track accessories, 2 tyrphon wrapping machines, 1 10.0 t lifter, 10 forks for gravel, 11 pick-ups and 10 bars. The mentioned mechanization and tools are sufficient for the maintenance of the railway line with the existing number of executors, but they are not sufficient for the necessary number of executors in order to ensure safe and orderly railway traffic.

On the main arterial line 102: Belgrade Center - Junction "G" - Rakovica - Mladenovac - Lapovo - Niš - Preševo - state border - (Tabanovce), between the stations Markovac and Trupale, track keepers have been cancelled and have not been foreseen in systematization that came into force in January 2006 due to the equipment of the APB railway line.

On the main arterial line 102: Belgrade Center - Junction "G" - Rakovica - Mladenovac - Lapovo - Niš - Preševo - state border - (Tabanovce), between the station Bagrdan (km 120+300) and the station Jagodina (km 135+235), on the left track, projected speed is 120 km/h. According to the Timetable Booklet 9.1 - 9.2, which was valid at the time of occurrence of this accident, from km 120+900 to km 125+100 the restricted speed is 70 km/h and from km 130+400 to km 134+692 the restricted speed is 50 km/h and on the other part of the line regular speed is 100 km/h.

On the section between the station Bagrdan (*km* 120+300) and the station Jagodina (*km* 135+235) the left track:

- from km 121+400 to km 123+900, is welded in DTŠ with rails S49 on reinforced concrete prestressed sleepers JŽ70 which are sloping in places, distance 60 cm and fastening accessories type "SKL 2". This section of the railway was repaired **in 1986,**
- from km 126+800 to km 126+860, it is welded in DTŠ with rails S49 on reinforced concrete prestressed sleepers JŽ70, distance 60 cm, which is characterized by poor track geometry (level, stability and direction). This section of the railway was repaired in 1973,
- from km 126+860 to km 128+100, is welded in DTŠ with rails S49 on wooden sleepers and fastening track accessories type "K". The track fasteners are of bad quality, not lubricated, insufficiently tightened, the double elastic washer ("grover's ring") is not working or missing and the poplar inserts are crushed ("stiff") or missing. The wooden sleepers are rotten and in a very bad condition, and the "DŽ6" baseboards have sunk into the sleeper. Tyrphoons are in some parts without function or missing. The highest rot of wooden sleepers is: from km 127+000 to km 127+300 (from 37% to 44%) and from km 127+400 to km 127+600 (from 37% to 40%). The numerators on some wooden sleepers are from 1957. Track geometry is poor: at km 127+010 (poor track direction due to poor leveling and welding of the initial joint when changing rails in the outer curve), from km 127+100 to km 127+600 (poor level and track stability) and from km 127+780 to km 127+940 (bad camber in the transition curve). The last overhaul of this part of the track was in 1973,
- from km 130+400 to km 134+692, is welded in DTŠ with S49 rails on wooden sleepers and "DŽ6" baseboard. The fastening track accessories are of the "K" type, and a smaller part of the wooden sleepers is with the "DŽ71" baseboard and the "DŽ-13" tyrphon. The track accessories are of bad quality, not lubricated, not tightened enough, the double elastic washer ("grover's ring") is not working or missing. The track accessories are not tightened: from km 131+300 to km 133+400 and from km 133+800 to km 134+300, the poplar inserts are crushed ("stiff ") or missing. The wooden sleepers are rotten with visibly sunken baseboards "DŽ6" and "DŽ71". Tyrphoons are in some parts without function or missing. The highest rot of wooden sleepers is: from km130+500 to km 130+600 (54%), from km 130+600 to km 130+700 (61%), from km 131+300 to km 131+400 (53%), from km 131+500 to km 131+600 (52%) and from km 131+700 to km 131+800 (50%). The last overhaul of this part of the track was in 1982.

Having in mind the above text and the years of the last overhauls of the track, it can be concluded that the maintenance of the superstructure was not performed in accordance with area III method and deadlines for maintenance of the superstructure, types of maintenance of the superstructure Article 66 of the Rulebook on technical conditions and maintenance of the railway lines superstructure ("Official Gazette of RS" No. 39/16 and 74/16). Considering that fact, the consequence of untimely overhaul conditioned the state of the track as described in the previous text, which could have contributed to the occurrence of the accident in question.

According to the data submitted by letter No. 20/2021-97 from 19.01. 2021. of the Sector for Construction Affairs, which was submitted as an attachment to letter No. 1/2021-169 of 28.01.2021. "IŽS"a.d., for the period from 01.01.2017. until the occurrence of the accident in question, between the station Bagrdan (km 120+300) and the station Jagodina (km 135+235), on the left track, the works performed on the superstructure are given in the following text.

Works on regulating the track in the direction and level with the release of the sleepers from the curtain, raising the track to 5.0 cm with a manual crane with the packing of the sleepers and planning the curtain were performed as follows:

During 2017, from km 120+770 to km 136+030 in twenty-five segments, including segments from **km 123+650 to km 123+670 and from km 123+910 to km 123+950,** with a total length of 1360 m.

During 2018, from km 122+000 to km 134+870 in thirteen segments, with a total length of 665 m.

During 2019, from km 122+050 to km 134+985 in fifteen segments, including the segment **from km 123+660 to km 123+700,** with a total length of 915 m.

During 2020, from km 120+800 to km 134+980 in twenty-eight segments, with a total length of 1245 m.

The works on releasing the sleepers from the ballast bed, returning the sloping sleepers, tightening and replacing the track accessories at times, planning the ballast bed and pushing the sleepers with the regulation of the track in the direction and level were performed as follows:

During 2017, from km **123+650 to km 123+670** and from km 122+000 to km 122+300, total length 320 m.

During 2018, from km 122+000 to km 122+500 and from km 122+600 to km 122+840, total length 740 m.

During 2019, from km 121+950 to km 122+150, from km **123+670 to km 123+700** and from km **123+000 to km 123+700,** total length 930 m.

During 2020, from km 121+600 to km 121+650, from km 121+700 to km 121+950, from km 122+010 to km 122+150, from **km 122+500 to km 123+100, from km 122+550 to km 123+450, from km 123+400 to km 123+700,** total length 2240 m.

Works on replacement of rails and insulated joints, return of shifted rails, repair of rail cracks and release of DTŠ (release of rails from sleepers by unscrewing fastening track accessories, ejection of old rails and insertion of new rails, replacement of inserts and occasional replacement of track accessories) were performed, as follows:

During 2017, from km 122+000 to km 132+000 in nine segments, including segments from km 123+640 to km **123+680 and from km 123+650 to km 123+658**, with a total length of 436 m.

During 2018, from km 122+020 to km 132+605 in five segments, total length 333 m and seven positions.

During 2019, from km 123+686 to km 132+550 on five segments including segments from km 123+686 to km **123+691, from km 123+682 to km 123+687 and from km 123+682 to km 123 +686, total length 144 m.**

During 2020, from km 120+900 to km 133+800 in eleven segments, including the segment from km **123+780 to km 123+785,** with a total length of 3613 m.

The works on the replacement of the sleepers with the excavation of the old ones, the release of accessories, the extraction and insertion of the new ones and the fastening to the rail with the first packing of sleepers were also performed:

During 2018: from km 133+760 to km 133+770 and from km 133+780 to km 133+790.

During 2019: from km 123+680 to km 123+690 and from km 132+400 to km 132+500.

During 2020: from km 122+300 to km 122+900.

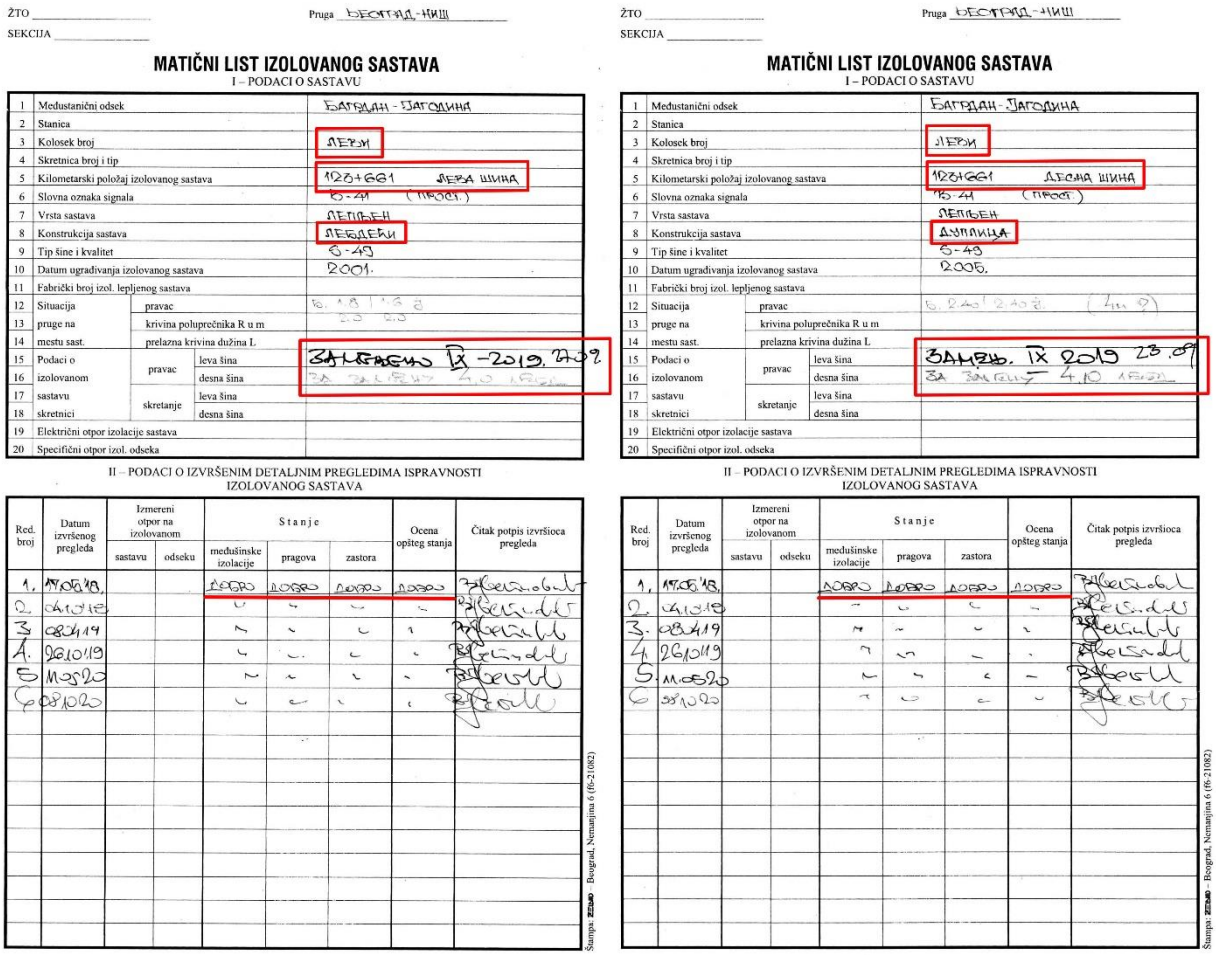
On the section of the railway Bagrdan - Jagodina, left track, from km 117+000 to km 125+315 by telegram "IŽS"a.d. No. 117 from 18.09.2017., restricted speed running with Vmax = 30 km/h was introduced, due to the alienation of the supporting rope on the catenary and **rotten sleepers**. It was abolished on 05.10.2017., by telegram "IŽS"a.d. No. 123 from 05.10.2017., and from the submitted documentation by "IŽS"a.d. it cannot be stated that the rotten sleepers have been replaced.

Regular inspections from the traction vehicle of the left track of the Belgrade Center - Junction "G" - Rakovica - Mladenovac - Lapovo - Niš - Preševo - state border - (Tabanovce), performed in 2019 and 2020 in the area of the accident of km 123+000 to km 124+000, no **defects were observed on the superstructure of the railway.**

Visual inspection of the railway performed by the expert service of OC ZOP Paraćin in accordance with the Rulebook on technical conditions and maintenance of the railway line substructure ("Official Gazette of RS" No. 39/16 and 74/16), on the section from the station Markovac (exclusively) km 101+057 to the station Jagodina (inclusive) km 136+000 which includes the zone of occurrence of the accident in question (from km 123+000 to km 124+000), it was stated **that there are no visible deformations of the earth body** (Minutes No. 20/2018-3.2-159/1 of 25.10.2018 OC ZOP Paraćin). After that, by telegram "IŽS"a.d. No. 5 from 03.12.2018. from km 120+900 to km 125+100 on the left track between the stations Bagrdan and Jagodina was introduced restricted speed running with Vmax = 70 km/h, and the reason for the introduction of restricted speed running (which was changed to a limited speed Timetable for 2018/2019) **is a poor condition of the substructure**. The reason for the introduction of restricted speed running is the **poor condition of the substructure**, and it was previously stated that there are **no visible deformations of the ground**, which is contrary to Article 55 of the Law on Railways ("Official Gazette of RS" No. 41/2018).

The planned detailed inspections of insulated joints in 2018 and 2019 were not performed due to TMD failure, lack of fuel and priority work, and by order of the head of OC ZOP Paraćin, which is contrary to Article 83 of the Rulebook on technical conditions and maintenance of the superstructure of railway line ("Official Gazette of RS" No. 39/16 and 74/16). However, in the registry sheet of the insulated joint at km 123+660.80 **good condition was recorded,** which is in contradiction with the report of the Working Group of the OC ZOP Paraćin on the visual inspection of the left track from 04.10.2018. where it was stated that "**the insulated joints at km 123+660.80 on the left and right rails are unglued and dilated by 10 mm,** and the track grille is made of wooden sleepers and they are sloped and damaged." The registry sheet of the insulated joint at km 123+660.80 is shown in Figure 4.2.7.1.

Based on the submitted material by "IŽS"a.d. it can be stated that during 2018 and 2019 the planned detailed inspections of insulated joints were not done by OC ZOP Paraćin and in the registry sheet it is stated that the insulated joint at km 123+660.80 on the left track on the left rail was replaced 27.09.2019. and that it was replaced on the right rail on 23.09.2019. (no work orders were submitted). Also, the registry sheet states that the construction of the duplicate composition of sleeper is on the right rail, which does not correspond to the condition found during the investigation of the accident by the CINS' representatives (see Figures 4.2.7.1 and 4.2.7.2. b and c).



ŽTO _____ Pruga БЕОГРАД - НИШ
SEKCIJA _____

**MATIČNI LIST IZOLOVANOG SASTAVA**
I – PODACI O SASTAVU

| | | | | |
|---|---|---|---|---|
| 1 | Međustanični odsek | | | БАТАЈНИЦА - ЈАГОДИНА |
| 2 | Stanica | | | |
| 3 | Kolosek broj | | | ЈЕРЕМ |
| 4 | Skretnica broj i tip | | | |
| 5 | Kilometarski položaj izolovanog sastava | | | 123+661 ЛЕВА ШИНА |
| 6 | Slovna oznaka signala | | | 15-24 (ПРОТ.) |
| 7 | Vrsta sastava | | | ЈЕТИБЕН |
| 8 | Konstrukcija sastava | | | ЛЕЖЕЋИ |
| 9 | Tip šine i kvalitet | | | S-49 |
| 10 | Datum ugrađivanja izolovanog sastava | | | 2001. |
| 11 | Fabrički broj izol. lepljenog sastava | | | |
| 12 | Situacija | pravac | | R. 181°38 |
| 13 | pruge na | krivina poluprečnika R u m | | 23 23 |
| 14 | mestu sast. | prelazna krivina dužina L | | |
| 15 | Podaci o | pravac | leva šina | ЗАМЕЊЕНО IX-2019. 23.09 |
| 16 | izolovanom | | desna šina | ЗА ЗАМЕЊУ 4.10 |
| 17 | sastavu | skretanje | leva šina | |
| 18 | skretnici | | desna šina | |
| 19 | Električni otpor izolacije sastava | | | |
| 20 | Specifični otpor izol. odseka | | | |

II – PODACI O IZVRŠENIM DETALJNIM PREGLEDIMA ISPRAVNOSTI IZOLOVANOG SASTAVA

| Red. broj | Datum izvršenog pregleda | Izmereni otpor na izolovanom: sastavu | Izmereni otpor na izolovanom: odseku | Stanje: međušinske izolacije | Stanje: pragova | Stanje: zastora | Ocena opšteg stanja | Čitak potpis izvršioca pregleda |
|---|---|---|---|---|---|---|---|---|
| 1. | 17.05.'18. | | | ДОБРО | ДОБРО | ДОБРО | ДОБРО | |
| 2. | 04.10.18 | | | " | " | " | " | |
| 3. | 08.04.19 | | | " | " | " | " | |
| 4. | 26.10.19 | | | " | " | " | " | |
| 5. | 11.05.20 | | | " | " | " | " | |
| 6. | 08.10.20 | | | " | " | " | " | |

Štampa: [illegible] – Beograd, Nemanjina 6 (ff6-21082)

ŽTO _____ Pruga БЕОГРАД - НИШ
SEKCIJA _____

**MATIČNI LIST IZOLOVANOG SASTAVA**
I – PODACI O SASTAVU

| | | | | |
|---|---|---|---|---|
| 1 | Međustanični odsek | | | БАТАЈНИЦА - ЈАГОДИНА |
| 2 | Stanica | | | |
| 3 | Kolosek broj | | | ЈЕРЕМ |
| 4 | Skretnica broj i tip | | | |
| 5 | Kilometarski položaj izolovanog sastava | | | 123+661 ДЕСНА ШИНА |
| 6 | Slovna oznaka signala | | | 15-24 (ПРОТ.) |
| 7 | Vrsta sastava | | | ЈЕТИБЕН |
| 8 | Konstrukcija sastava | | | ДУПАЊИЦА |
| 9 | Tip šine i kvalitet | | | S-49 |
| 10 | Datum ugrađivanja izolovanog sastava | | | 2006. |
| 11 | Fabrički broj izol. lepljenog sastava | | | |
| 12 | Situacija | pravac | | R. 240 240 (ПРАВ) |
| 13 | pruge na | krivina poluprečnika R u m | | |
| 14 | mestu sast. | prelazna krivina dužina L | | |
| 15 | Podaci o | pravac | leva šina | ЗАМЕЊЕНО IX 2019 23.09 |
| 16 | izolovanom | | desna šina | ЗА ЗАМЕЊУ 4.10 |
| 17 | sastavu | skretanje | leva šina | |
| 18 | skretnici | | desna šina | |
| 19 | Električni otpor izolacije sastava | | | |
| 20 | Specifični otpor izol. odseka | | | |

II – PODACI O IZVRŠENIM DETALJNIM PREGLEDIMA ISPRAVNOSTI IZOLOVANOG SASTAVA

| Red. broj | Datum izvršenog pregleda | Izmereni otpor na izolovanom: sastavu | Izmereni otpor na izolovanom: odseku | Stanje: međušinske izolacije | Stanje: pragova | Stanje: zastora | Ocena opšteg stanja | Čitak potpis izvršioca pregleda |
|---|---|---|---|---|---|---|---|---|
| 1. | 17.05.'18. | | | ДОБРО | ДОБРО | ДОБРО | ДОБРО | |
| 2. | 04.10.18 | | | " | " | " | " | |
| 3. | 08.04.19 | | | " | " | " | " | |
| 4. | 26.10.19 | | | " | " | " | " | |
| 5. | 11.05.20 | | | " | " | " | " | |
| 6. | 08.10.20 | | | " | " | " | " | |

Štampa: [illegible] – Beograd, Nemanjina 6 (ff6-21082)

**Figure 4.2.7.1:** Registry sheets of insulated joint at km 123+660.80

*a) The view of the insulated joint on the left rail in direction of increasing stationing*

*b) The view of the insulated joint on the right rail in direction of increasing stationing*

*c) The view of the insulated joint on both rails*

**Figure 4.2.7.2:** The view of insulated joint at km 123+660.80

By the professional services of the Sector for Construction Affairs, in the period from 01.01.2017. until the occurrence of the accident between the station Bagrdan and Jagodina, there was no inspection, control of the correctness of the sub and super structure as a whole, as well as individual groups of elements or individual elements, checking the technical parameters of the track, track arrangement and condition of installed material.

According to the data submitted by letter No. 14/2021-12 from 22.01.2021. of the Center for Internal Control, which was submitted in the attachment to the letter No. 1/2021-169 of 28.01.2021. "IŽS"a.d., it can be stated that the controls of the left track were performed in the period from January 2017 until the occurrence of the accident in question, between the stations Bagrdan (km 120+300) and Jagodina (km 135+235). The controls were performed on the basis of Articles 22 and 36 of the Rulebook on the organization and performance of internal control and supervision in the Joint Stock Company for Management of Public Railway Infrastructure "IŽS" (Official Gazette of ŽS, No. 13/17, 50/19 and 20/20). The found irregularities were ascertained by the established factual situation and stated in the Minutes on the performed control, and the elimination of irregularities was given in the Decisions on the imposed measures.

Acting on the Decisions on the ordered measures of the Center for Internal Control, OC ZOP Paraćin executed some of the ordered measures in accordance with the available labor force and materials.

Based on the presented condition of the track and the scope and type of work performed in the period from 01.01.2017. until the occurrence of the accident in question, according to the data submitted by letter No. 20/2021-97 from 19.01.2021. of the Sector for Construction Affairs, which was submitted as an attachment to letter No. 1/2021-169 of 28.01.2021. "IŽS"a.d, it can be concluded that between the station Bagrdan (km 120+300) and the station Jagodina (km 135+235), the left track:

- Some sections of the railway have been in operation for almost 50 years since the overhaul, which is unacceptable, because it exceeds the service life of installed materials (high rot of wooden sleepers on some sections and more than 50%, which is manifested by visibly sunken baseboards "DZ6" and "DZ71", wooden plugs in reinforced concrete prestressed sleepers "IM-2" are rotten, which weakens the connection between the baseboard and the sleeper, track fastening accessories are poor, not lubricated, insufficiently tightened, double elastic washers ("grover's rings") are not working or missing and poplars inserts are crushed ("stiffed") or missing, tyrphons are in some parts without function or missing,…), which is contrary to Articles 80 and 81 of the Rulebook on technical conditions and maintenance of the railway lines superstructure ("Official Gazette RS" No. 39/16 and 74/16);
- The condition of the track is such that the instability of the track is expressed, which manifests itself as deformation in the transversal and longitudinal direction, which leads to a reduction in speed, the introduction of restricted speed runnings and limited speeds;
- The track is welded in DTŠ. Having in mind that there is no record of longitudinal and transversal movement of tracks, therefore the voltage condition in the rails is not known, it can be stated that maintenance and control were not performed in accordance with Articles 74 and 76 of the Rulebook on technical conditions and maintenance of railway lines superstructure. ("Official Gazette of RS" No. 39/16 and 74/16). Sloped sleepers are common, as well as track deformations at high temperatures.

### 4.2.8. Track inspection coach record

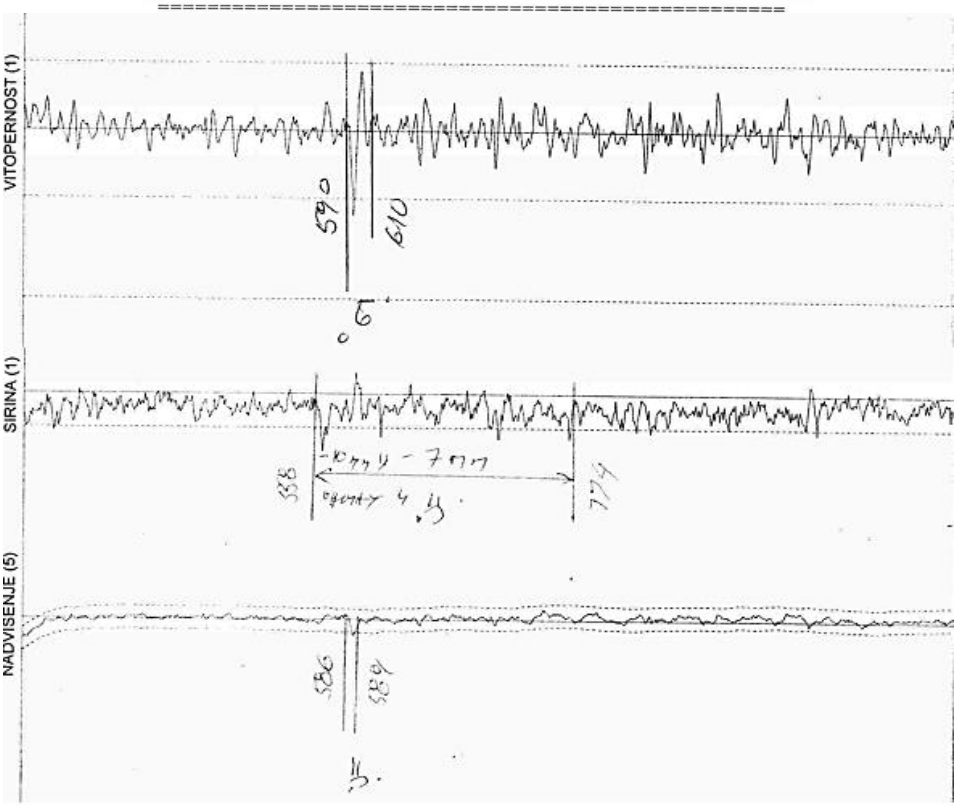
During 2017, 2018 and 2019, measurements of the condition of section of the railway line 102: Belgrade Center - Junction "G" - Rakovica - Mladenovac - Lapovo - Niš - Presevo - state border - (Tabanovce), were performed from the station Markovac (exclusively) km 101+057 to the station Jagodina (inclusive) km 136+000 on the left track with track inspection coach EM-80L. Excerpts from numerical and graphic records from the measurement of the condition in the zone of derailment of the train No. 45022 (from km 123+000 to km 124+000) are given in Figures 4.2.8.1, 4.2.8.2, 4.2.8.3, 4.2.8.4, 4.2.8.5. and 4.2.8.6.

==========PLANIRANJE RADOVA==========

| START KM/M | END KM/M | SPD | TAMP 126 | LINE 186 | TQI 200 | GAUGE 246 | BAL 161 |
|---|---|---|---|---|---|---|---|
| 123.000 | 124.000 | 100 | 42 | 92 | 65 | 136 | -569 |

<<<SUMMARY>>> KM 123.000 TO 124.000 = 1000M

| ====CLASS: 2 PARAMETER | =====A===== LEN(M) | #DEF | =====B===== LEN(M) | #DEF | =====C===== LEN(M) | #DEF |
|---|---|---|---|---|---|---|
| STABILNOST-L | 54 | 18 | 0 | 0 | 0 | 0 |
| STABILNOST-D | 78 | 25 | 2 | 1 | 0 | 0 |
| SMER-LEVO | 0 | 0 | 0 | 0 | 0 | 0 |
| SMER-DESNO | 0 | 0 | 0 | 0 | 0 | 0 |
| PROSIRENJE | 158 | 19 | 0 | 0 | 0 | 0 |
| SUZENJE | 240 | 51 | 100 | 29 | 9 | 4 |
| NADVISENJE | 47 | 18 | 8 | 2 | 3 | 1 |
| NADV. > 150mm | 0 | 0 | 0 | 0 | 0 | 0 |
| VITO. 3.5m | 13 | 4 | 6 | 2 | 0 | 0 |
| TOTAL | 486 | 135 | 111 | 34 | 12 | 5 |




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| SUZENJE | 123.558 | 123.561 | 3 | -10MM18 559 | 6MM | 2 | 5 T |
| SUZENJE | 123.562 | 123.564 | 2 | -7MM40 562 | 6MM | 2 | 3 T |
| NADVISENJE | 123.586 | 123.589 | 3 | -12MM79 587 | 10MM | 2 | 3 T |
| SUZENJE | 123.711 | 123.713 | 2 | -7MM88 711 | 6MM | 2 | 3 T |
| SUZENJE | 123.772 | 123.774 | 2 | -7MM92 772 | 6MM | 2 | 3 T |

**Figure 4.2.8.1:** Numerical and graphic record excerpt of track inspection coach from 02.03.2017.

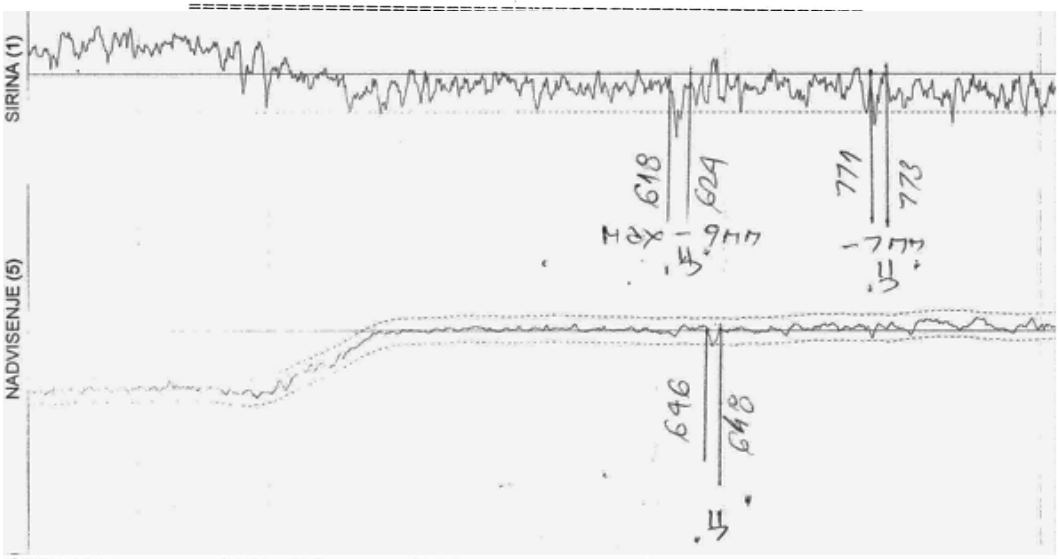
==========PLANIRANJE RADOVA==========

| START KM/M | END KM/M | SPD | TAMP | LINE | TQI | GAUGE | BAL |
|---|---|---|---|---|---|---|---|
| | | | 126 | 186 | 200 | 246 | 161 |
| 123.000 | 124.000 | 100 | 38 | 115 | 74 | 137 | -758 |

<<<SUMMARY>>> KM 123.000 TO 124.000 = 1000M

| ====CLASS: 2 | =====A===== | | =====B===== | | =====C===== | |
|---|---|---|---|---|---|---|
| PARAMETER | LEN(M) | #DEF | LEN(M) | #DEF | LEN(M) | #DEF |
| STABILNOST-L | 62 | 20 | 0 | 0 | 0 | 0 |
| STABILNOST-D | 54 | 20 | 2 | 1 | 0 | 0 |
| SMER-LEVO | 0 | 0 | 0 | 0 | 0 | 0 |
| SMER-DESNO | 2 | 1 | 0 | 0 | 0 | 0 |
| PROSIRENJE | 223 | 21 | 0 | 0 | 0 | 0 |
| SUZENJE | 174 | 37 | 79 | 23 | 7 | 3 |
| NADVISENJE | 41 | 12 | 9 | 3 | 2 | 1 |
| NADV. > 150mm | 0 | 0 | 0 | 0 | 0 | 0 |
| VITO. 3.5m | 27 | 9 | 2 | 1 | 0 | 0 |
| TOTAL | 473 | 120 | 88 | 28 | 9 | 4 |

==========



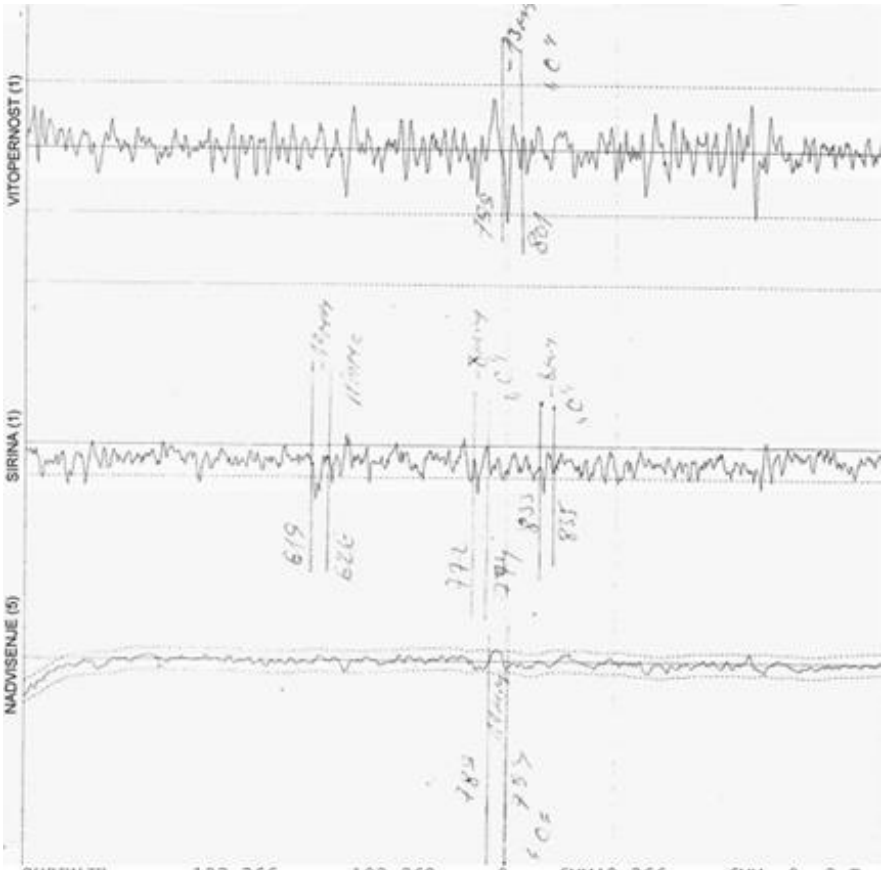

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SUZENJE | 123.618 | 123.620 | 2 | -9MM93 | 619 | 6MM | 2 | 4 T |
| SUZENJE | 123.621 | 123.624 | 3 | -7MM17 | 622 | 6MM | 2 | 3 T |
| NADVISENJE | 123.646 | 123.648 | 2 | -11MM75 | 646 | 10MM | 2 | 3 T |
| SUZENJE | 123.771 | 123.773 | 2 | -7MM96 | 771 | 6MM | 2 | 3 T |

**Figure 4.2.8.2:** Numerical and graphic record excerpt of track inspection coach from 23.05.2017.

```
=================PLANIRANJE RADOVA=================
 START       END              TAMP LINE TQI GAUGE BAL
  KM/M      KM/M    SPD        126  186  200  246  161
123.000   124.000    100         27  116   63  155 -386

<<<SUMMARY>>>  KM 123.000   TO  124.000  =  1000M

====CLASS: 2   =====A=====  =====B=====  =====C=====
PARAMETER      LEN(M) #DEF  LEN(M) #DEF  LEN(M) #DEF
STABILNOST-L     113    35      5     2      0     0
STABILNOST-D     120    37      6     3      0     0
SMER-LEVO          0     0      0     0      0     0
SMER-DESNO         0     0      0     0      0     0
PROSIRENJE       187    20      0     0      0     0
SUZENJE          308    53    146    35     33    13
NADVISENJE        88    20     28     6      5     1
NADV. > 150mm      0     0      0     0      0     0
VITO. 3.5m        23     8     10     4      2     1
TOTAL            603   173    172    50     40    15
=================================================
```




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| SUZENJE | 123.366 | 123.368 | 2 | -6MM48 366 | 6MM | 2 | 3 T |
| SUZENJE | 123.389 | 123.391 | 2 | -7MM63 390 | 6MM | 2 | 3 T |
| SUZENJE | 123.393 | 123.395 | 2 | -6MM11 394 | 6MM | 2 | 3 T |
| SUZENJE | 123.406 | 123.408 | 2 | -7MM61 406 | 6MM | 2 | 3 T |
| SUZENJE | 123.511 | 123.514 | 3 | -7MM03 513 | 6MM | 2 | 3 T |
| SUZENJE | 123.619 | 123.626 | 7 | -10MM06 620 | 6MM | 2 | 5 T |
| SUZENJE | 123.670 | 123.672 | 2 | -6MM94 671 | 6MM | 2 | 3 T |
| SUZENJE | 123.765 | 123.768 | 3 | -6MM65 766 | 6MM | 2 | 3 T |
| SUZENJE | 123.772 | 123.774 | 2 | -8MM96 773 | 6MM | 2 | 4 T |
| NADVISENJE | 123.789 | 123.794 | 5 | 11MM53 791 | 10MM | 2 | 3 T |
| VITO. 3.5m | 123.799 | 123.801 | 2 | -13MM35 799 | 12MM | 2 | 3 T |
| SUZENJE | 123.833 | 123.835 | 2 | -8MM71 834 | 6MM | 2 | 4 T |
| SUZENJE | 123.890 | 123.892 | 2 | -6MM61 891 | 6MM | 2 | 3 T |
| SUZENJE | 123.902 | 123.904 | 2 | -6MM90 902 | 6MM | 2 | 3 T |
| SUZENJE | 123.905 | 123.907 | 2 | -6MM07 905 | 6MM | 2 | 3 T |

**Figure 4.2.8.3:** Numerical and graphic record excerpt of track inspection coach from 27.10.2017.

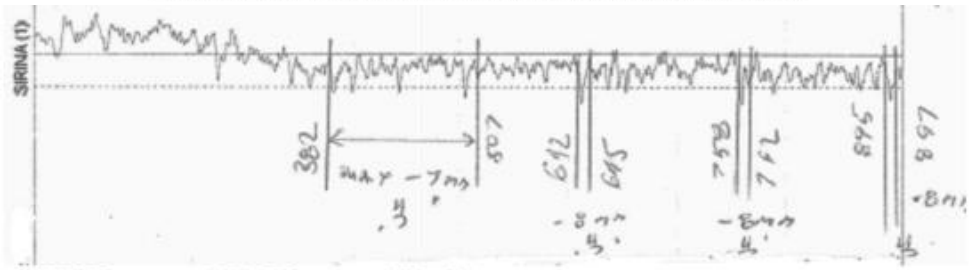
==========PLANIRANJE RADOVA==========

| START KM/M | END KM/M | SPD | TAMP 126 | LINE 186 | TQI 200 | GAUGE 246 | BAL 161 |
|---|---|---|---|---|---|---|---|
| 123.000 | 124.000 | 100 | 20 | 111 | 46 | 140 | -259 |

<<<SUMMARY>>> KM 123.000 TO 124.000 = 1000M

| ====CLASS: 2 | =====A===== | | =====B===== | | =====C===== | |
|---|---|---|---|---|---|---|
| PARAMETER | LEN(M) | #DEF | LEN(M) | #DEF | LEN(M) | #DEF |
| STABILNOST-L | 71 | 30 | 0 | 0 | 0 | 0 |
| STABILNOST-D | 46 | 14 | 4 | 2 | 0 | 0 |
| SMER-LEVO | 0 | 0 | 0 | 0 | 0 | 0 |
| SMER-DESNO | 0 | 0 | 0 | 0 | 0 | 0 |
| PROSIRENJE | 181 | 19 | 0 | 0 | 0 | 0 |
| SUZENJE | 235 | 47 | 114 | 30 | 19 | 7 |
| NADVISENJE | 56 | 14 | 12 | 5 | 0 | 0 |
| NADV. > 150mm | 0 | 0 | 0 | 0 | 0 | 0 |
| VITO. 3.5m | 13 | 7 | 0 | 0 | 0 | 0 |
| TOTAL | 499 | 131 | 125 | 37 | 19 | 7 |

==========




| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SUZENJE | 123.382 | 123.385 | 3 | -6MM94 383 | 6MM | 2 | 3 | T |
| SUZENJE | 123.399 | 123.402 | 3 | -6MM82 399 | 6MM | 2 | 3 | T |
| SUZENJE | 123.505 | 123.507 | 2 | -7MM76 505 | 6MM | 2 | 3 | T |
| SUZENJE | 123.612 | 123.615 | 3 | -8MM76 613 | 6MM | 2 | 4 | T |
| SUZENJE | 123.636 | 123.638 | 2 | -6MM42 636 | 6MM | 2 | 3 | T |
| SUZENJE | 123.758 | 123.762 | 4 | -8MM97 760 | 6MM | 2 | 4 | T |
| SUZENJE | 123.895 | 123.897 | 2 | -8MM10 895 | 6MM | 2 | 4 | T |

**Figure 4.2.8.4:** Numerical and graphic record excerpt of track inspection coach from 26.10.2018.

==========PLANIRANJE RADOVA==========

| START KM/M | END KM/M | SPD | TAMP 126 | LINE 186 | TQI 200 | GAUGE 246 | BAL 161 |
|---|---|---|---|---|---|---|---|
| 123.000 | 124.000 | 100 | 2 | 111 | 41 | 138 | -211 |

<<<SUMMARY>>> KM 123.000 TO 124.000 = 1000M

| ====CLASS: 2 | =====A===== | | =====B===== | | =====C===== | |
|---|---|---|---|---|---|---|
| PARAMETER | LEN(M) | #DEF | LEN(M) | #DEF | LEN(M) | #DEF |
| STABILNOST-L | 33 | 13 | 0 | 0 | 0 | 0 |
| STABILNOST-D | 40 | 17 | 2 | 1 | 0 | 0 |
| SMER-LEVO | 2 | 1 | 0 | 0 | 0 | 0 |
| SMER-DESNO | 3 | 1 | 0 | 0 | 0 | 0 |
| PROSIRENJE | 224 | 20 | 0 | 0 | 0 | 0 |
| SUZENJE | 118 | 31 | 42 | 16 | 2 | 1 |
| NADVISENJE | 63 | 13 | 20 | 5 | 0 | 0 |
| NADV. > 150mm | 0 | 0 | 0 | 0 | 0 | 0 |
| VITO. 3.5m | 16 | 6 | 2 | 1 | 0 | 0 |
| TOTAL | 430 | 102 | 66 | 23 | 2 | 1 |

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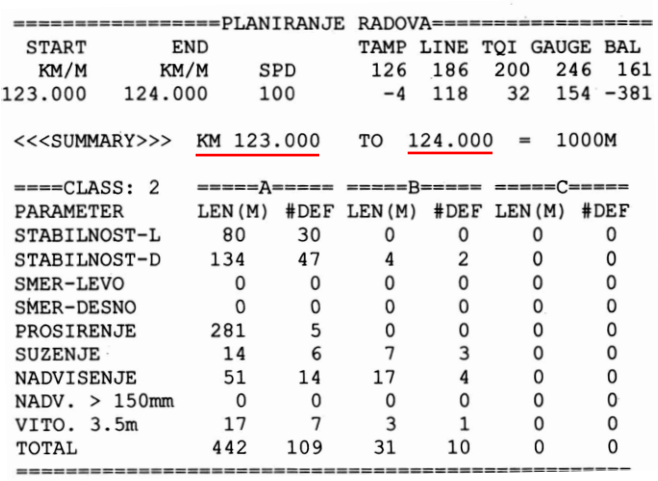
**Figure 4.2.8.5:** Numerical record excerpt of track inspection coach from 19.04.2019.



```
=================PLANIRANJE RADOVA=================
 START       END              TAMP LINE TQI GAUGE BAL
  KM/M       KM/M     SPD      126  186  200  246  161
123.000   124.000     100       -4  118   32  154 -381

<<<SUMMARY>>>  KM 123.000   TO  124.000  =  1000M

====CLASS: 2   =====A=====  =====B=====  =====C=====
PARAMETER      LEN(M) #DEF  LEN(M) #DEF  LEN(M) #DEF
STABILNOST-L      80    30      0    0      0    0
STABILNOST-D     134    47      4    2      0    0
SMER-LEVO          0     0      0    0      0    0
SMER-DESNO         0     0      0    0      0    0
PROSIRENJE       281     5      0    0      0    0
SUZENJE           14     6      7    3      0    0
NADVISENJE        51    14     17    4      0    0
NADV. > 150mm      0     0      0    0      0    0
VITO. 3.5m        17     7      3    1      0    0
TOTAL            442   109     31   10      0    0
=================================================
```

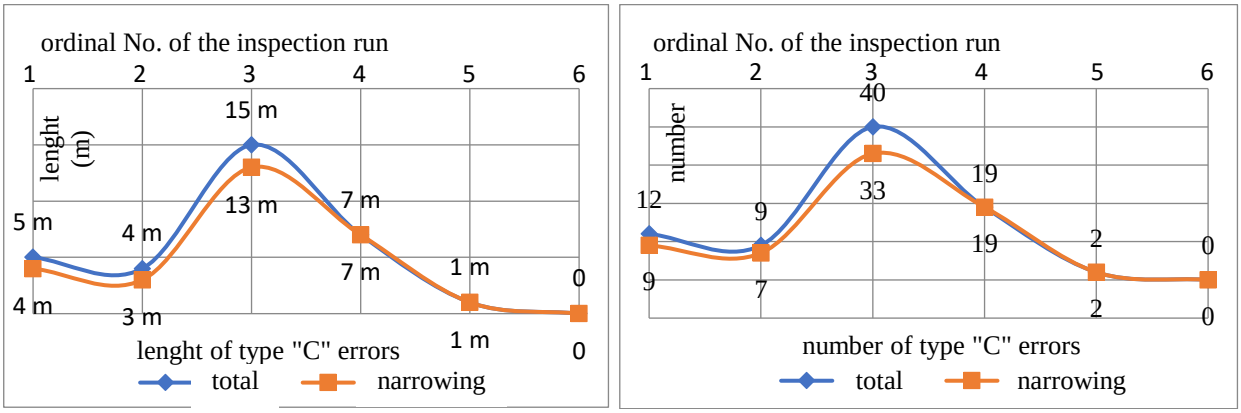
**Figure 4.2.8.6:** Numerical record excerpt of track inspection coach from 31.12.2019.

The share of errors of type “B” and “C” in the narrowing of the track in relation to the total number of errors of type “B” and “C” in the zone of derailment of train No. 45022 (from km 123+000 to km 124+000) is shown in Table 4.2.8.1

**Table 4.2.8.1:** Lengths and number of errors of type “B” and type “C” determined by track inspection coach runs from km 123+000 to km 124+000

| Ordinal No. of track inspection coach run | Date of the track inspection | Errors type “*B*” | | Errors type “*C*” | |
|---|---|---|---|---|---|
| | | Total length/ length of narrowing [*m*] | The total number of/ number of narrowing | Total length/ length of narrowing [*m*] | The total number of/ number of narrowing |
| 1 | 02.03.2017. | 111/100 | 34/29 | 12/9 | 5/4 |
| 2 | 23.05.2017. | 88/79 | 28/23 | 9/7 | 4/3 |
| 3 | 27.10.2017. | 172/146 | 50/35 | 40/33 | 15/13 |
| 4 | 26.10.2018. | 127/114 | 37/30 | 17/19 | 7/7 |
| 5 | 19.04.2019. | 66/42 | 23/16 | 2/2 | 1/1 |
| 6 | 31.12.2019. | 3/7 | 10/3 | 0/0 | 0/0 |

The share of type “C” errors in track narrowing in relation to the total number of type “C” errors in the zone of derailment of train No. 45022 (from km 123+000 to km 124+000) is shown in Graph 4.2.8.1.




**Graph 4.2.8.1:** Overview of the length and number of "C" type errors over time from km 123+000 to km 124+000

From the submitted numerical and graphic records from the measurement of the condition of section of the railway line 102: Belgrade Center - Junction "G" - Rakovica - Mladenovac - Lapovo - Niš - Preševo - state border - (Tabanovce), from the station Markovac (exclusively) km 101+057 to station Jagodina (inclusive) km 136+000 on the left track with track inspection coach EM-80L it can be concluded that in the zone of derailment of the train No. 45022 in the summary of the report from km 123+000 to km 124+000, of the total number of errors type "C" **more than 75% are track narrowing errors**, indicating uneven longitudinal movement of the rails in the track.

Also, comparing the values measured on 05.08.2020. after the mechanical regulation of the track was performed, which were submitted by letter No. 20/2021-97 of 19.01.2021. of the Sector for Construction Affairs and attached to the letter No. 1/2021-169 of 28.01.2021. "IŽS"a.d. and the values measured after the accident (see Table 3.4.2.2.), a tendency of narrowing the track can be observed, which also indicates uneven longitudinal movement of the rails in the track.

### 4.2.9. Influence of longitudinal forces on track deformation

The occurrence of longitudinal movement of the rails occurs due to the action of horizontal longitudinal forces, ie forces directed in the direction of the track axis. Some parasitic movements of vehicles can affect the occurrence of rail travel, especially braking or starting the train, as well as temperature changes, which lead to stretching of the rails.

The braking forces of the vehicle act on the track construction. They have a short-term effect, unlike forces due to temperature changes. The braking forces of the vehicle are limited based on the maximum available friction in the wheel/rail contact (steel on steel). Tensile stresses occur behind the braking vehicle, while rail pressure stresses occur in front of the braking vehicle. The diagram of the rail stresses due to the braking of the train is shown in Figure 4.2.9.1.

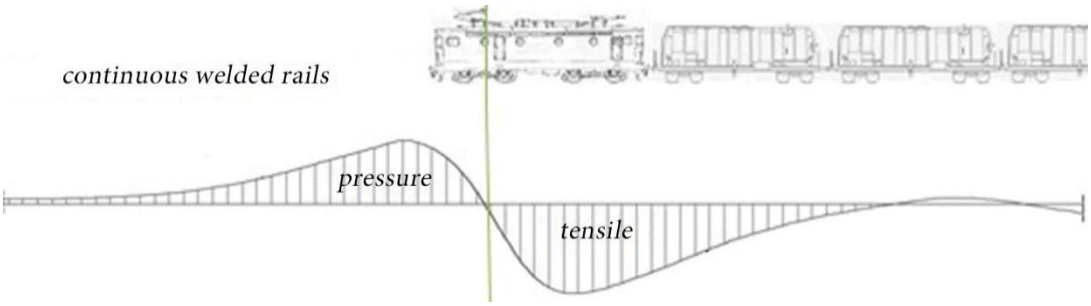



**Figure 4.2.9.1:** Diagram of the rail stresses due to train braking

Friction brakes of railway vehicles act on the basis of friction, which in most cases is achieved by using compressed air. The vehicle brakes with a delay - the so-called brake preparation time. Delayed brake action time, especially in the case of long compositions, leads to the appearance of longitudinal dynamic forces. These forces are a consequence of non-simultaneous braking of individual wagons, which leads to the appearance of pressure forces between them.

By the action of longitudinal forces that tend to move the rail, is opposed by the friction between the rail foot and its base. The friction between the sleeper and the curtain material also plays a significant role, while the fastening accessories are especially important since it is necessary for the tightening force to be constant and to ensure the greatest possible friction between the rail and its base.

The travel of the rails, when the resistance of the sleepers is weaker in the curtain, can lead to the sloping of the sleepers towards the track axis. In that case, there is an irregular spacing of the sleepers and the track gauge is reduced, which at the same time entails the loosening of the accessories and the movement of the sleepers from the packed to the unpacked place.

On double-track lines, the rail travel occurs on each track in the direction of traffic, and on single-track lines in a heavier load direction.

Rail travel should be combated primarily by using good fastening accessories and regular control of its tightness.

Since temperature is a time-varying parameter, in reality, the internal stresses in the track will be different at all times, ie. their diagram will have a different look. This process of changing the stress state takes place in cycles depending on temperature changes and is reversible. At temperatures higher than $t_p$ (required temperature) or $t_{ekspl.}$ (operating temperature) in the rails of the middle fixed part of the DTŠ, additional compressive stresses will occur, and at temperatures lower than the above, additional tensile stresses will occur.

The diagram of stresses and displacement in the rail depending on the temperature, the theoretical definition of DTŠ, is shown in Figure 4.2.9.2, for a track that ends with classic assemblies secured with devices against rail travel and a track with expansion devices.

**Figure 4.2.9.2:** The diagram of stresses and displacement in the rail depending on the temperature

In Figure 4.2.9.3. one cycle of stresses state in DTŠ is shown, from which it follows that the shape of diagram 1 occurs only once, immediately at the moment of formation (release) of DTŠ at the required temperature $t_p$.

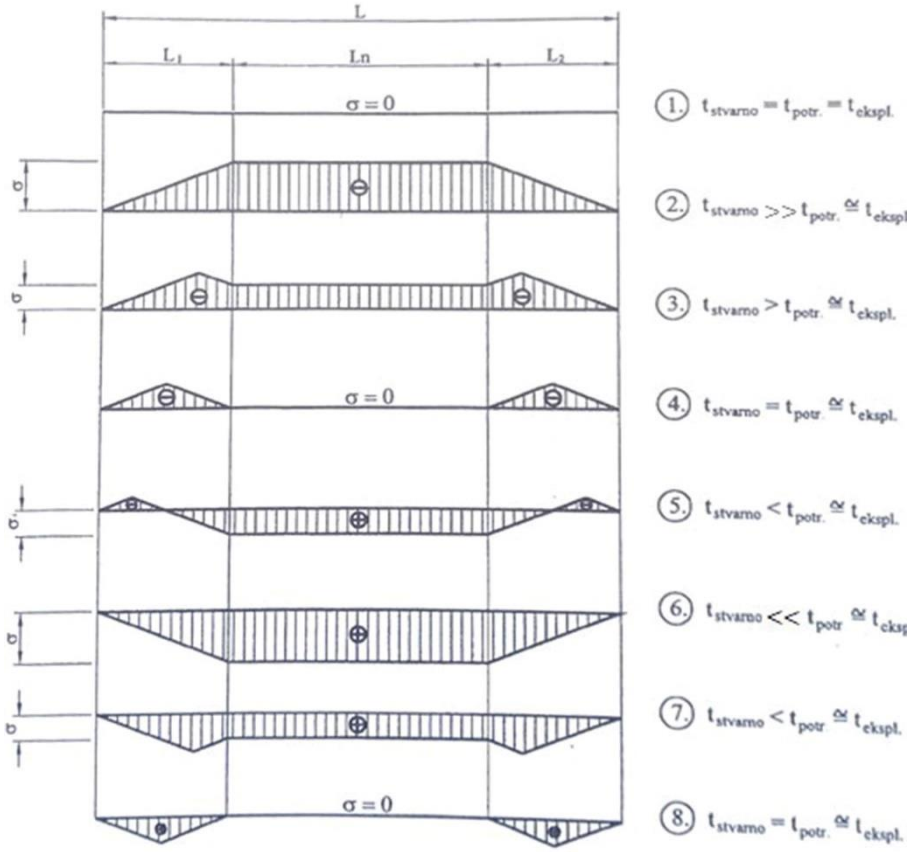



**Figure 4.2.9.3:** Stresses state cycle in DTŠ

In Figure 4.2.9.4. a schematic representation of the sloping sleepers in the accident zone is presented.

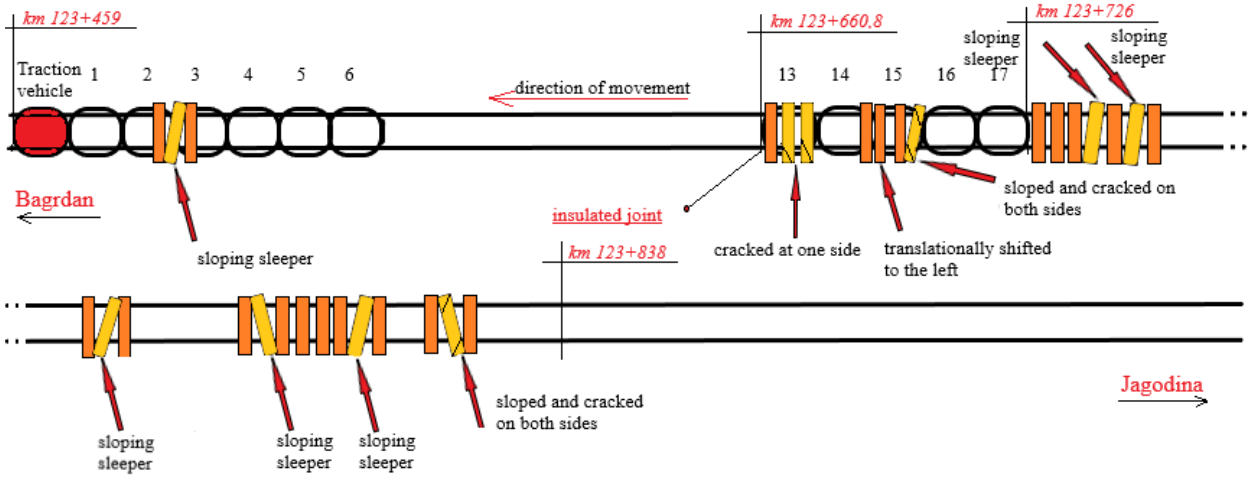



**Figure 4.2.9.4:** A schematic representation of the sloping sleepers in the accident zone

In Figure 4.2.9.5. the condition of the sloping sleepers in the accident zone as shown on the spot by the representatives of CINS is shown.

**Figure 4.2.9.5:** The view of sloping sleepers in the accident zone

In Figure 4.2.9.6. the condition of the track accessories in the area of the accident as shown on the spot by the representatives of CINS is shown.

**Figure 4.2.9.6:** The view of the track accessories in the accident zone

**Figure 4.2.9.7:** Sleeper rupture at the base board-sleeper connection point

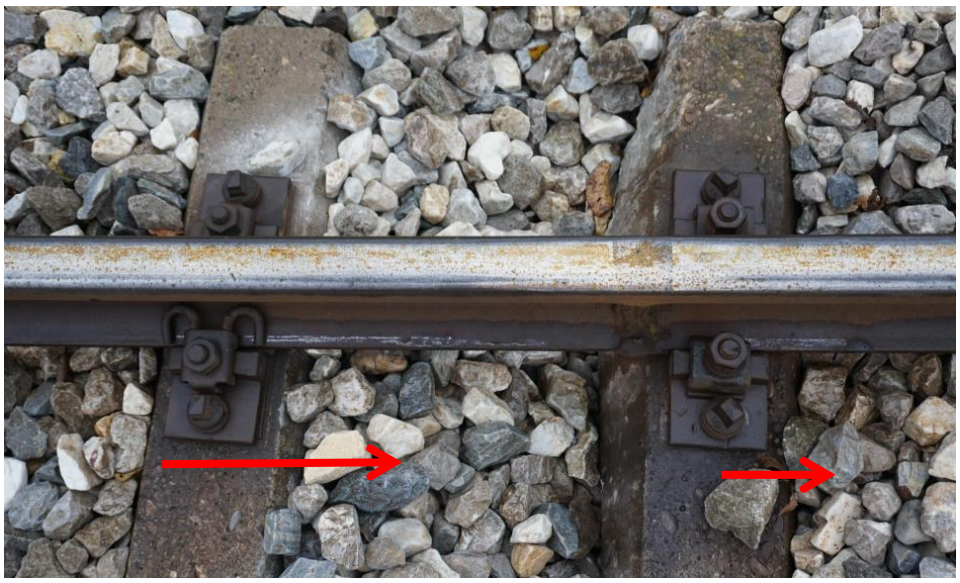


**Figure 4.2.9.8:** Longitudinal movement of the rail

Inadequate maintenance of the track welded in DTŠ for which there are no records of longitudinal and transversal movement of the track, is manifested in the form of sloping of the sleepers that occurs continuously (in the period from 2017 to 2020 from km 122+000 to km 123+700 works were carried out ten times on the removal of sloping sleepers by the OC ZOP Paraćin, and from that number, four times from km 123+000 to km 123+700).

The sloping of the sleepers is a consequence of the uneven travel of the rails caused by the change of the stress state that takes place in cycles depending on the temperature changes, as well as the braking or starting of the train.

Due to the weaker resistance of the sleepers in the curtain, as well as the friction between the rail foot and its base, the sleepers are sloped towards the track axis. In this case, there occurs an irregular spacing of the sleepers and the track gauge is reduced, which at the same time leads to loosening of the fastening accessories and moving the sleeper from the packed to the unpacked place, weakening the connections between the base board and the sleeper (Figure 4.2.9.7) and longitudinal movement of rails. .9.8.). Sloping of the sleepers due to rail travel causes disturbed geometry and track instability.

An overview of works on the removal (return) of sloping sleepers by OC ZOP Paraćin in the period from 2017 to 2020 from km 122+000 to km 123+700 is shown in Table 4.2.9.1.

**Table 4.2.9.1:** Review of performed works on removal of sloping sleepers by OC ZOP Paraćin

| Ordinal No. | Date of works performed | Track section (*km*) | Section length (*m*) |
|---|---|---|---|
| 2017. | | | |
| 1 | 22.02. | 123+650 - 123+670 | 20 |
| 2 | 10.04. | 122+000 - 122+300 | 300 |
| 2018. | | | |
| 3 | 16.05. | 122+000 - 122+500 | 500 |
| 4 | 30.11. | 122+600 - 122+840 | 240 |
| 2019. | | | |
| 5 | 27.09. | 123+670 - 123+700 | 30 |
| 6 | 03.10. | 123+000 - 123+700 | 700 |
| 7 | 02.12. | 121+950 - 122+150 | 200 |
| 2020. | | | |
| 8 | 13.05. | 123+400 - 123+700 | 300 |
| 9 | 02.06. | 122+500 - 122+800 | 300 |
| 10 | 21.07.-23.07. | 122+550 - 123+450 | 900 |

### 4.2.10. Conclusion

Taking into account the available facts about the condition of the track (item 4.2.7.), records from track inspection coach runs (item 4.2.8.), about the action of horizontal longitudinal forces in the direction of the track axis which influence the tendency of rail movement (item 4.2.9.), as well as the fact that the rail temperature at the time of the accident most likely caused tensile stresses in the rails ($t_{air}$ = - 0,4°C≈ $t_{rail}$ < $t_p$) and that due to the train braking, additional tensile stresses in the rails occurred, it is probable that the rupture of the track (the appearance of the rupture of the track is shown in Figure 4.2.10.1.) was due to the rupture of the connecting screws in the insulated joint on the left rail at km 123+660.80 in the direction of increasing stationing, that is, the right rail in the direction of train No. 45022 movement (the appearance of the rupture of the connecting screws is given in Figure 4.2.10.2) and rupture of the right rail at km 123+660.20 in the direction of increasing stationing, that is, the left rail in the direction of train No. 45022 movement (the appearance of the rupture of the rail is shown in Figure 4.2.10.3.).

Such a rupture of the track could have caused the train No. 45022 derailment.

**Figure 4.2.10.1:** The view of the track rupture at the point of insulated joint at km 123+660.80

**Figure 4.2.10.2:** The view of rupture of the connecting screws in insulated joint at km 123+660.80 (left rail in the direction of increasing stationing of the left track)

**Figure 4.2.10.3:** The view of the right rail rupture in the direction of increasing stationing of the left track at km 123+660.20

### 4.2.11. Inspection control

Considering the condition of the main arterial line 102: Belgrade Center - Junction "G" - Rakovica - Mladenovac - Lapovo - Niš - Preševo - state border - (Tabanovce), based on the Law on Investigation of Accidents in Air, Railway and Waterborne Traffic ("Official Gazette of RS" No. 66/15 and 83/18), CINS sent a Letter No. 340-00-2/2020-02-1-14 of 21.12.2020. to the Ministry of Construction, Transport and Infrastructure, the Sector for Inspection Supervision, the Department for Railway Traffic Inspection Affairs, with a request to submit the following:

- how many inspections (regular, extraordinary, control and additional) were performed on the main arterial line between the stations Bagrdan and Jagodina in the period from 01.01.2010. to 28.11.2020.,

- to submit the Minutes on inspection supervision and the Decision on ordered measures (if any) for each performed inspection and

- Minutes on the inspection performed after the accident in question by the Department for Railway Traffic Inspection Affairs and the Department for Transport of Dangerous Goods Inspection Affairs.

Until the conclusion of this report, CINS did not receive a response to the Letter.

### 4.2.12. Rescue service performance analysis

Considering that the train contained a substance that in case of uncontrolled release from the wagon tank could endanger human health and is potentially dangerous for the environment,

members of MUP RS, the Sector for Emergency Situations, Emergency Situations Department, members of MUP RS, the Police Directorate, the Police Administration in Jagodina, Traffic Police Department Jagodina, the Traffic Police Office on the state road IA rank, and members of the JP "Putevi Srbije" came to the scene upon invitation.

A patrol of the Traffic Police Office on the state road of the IA order went to the scene, which determined that the territory covered by the Traffic Police Office on the state road of the IA rank was not endangered for traffic. The patrol remained on the spot to provide assistance and security to the Jagodina Fire Brigade because they were operating from the direction of the state road IA rank No.1. Also, the JP"Putevi Srbije" was informed, which sent its on-duty team for security with barriers to the scene.

A total of ten members of the fire and rescue unit of the Emergency Situations Department in Jagodina came to the scene with four fire trucks. On the spot, the team of the fire and rescue unit, equipped with adequate protective equipment, performed a closer scouting. It was not possible to seal the leak with the equipment possessed by the fire and rescue team, so in agreement with the representatives of the railway, a part of the members of the fire and rescue team was withdrawn from the scene. One fire truck with two rescue firefighters was left at the scene to be on duty. The permanent duty lasted until 01.12.2020. at 16:30.

## 4.3. Conclusions on the causes of the accident

### 4.3.1. Direct and immediate causes of the accident

Based on the facts and evidence established during the accident investigation by the Working Group of CINS and the data submitted, the probable direct and immediate cause of the accident is the rupture of the track which was not maintained in accordance with Articles 74 and 76 of the Rulebook on technical conditions and maintenance of railway lines superstructure ("Official Gazette of RS" No. 39/16 and 74/16).

Taking into account the available facts about the condition of the track (item 4.2.7.), records from track inspection coach runs (item 4.2.8.), about the action of horizontal longitudinal forces in the direction of the track axis which influence the tendency of rail movement (item 4.2.9.), as well as the fact that the temperature of the rail at the time of the accident most likely caused tensile stresses in the rails ($t_{air}$ = - 0,4°C≈ $t_{rail}$ < $t_p$) and that due to the braking of the train there occurred an additional tensile stresses in the rails, it is probable that, during the passage of the train, the rupture of the track occurred due to the rupture of the connecting screws in the insulated joint on the left rail at km 123+660.80 in the direction of increasing stationing, that is, the right rail in the direction of train No. 45022 movement and the rupture of the right rail at km 123+660.20 in the direction of increasing stationing, that is, the left rail in the direction of train No. 45022 movement.

### 4.3.2. Basic causes deriving from skills, procedures and maintenance

The maintenance of the railway on the observed section was not performed in accordance with the Rulebook on technical conditions and maintenance of railway lines superstructure ("Official Gazette of RS" No. 39/16 and 74/16) having in mind the years of last railway overhauls and insufficient number of executors, mechanization and tools (see section 4.2.7).

### 4.3.3. The main causes of the accident deriving from the conditions established by the legal framework and the safety management system application

N/A.

### 4.3.4. Additional remarks on the shortcomings and flaws identified during the investigation, but not relevant to the conclusions on the causes

One or two screws out of four were missing on the lids of the filling and emptying openings of the overturned wagons Nos. 31 72 7865 013-8, 33 72 7867 853-3 and 31 72 7865 010-4, which contributed to a greater leakage of sulfuric acid after the accident.

The front bogie of the ninth wagon No. 33 72 7867 846-7, separated from the wagon box during derailment due to the cracking of the fastening screws and the fastening board of the center bowl upper part. The fracture was made as a consequence of derailment and overturning, but on that occasion, it was shown that there was already a fracture of the center bowl upper part and one screw on that vehicle, which was not determined during regular maintenance.

During the on-site inspection of the wagon, it was noticed that on some buffers the trace on the lubricant indicates insufficient travel, which could contribute to the increase of the consequences of the accident. In the case of separate bogies, it has been noticed that the wear parts of the side bearers go beyond the exploitation tolerances. Also, the plastic inserts of the center bowls of some vehicles were excessively worn, which in operation causes an increase in the torque moment of the rotating the bogie in relation to the wagon body when passing through curves and reducing the safety against derailment.

A broken wire was found on the first wagon in train No. 33 87 7864 174-0, with which the G-P brake mode switch was previously fixed in the P position, which is in itself a technical malfunction, which requires immediate labelling and elimination of the wagon from traffic.

The Rulebook on Amendments to the Rulebook on technical conditions and maintenance of the railway lines superstructure (“Official Gazette of RS”, No. 74/16) (see item 3.3.7), amended Article 8 of the Rulebook on technical conditions and maintenance of the railway lines superstructure (“Official Gazette of RS”, No. 36/16) (see item 3.3.6), so that in Article 8 of the Rulebook on technical conditions and maintenance of the railway lines superstructure (“Official Gazette of RS”, No. 36/16 and 74/16) there is no longer a provision with the following content: “Alternating (mixed) installation of wooden and concrete sleepers is not allowed”, from which it can be unequivocally concluded that alternate (mixed) installation of wooden and concrete sleepers is allowed (see point 3.3.8.). Taking into account the provisions of other Paragraphs from Article 8 of the Rulebook on technical conditions and maintenance of the railway lines superstructure (“Official Gazette of RS”, No. 36/16 and 74/16) and differences in technical characteristics between wooden and concrete sleepers, we are of the opinion that wooden and concrete sleepers should not be installed alternately (mixed) in the track. Also, after the adopted amendments, in Article 8 of the said Rulebook, there are two paragraphs of similar content (paragraph 12 and paragraph 13, see point 3.3.8).

# 5. Measures taken

According to the data obtained from "IŽS"a.d. (letter of the Sector for Traffic Affairs No. 15/2021-21 of 11.01.2021), immediately after the occurrence of the accident in question, section of the main arterial line 102: Belgrade Center - Junction "G" - Rakovica - Mladenovac - Lapovo - Niš - Preševo - state border - (Tabanovce), between the stations Bagrdan and Jagodina was closed for train traffic (28.11.2020 at 19:27 the left and right tracks were closed).

After removing the derailed and overturned wagons from the right track of the two-track railway line and removing the material and forming a free profile, on 01.12.2020. at 22:00, the right track of the two-track railway line between the stations Bagrdan and Jagodina was opened for train traffic with the introduction of restricted speed running from km 123+545 to km 123+660 with 10 km/h.

In the period from 23.12.2020. at 04:00 to 24.12.2020. at 23:01, a continuous closure of the right track between the stations Bagrdan and Jagodina was held, during which, by engaging the equipment and manpower of breakdown trains of "IŽS"a.d., overturned and derailed wagons and wagon parts were lifted and loaded on other wagons of the Rgs and Eas series and transferred to the Jagodina station.

After removing the derailed wagons and derailed wagon parts from the scene, the members of the Sector for Construction Affairs took measures to organize the repair of the damages caused to the left track of the two-track railway line between the stations Bagrdan and Jagodina. The works on the reconstruction and preparation of the left track for traffic were completed on 31.01.2021. at 16:00, when the left track of the two-track railway line between the stations Bagrdan and Jagodina was opened for train traffic with the introduction of restricted speed running from km 123+450 to km 123+800 with 20 km/h.

# 6. Safety recommendations

Aiming to improve safety on the railway and prevent occurrence of the new accidents, CINS has issued the following safety recommendations:

**To the Directorate for Railways recommendations SR_12/21, SR_13/21, SR_14/21, SR_15/21, SR_16/21, SR_17/21, SR_18/21, SR_19/21, SR_20/21 and SR_21/21 are issued:**

**SR_12/21** Directorate for Railways, to consider the justification of the abolition of Paragraph 9 of Article 8 of the Rulebook on technical conditions and maintenance of railway lines superstructure ("Official Gazette of RS", No. 36/16), which reads: "Alternate (mixed) installation of wooden and concrete sleepers is not allowed" and justification to return via amendments to the stated Article ("Official Gazette of RS", No. 36/16 and 74/16) the aforementioned Paragraph of the Rulebook on technical conditions and maintenance of railway lines superstructure (see item 4.3.4.).

**SR_13/21** **"**IŽS"a.d., to conduct the risk assessment of train traffic on the main arterial line 102: Belgrade Center - Junction "G"- Rakovica - Mladenovac - Lapovo - Niš - Preševo - state border - (Tabanovce), left track, from Markovac station (exclusively) km 101+057 to Jagodina station (inclusive) km 136+000, given the inadequate maintenance and condition of tracks, sleepers and fasteners and the insufficient number of executors for maintenance from the construction industry; and take measures to reduce the risk to an acceptable level (see points 3.4.2 and 4.2.7.).

**SR_14/21** "IŽS"a.d., in the Rulebook on organization and work positions systematization of "IŽS"a.d., Belgrade, to consider the adequacy of the existing ones and consider the possibility to predict the appropriate number of executors in the construction industry both on the section of the railway on which the accident occurred and on the entire network in order to ensure the safe conduct of railway traffic. In accordance with the appropriate number of executors to plan the procurement of the necessary machinery and tools, all in order to ensure the safe conduct of railway traffic (see point 4.2.7.).

**SR_15/21** Elixir Zorka Mineralna đubriva d.o.o**.** Šabac**,** to establish maintenance procedures with a list of instructions that must be an integral part of the maintenance file with a detailed list of scope of work in regular repairs of wagon-tanks for transportation of sulfuric acid (see item 4.2.2.1.).

**SR_16/21** Elixir Zorka Mineralna đubriva d.o.o. Šabac, to establish maintenance procedures, in accordance with the requirements of the Rulebook on maintenance of railway vehicles ("Official Gazette of RS" No. 144/2020), where the maintenance of bogies must be performed according to the manufacturer's instructions, and the procedures must be harmonized with that instruction, considering that wagons with worn inserts of the center bowl and side bearers represent a significant risk of derailment in curves (see item 4.2.2.1.) and in which the documentation of the characteristics of the buffer after repair and comparison with the characteristic given by the manufacturer will be defined, i.e. for newer and reconstructed wagons in accordance with the required characteristic according to EN 15551 for the corresponding type of buffer (see item 4.2.2.2.).

**SR_17/21** Elixir Group d.o.o. Šabac, as the holder for whose needs the transport is performed, it is necessary to provide procedures for proper closing of tank lids in accordance with the manufacturer's instructions, which include: checking the cleanliness and flatness of adjacent surfaces, use of undamaged prescribed seals, closing the opening with the projected number of screws with a torque wrench with the torque prescribed by the manufacturer. If this information is not known from the manufacturer, the tightening torque must be prescribed according to the general technical standards for pressure vessels (see item 4.2.6.).

**SR_18/21** Elixir Group d.o.o. Šabac, as the holder for whose needs the transport is performed, should require that staff be trained at all loading and unloading points to properly close the lids and carry it out according to the adopted procedure (see item 4.2.6.).

**SR_19/21** Elixir Group d.o.o. Šabac, as the holder of the wagons which did not have individual licenses (see items 2.2.2 and 3.4.4), to prescribe in its acts the verification of the existence of an individual license for use, before using the wagon and to conduct additional training of its staff on this issue (see item 4.2.6.).

**SR_20/21** "Srbija Kargo"a.d., to train the staff to carry out the measure at the reception points, that if it is possible to establish the lack of screws on the tank lids by visual inspection, to refuse the transport of improperly closed tanks (see item 4.2.6.).

**SR_21/21** "Srbija Kargo"a.d., to train the staff that wagons due to defects (as stated in item 4.2.2.3, in one tank it was determined that the GP gearbox was defective when the handle could turn without resistance and without arrest in the end positions and said gearbox has been fixed with wire in position P) must be labelled and sent for repair (see item 4.2.6.).

**To the Ministry of Construction, Traffic and Infrastructure SR_22/21, SR_23/21 and SR_24/21 are issued:**

**SR_22/21** Ministry of Construction, Transport and Infrastructure, Sector for Inspection Supervision, Department for Railway Traffic Inspection Affairs, to perform an extraordinary inspection of the condition of the railway infrastructure on the main arterial line 102: Belgrade Center - Junction "G" - Rakovica - Mladenovac - Lapovo - Niš - Preševo - state border - (Tabanovce), left track, from the station Markovac (exclusively) km 101+057 to the station Jagodina (inclusive) km 136+000 and take measures within its competence (see items 3.4.2, 4.2.7. and 4.2.8.).

**SR_23/21** Ministry of Construction, Transport and Infrastructure, Sector for Inspection Supervision, Department for Railway Traffic Inspection Affairs, to perform an extraordinary inspection of Elixir Group d.o.o. Šabac which used railway vehicles that do not have a type license and without an individual license for use (see items 2.2.2. and 3.4.4.) and take measures within its competence.

**SR_24/21** The Ministry of Construction, Transport and Infrastructure, Sector for Railways and Intermodal Transport, to consider possible amendments in the existing legislation in order to facilitate the procedure of issuing type licenses and licenses for use only for existing vehicles in long-term operation in RS for which, due to current legal regulations, licenses cannot be issued by the Railway Directorate (see item 3.4.4.).

**To *Autorité française de sécurité ferroviaire* SR_25/21 is issued:**

**SR_25/21** Atir-Rail SA, to prescribe in maintenance procedures the control of the condition and wear of wearing inserts of center bowls and side bearers (see item 4.2.2.1.) as well as other elements that can reach the limit measures between the two repairs and define the documentation of buffer characteristics after repair and comparison with the characteristic given by the manufacturer (see item 4.2.2.2.).