MINISTRY OF TRANSPORTS AND INFRASTRUCTURE
ROMANIAN RAILWAY AUTHORITY - AFER

ROMANIAN RAILWAY INVESTIGATING BODY

INVESTIGATING REPORT

on the technical failure of the structural subsystem infrastructure
occurred on the line Babeni – Alunu on the 15th and 24th of October 2010

Final edition
The 28th of March 2011

NOTICE

With reference to the technical failure of the structural subsystem infrastructure occurred on the range of activity of CF Craiova Regional Branch, on the running section Babeni - Alunu (simple line non-electrified), between the flag stations Popesti Valcea - Copaceni, at km 18+890 and km 21+900, that had as consequence failures on the line which led to the derailment by the first bogie in the running direction of the 10th wagon (no. 825366536571) in the composition of the freight train no. 23748 belonging to the railway undertaking SNTFM "CFR Marfa" SA, respectively the derailment by the first axle of the locomotive DHC 514 (belonging to the railway undertaking SNTFC "CFR Calatori" SA) hauling the passenger train no. 2835, Romanian Railway Investigating Body carried out an investigation according to the provisions of the art.19(2) of Law no.55/2006 on the railway safety, corroborated with the provisions of the art. 49(1) from the Regulations for the investigation of the accidents and incidents, for the development and improvement of Romanian railway and subway safety, approved by Government Decision no. 117/2010.
Through the investigation, the information on the occurrence of the technical failure was gathered and analyzed, the conditions were established and the causes determined.
Also, in order to improve the railway safety were issued a series of safety recommendations.
The action of Romanian Railway Investigating Body did not aim to establish the guilty or the responsibility in this situation.

Bucharest, the 28th of March 2011

approved by

Dragoş FLOROIU
Director

I agree the compliance with the legal provisions
on the investigation performance and
drawing up of this Investigation Report,
*that **I submit for approval***

Chief Investigator
Sorin CONSTANTINESCU

This Approval is part of the Report for the investigation of the technical failure of the structural subsystem infrastructure occurred on the range of activity of CF Craiova Regional Branch, on the 15th of October 2010 and on the 24th of October 2010 and that affected the running of the freight train no. 23748 belonging to the railway undertaking SNTFM "CFR Marfa" SA, respectively of the passenger train no. 2835 belonging to the passenger railway undertaking SNTFC "CFR Calatori" SA.

SUMMARY

I. PREAMBLE

I.1. Introduction

Romanian Railway Investigating Body was notified by the Romanian Railway Safety Authority about the occurrence of two derailments on the range of activity of CF Craiova Regional Branch, the running section Babeni-Alunu, between the flag stations Popesti Valcea-Copaceni, without deaths or injuries.

After analyzing the information on the technical condition of the railway infrastructure registered in the primary documents, the members of the investigation commission concluded that the two derailments were favored by a technical failure of the structural subsystem infrastructure.

As the technical failure of the structural subsystem infrastructure could have led to serious accidents, Romanian Railway Investigating Body according to the provisions of the art. 49 from the ***Regulations for the investigation of the accidents and incidents, for the development and improvement of Romanian railway and subway safety***, approved by Government Decision no. 117/2010 named the investigation commission president to start the investigation in order to establish the conditions, determine the causes and prepare safety recommendations to prevent incidents with similar causes.

The action of the investigation commission did not aim to establish the guilty or the responsibility, its objective being to improve the railway safety and to prevent railway accidents or incidents.

I.2. Investigation process

According to the provisions of the art. 19 (2) of Law 55/2006 on railway safety and of the art. 49 from the *Regulations for the investigation of the accidents and incidents, for the development and improvement of Romanian railway and subway safety*, approved by Government Decision no. 117/2010 the happenings are defined as technical failure of the structural subsystem infrastructure, for which OIFR decided to start an investigation.

Through the decision no. 35 of the 25th of October 2010, of the OIFR Director, the investigation commission was appointed, consisting in:

Eduard Stoian	- main investigator
Nicolae Popescu	- investigator
Dumitru Sfârlos	- investigator
Luca Păiş	- investigator

A. BRIEF PRESENTATION OF THE ACCIDENTS

A.1. Brief presentation

On the 15th of October 2010 on the range of activity of Craiova Railway Regional Branch, the running section Babeni-Alunu (simple line non-electrified), on the current line between the flag stations Popesti Valcea – Copaceni, at km 18+890 occurred a compaction of the railway embankment, which had as consequence the derailment of the first bogie in the running direction of the 10th wagon in the composition of the freight train no.23748 belonging to the freight railway undertaking SNTFM "CFR Marfa" SA. The compaction of the embankment occurred due to heavy rainfall that day and the previous days. The freight train no.23748 had in composition 25 wagons type "Fals" all loaded with coal from Berbesti quarrying, was hauled by two locomotives and had pushing locomotive. The derailment occurred around 9:50 p.m.
Shortly after, on the 24th of October 2010 on the same current line and the same atmospheric conditions, but at km 21+900 occurred a new compaction of the railway embankment, which had as consequence the derailment by the first axle in the running direction of the locomotive DHC 514, hauling the passenger train no. 2835 belonging to the railway undertaking SNTFC "CFR Calatori" SA. The passenger train was composed of the traction locomotive DHC 514 and two coaches. The derailment occurred at 5:05p.m.

A.2. Direct cause, contributing factors and root causes

A.2.1. Direct cause

The direct cause of the technical failure of the structural subsystem infrastructure was the uneven compaction of the embankment under load, which caused a twisting of the rail and led to loss of guidance of the rail on the right in the running direction followed by the escalation of the rail on the right in the running direction by the appeal wheel of the railway vehicles, its fall outside the rail (on the right in the running direction), followed by the fall inside the rail of the wheel on the left.

Contributing factors to the compaction of the rail embankment were:

- saturation of the ground in the embankment body after heavy rainfall, which resulted in a decrease of the bearing capacity of the ground in the embankment body by the emergence and amplification of residual deformations in its body. This was possible because there was not insured the draining capacity of the prism of broken stone by works of cutting the banquets for storm water discharge from the embankment platform, contrary to the provisions of chapter II point B.4, letter b of the Instruction for the execution of radical repair of the railway line nr.302/1986 (reprinted in 1997);
- existence of an effective super-elevation of the line in curve, bigger than the one corresponding to a maximum running speed of 15 km/h, led to the overloading of the inner wire of the curve, which had as consequence the increase of the vertical forces transmitted by each fastener of the sleepers on the inner wire of the curve. This resulted in increasing the vertical stress on the layer of broken stone, ballast and on the ground in the embankment body, leading to the increase of the residual deformation of this layered system, manifested on the running surface of the rail by rail defects in transverse and longitudinal profile.
- failure to ensure the proper elasticity of the prism of broken stone, which resulted in the transmission of higher pressures on the surface of the embankment platform, causing strains in the body of the embankment. This was possible because it could not be achieved the appropriate thickness of the layer of broken stone under the sleepers sole, because at periodic repair works with full screening of broken stone prism was not provided all of the necessary broken stone for this work, in contravention with the provisions of the Chapter II point B.2a of the Instruction for the execution of radical repair of the railway line nr.302/1986 (reprinted in 1997);

A.2.3. Underlying causes

- noncompliance with the provisions of the art. 66 letter b) and letter d) of the Instructions on the capital repair works of railway lines no. 303/2003 on the restoration of the embankments and of the works of its protection-consolidation and with the provisions of Chapter 2, point 2.10. of Railway Technical Norm 72-003/2004 on the types of intervention on the embankments depending on the classification of the defects in levels of priority;
- noncompliance with the provisions of the Annex no.8 to the Instruction on the maintenance of the railway lines no. 300/1982 by partial execution of the works of the technological process of periodic repair with full screening of the broken stone.

A.2.4. Root causes
None.

A.3. Safety recommendations
The addressee of the safety recommendations is the National Railway Company "CFR" S.A as administrator of the railway infrastructure.
The safety recommendations aim to solve the next issues:

1. The National Railway Company "CFR" S.A will conduct a geophysical survey to identify the actual thickness of the layer of broken stone under the sole sleepers, the ballast bags and areas in which are formed slip plans in the embankment body of the line CF Babeni-Alunu. Depending on the results will be established the technical documentation for the execution of the works to ensure thickness of broken stone under the sole sleepers and remove the sliding effect of the embankment.
2. The National Railway Company "CFR" S.A will analyze how to reduce the aggressiveness of the rolling stock on the railway superstructure and infrastructure on the line CF Babeni-Alunu.

This investigation report will be sent to Romanian Railway Safety Authority - ASFR, to the public railway infrastructure manager - The National Railway Company "CFR" S.A, to the freight railway undertaking - SNTFM "CFR Marfa" SA and to the passenger railway undertaking - SNTFC "CFR Calatori" SA.

B. INVESTIGATING REPORT

B.1. Description of the events

On the 15th of October 2010 at 7:40p.m. in the railway station CFR Berbesti was formed the freight train no. 23748. The train was composed of the towing locomotive DA 1326 to which was linked the second locomotive DA 109 followed by a number of 25 wagons type "Fals" loaded with coal (by Berbesti quarrying) and by the pushing locomotive DA 1262.
On the 15th of October 2010 at 7:40 p.m. the train was formed and sent from the railway station CFR Berbesti having as destination the railway station CFR Valea Seaca.

At 8:10p.m. the train no. 23748 was stopped in Hm. Copaceni for the entry in the station of the passenger train no.2468-1. At 9:14p.m. the freight train no.23748 was sent to H.m. Popesti Valcea and ran until the km 18+960 where was braked, at 9:50p.m., as consequence of the derailment of the 10th wagon by locomotive, by the first bogie in the running direction and of the disruption of the general air pipeline.

On the 24th of October 2010 at 2:06p.m. the passenger train no. 2835 hauled by the locomotive DHC 514 having in composition a number of 2 coaches, 8 axles, 100 tons, actual braked tonnage 128 tons, necessary braked tonnage 85 tons, was sent from the railway station CFR Babeni to H.m. Alunu.
At 4:55p.m. the train no. 2835 stopped in P.O. Cernisoara where stationed until 4:56p.m. At 4:56p.m. the train no. 2835 was sent to Berbesti and ran until the km 21+900, where occurred the derailment by the first axle of the first bogie of the locomotive, the train being stopped at 5:01 p.m. as consequence of the train braking by the driver.

B.2. The circumstances of the events

B.2.1. Involved parties

The running section where the railway accident occurred is managed by CNCF "CFR" SA and maintained by its employees.

The railway infrastructure on which the accident occurred belongs to CNCF "CFR" SA and is maintained by the staff from the section L3 Ramnicu Valcea.

The rolling stock involved in the two events belongs to:

- the freight railway undertaking SNTFM "CFR Marfa" SA, in the case of the event occurred on the 15th of October 2010

respectively

- the passenger railway undertaking SNTFC "CFR Calatori" SA, in the case of the event occurred on the 24th of October 2010

B.2.2. Forming and equipments of the train

The event occurred on the 15th of October 2010

The freight train no. 23748 belonging to the freight railway undertaking SNTFM "CFR Marfa" SA was hauled by the locomotives DA 1326 and DA 109 and had pushing locomotive DA 1262. The composition of the train was the following: 25 wagons type "Fals" all loaded with coal, 100 axles, 1988 tons, length 400 m.

The event occurred on the 24th of October 2010

The passenger train no. 2835 belonging to the passenger railway undertaking SNTFC "CFR Calatori" SA was hauled by the locomotive DHC 514 (belonging to the same railway undertaking) and had the following composition: two coaches, 8 axles, 100 tons, length 75 m.

B.2.3. Railway equipments

The railway traffic between H.m. Popesti Valcea-Copaceni is carried out based on the understanding by phone – free way.

The flag stations Popesti Valcea and Copaceni are equipped with installations with key lock and block type SBW.

B.2.4. Means of communication

The communication between the locomotive drivers and the movement inspectors was insured through the radio-telephone installation.

B.2.5. Triggering the railway emergency plan

In the two cases investigated according to the provisions of the Regulations for the investigation of the accidents and incidents, for the development and improvement of Romanian railway and subway safety, approved by Government Decision no. 117/2010, at the place of the accidents came representatives of the public railway infrastructure manager CNCF "CFR" SA - CF Craiova Regional Branch, of the freight railway undertaking SNTFC "CFR Marfa" SA, of the passenger railway undertaking SNTFC "CFR Calatori" SA, of the Romanian Railway Authority – AFER and of the Operative Department of Railway Transports Police.

B.3. The consequences of the events

B.3.1. Deaths and injuries

None.

B.3.2. Material damages

***the derailment occurred on the 15th of October 2010*:**

damages at the wagon no. 825366536571

- according to the estimate no. 3825/19.10.2010 of the Section IRV Rosiori 820.46 lei
for the towing of the intervention train
- according to the estimate no. R2/1186/20.10.2010 of CFR Craiova Depot 10187.03 lei
the derailment occurred on the 24th of October 2010
none
TOTAL **11007.49 lei**

B.3.3. Consequences of the failure of the subsystem infrastructure in the railway traffic
the compaction from the km 18+860 occurred on the 15th of October 2010
- the railway traffic between Hm.COPACENI-Hm. POPESTI VILCEA was closed from 10:25 p.m. on the 16th of October 2010 to 7:20 p.m. on the 25th of October 2010.
- the passenger trains no. 2832 and no.2835 were canceled on the distance Babeni-Alunu;

the compaction from the km 21+900 occurred on the 24th of October 2010
- the railway traffic between Hm.COPACENI-Hm. POPESTI VILCEA was closed from the 24th of October 2010, 5:05 p.m. to the 25th of October 2010, 01:52 a.m.;
- the passenger train no. 2835 was canceled on the distance Popesti-Alunu;
- the passenger trains no. 2470 and no. 2468 were canceled on the distance Babeni-Alunu.

B.4. External circumstances
In both cases the visibility was good, air temperature between $+11^0$C - $+13^0$C.
The days of the two events and the previous days were recorded plentiful rainfall, this being also the subject of weather warnings to the population through the media.

B.5. Investigation course
B.5.1. The summary of the of the involved staff statements
The driver of the locomotive DA 1362 that on the 15th of October 2010 hauled the passenger train no. 23748 stated as follows:
- he left from H.m. Copaceni at 9:16p.m., and at 9:44p.m. occurred the emergency braking of the train no. 23748 by the drop of the air pressure in the general pipeline. He contacted through RER station the driver of the second locomotive, who checked the train and found that the first bogie from the 10th wagon by locomotive had derailed.

The driver of the second locomotive DA 1092 that on the 15th of October 2010 was in the composition of the freight train no. 23748, after the traction locomotive, stated as follows:
- he left from H.m. Copaceni at 9:15p.m., ran normally to near the signal harbinger of H.m. Popesti Valcea, when occurred the braking and the drop of the air pressure in the general pipeline.
- he contacted the driver of the double traction locomotive.
- he went besides the train and he noticed that the first bogie of the 10th wagon in the running direction was derailed;

The driver of the pushing locomotive DA 1262 in the composition of the freight train no. 23748 stated as follows:
- at 9:44 p.m. occurred the emergency braking of the train by the drop of the air pressure in the general pipeline.
- the contacted through RER station the driver of the second locomotive who told him that the 10th wagon by locomotive was derailed by the first bogie in the running direction.

The driver of the locomotive DHC 514 that on the 24th of October 2010 hauled the passenger train no. 2835 stated as follows:
- he took over the locomotive in the railway station CFR Ramnicu Valcea;
- he drove the locomotive DHC514 hauling the train no. 2436/2835 on the distance Ramnicu Valcea-Babeni;
- at 3:55p.m. from the railway station CFR Babeni was sent as train no. 2835 to Alunu;
- he ran in good conditions until P.O. Cernisoara;
- at km 21+900 he heard a noise in front of the locomotive;

- he braked the train and he insured the train against movement;
- he went down from the locomotive and found the axle no. 1 derailed;

B.5.2. Safety management system

On the date of the incident The National Railway Company "CFR" S.A had established its own safety management system.

Also the freight railway undertaking SNTFM "CFR Marfa" SA and the passenger railway undertaking - SNTFC "CFR Calatori" SA, had established their own safety management system.

B.5.3. Norms and regulations. Sources and references for the investigation

In the investigation of the railway incident one took into account:

- documents on the release of trains;
- documents on the management and control of the trains traffic;
- documents on the condition of the involved installations;
- documents on the skills, medical and psychological, of the involved staff;
- documents on the authorization of the involved staff;
- reports of reading the IVMS installations records in the equipment of the towing locomotive of the trains involved in the staff questioning on the incident occurrence;
- written documents, plans, projects, drawings provided by the Institute of Railway Studies and Design on the construction and release to service of the line CF Babeni-Alunu
- Regulation no. 005/2005 to trains running and shunting of the railway vehicles.
- Instruction of standards and tolerances for the construction and maintenance of the rail - standard gauge lines no. 314/1989
- Instructions on the capital repair works of railway lines no. 303/2003 on the restoration of the embankments and of the works of its protection-consolidation;
- Instruction for the execution of radical repair of the railway line nr.302/1986 (reprinted in 1997);
- Railway Technical Norm 72-003/2004;
- Instruction on the maintenance of the railway lines no. 300/1982

B.5.4. Work of the technical installations, of the infrastructure and of the rolling stock

There were no nonconformities in the operation of technical installations or of the rolling stock.

B.5.4.1. Data found on the line

Condition of the line Babeni –Alunul from the release to service

The line 204, Babeni –Alunul with a length of 41.415 km was released to service, successively on four sections, in the kilometer order of the five points of sectioning, during 1982-1987, with the running speed of 50 km/h.

The line was built with rail type 49, with joints, on wooden and reinforced concrete sleepers with clamping K and E2.

In 1996 was performed a capital repair work at the clamping when was replaced a part of the clamping E2 with the clamping K, work performed with semi-good materials.

In 1999 on the distance km 0+000 to km 16+000, between the railway stations Babeni and Popesti was performed a regular repair work of the line with full screening of the ballast prism with the rail heavy machinery (RPc).

Since 2006 the maximum running speed was limited to 30 km/h.

The line between hm. Copaceni and hm. Popesti Valcea was released to service in August 1986 with the maximum running speed of 50 km/h.

Since 2006 the maximum running speed was limited to 30 km/h due to the high degradation of the condition of the embankments, to the clogging of the prism of broken stone and of the metallic elements insuring the rails fixing on the sleepers.

Since 2009 the running speed was again limited to a maximum of 15 km/h on a distance of 18.9 km from hm Popesti to hm Berbesti due to the worsening of the defects that led to the first speed limitation in 2006.

Technical condition of the line before the derailment

In 2010 on the line Babeni-Alunul were reviewed 1798 normal wooden sleepers, 298 special sleepers and 684 reinforced concrete sleepers inappropriate.

On the line Popesti Valcea - Copaceni in October 2010 were performed RPc works from the km 26+130 to km 17+385.

Regarding the km 19+890 where occurred the derailment of the 15th of October 2010

In horizontal plane the area where occurred the embankment compaction and respectively the derailment of the 10th wagon by locomotive is on the curve km 18+886-19+295 on the surface of the parabolic curve of connection between the circular curve with R=535 m and the adjacent alignment. In this area the transverse profile of the rail is mixed and in the profile along the area is in ramp of 9.31‰.

The prism of broken stone was unclogged and unconsolidated. On the 15th of October 2010 were performed works of mechanical sifting, stuffing and shifting with railway heavy machineries on the area km 18+800 - 19+250 km. Stuffing and shifting I on this area was performed in two stages on the 29th of October 2010 and the 3rd of November 2010.

photo no.1

Regarding the km 21+900 where occurred the derailment of the 25th of October 2010

In the area of the derailment the line is in curve with the radius **R**=300 m, the over-elevation **h**=70 mm, over-enlargement **s**=15mm, the transverse profile is mixed, in ramp of 14.66‰ (on the area of km 21+775 - km 22+225).

photo no.2

The prism of broken stone was unclogged, unconsolidated. On the 11th of October 2010 were performed works of mechanical sifting, stuffing and shifting with railway heavy machineries on the area of km 21+700 - km 22+300, distance on which was performed the stuffing I on the 18th of October 2010.

Findings and measurements on the line, after the derailment and lifting of the rolling stock

The derailment of the 15th of October 2010

After restoring the derailed wagon on the line on the 16th of November 2010 were performed checks with the rail measuring pattern of the gauge and of the cross level, at the measuring base of 2.5 m before and after the derailment point.

After the measurements interpretation resulted that between the derailment point and the previous one the rail twisted as consequence of the compaction of the embankment, the rail twisting value being of 15 mm. This value, according to the provisions of the art.7, point A.4 of the Instruction no. 314/1989 of standards and tolerances for the construction and maintenance of the rail - standard gauge lines corresponds to a running speed of V≤10km/h.

Also in the previous point of the derailment and for the same reason the tolerance of 10 mm at the precise cross level of a wire to the other for the lines where the maximum running speed V_{max}≤50 km/h provided at the art. 7, point A, paragraph 1 of the same instruction was exceeded.

In the point where were performed the checks was not found the exceeding of the tolerances in operation of the gauge values.

The derailment of the 24th of October 2010

After restoring the derailed locomotive on the line on the 25th of November 2010 were performed checks with the rail measuring pattern of the gauge and of the cross level, at the measuring base of 2.5 m before and after the derailment point.

After the interpretation of the measured values resulted that due to the compaction under load of the embankment between the first two points before the derailment point occurred a rail twisting of 18 mm. This value, according to the provisions of the art.7, point A.4 of the Instruction no. 314/1989 of standards and tolerances for the construction and maintenance of the rail - standard gauge lines corresponds to a running speed of V≤10km/h.

The designed over-elevation of the curve with radius R=300 m should be 0 mm, for the limited speed of 15 km/h, but this corresponds to the excess of over-elevation of 70 mm. The consequence is the loading of the inner wire of the curve, the unloading of the appeal wheel on the outer wire of

the curve and loading of the wheel on the inner wire, corresponding to the same axle. The maximum over-elevation admitted by the Instruction no. 314/1989 table no. 3 was not exceeded.
In the point where were performed the checks was not found the exceeding of the tolerances in operation of the gauge values.

Data resulted from the checks performed on spot by the investigation commission on the 9th of November 2010

Regarding the position km 18+890 where occurred the derailment of the 15th of October 2010
The mechanical sifting and the intermediate stuffing were performed on the 15th of October 2010 and the stuffing I on the 29th of October 2010 from the km 19+400 to 19+000 and on the 3rd of November 2010 from the km 18+500 to km 19+000.
At sifting was removed from the rail around 0.5-0.6 mc of tailings per meter of sifted line.
The sifting was performed without addition of new broken stone, which resulted of decreasing the height of broken stone layer from under the sleeper sole.
The technological stuffing, intermediate and stuffing I, were performed without addition of broken stone, on the prism remained at the sizes after the sifting

photo no.3

The prism after the stuffing was complete from the point of view of the outer sizes which led to the conclusion that values of the outer sizes could have been obtained only by decreasing of the height of broken stone layer from under the sleeper sole.
The decrease of the width of broken stone layer led to an increase of the loads on the embankment platform surface from under the line by decreasing the coefficient of bed of the system between the sleeper sole and the embankment platform.
The water runoff is not provided from the level of the rail platform by cutting of the banquets or performing some end drains.

photo no.4

Vertical fixings with high degree of wear that led to the introduction of some metal spacers to keep the gauge in tolerances.

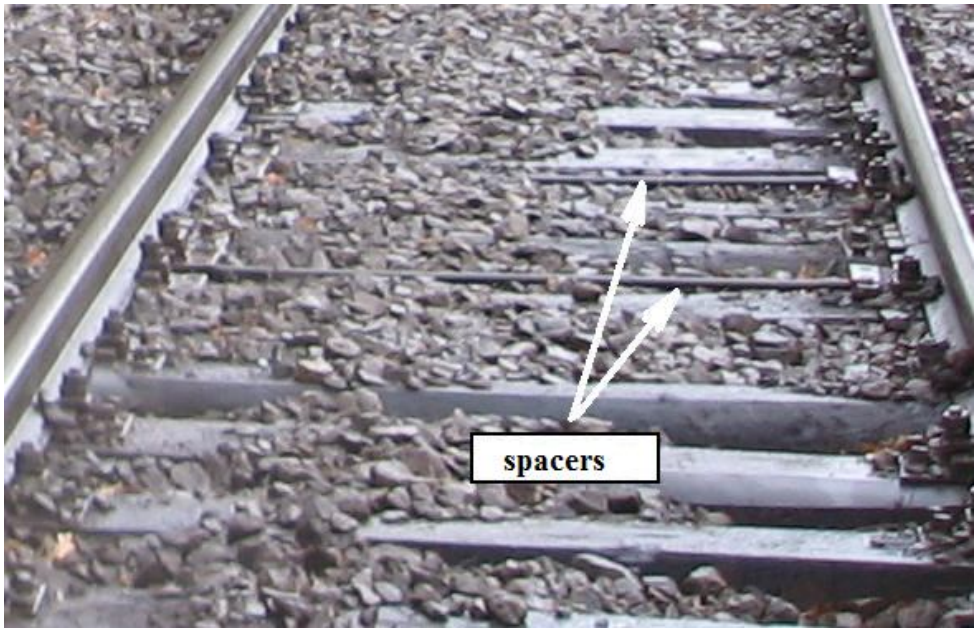

photo no.5 – fixing consolidated with spacers at km 21+900

<u>Regarding the position km 21+900 where occurred the derailment of the 24th of October 2010</u>

The mechanical sifting and the intermediate stuffing were performed on the 11th of October 2010 and the stuffing I on the 18th of October 2010 on the area of km 22+550 - 21+900 and on the 26th of October 2010 (the day after the derailment) on the area km 21+900 to 21+300.

At sifting was removed from the rail around 0.5-0.6 mc of tailings per meter of sifted line.

The sifting was performed without addition of new broken stone, which resulted of decreasing the height of broken stone layer from under the sleeper sole.

The technological stuffing, intermediate and stuffing I, were performed without addition of broken stone, on the prism remained at the sizes after the sifting.

After the technological stuffing the prism of broken stone had provided the instructional width but given the deficit of broken stone it can be provided only by decreasing the height of the broken stone layer under the sleeper sole.

The decrease of the width of broken stone layer led to an increase of the loads on the embankment platform surface from under the line by decreasing the coefficient of bed of the system between the sleeper sole and the embankment platform.
The water runoff is not provided from the level of the rail platform by cutting of the banquets or performing some end drains.

photo no.6

Vertical fixings with high degree of wear that led to the introduction of some metal spacers to keep the gauge in tolerances.
Due to rails reversals in curve performed over time, the gaps moved, some joints becoming suspended.

photo no.7

photo no.8

Data resulted from the analysis of the documents asked to the railway infrastructure manager

The line and the prism of broken stone

The last repair work on the two areas where occurred the derailments was performed in October 2010 by SIMC Craiova and consisted of the mechanical sifting of the prism of broken stone and the first two technological stuffing intermediate and stuffing I.

The last measurement with the rail measuring wagon, *before the derailments*, was performed on the 14th of May 2009 and were not found rail defects of 3 or higher grade in the two areas where the derailments occurred.

The last measurement with the rail measuring wagon, *after the derailments*, was performed on the 2nd of November 2010 and were not found rail defects of 3 or higher grade in the two areas where the derailments occurred, which proves that there were no more compactions of the embankment.

The annual measurement of the curve, within which occurred the second derailment, was performed on the 5th of March 2010, on the distance km 18+200 to km 26+800 the measured values of the arrows, of the over-enlargement, of the over-elevation and of the vertical and horizontal wears not exceeding the instructional limits.

The values of the existing normal over-elevations of the curve being calculated for the speed of 50 km/h (as they were designed for the release on service of the line) are higher than those that should correspond to the limited speed of 15 km/h. The consequence of this is the additional loading of the inner wire of the curve and acceleration of the vertical wear of the rail corresponding to it.

The embankment

From the written documents, plans, projects, drawings provided by the Institute of Railway Studies and Design on the construction and release to service of the line CF Babeni-Alunu resulted the following:

- the railway section between the railway stations Babeni and Popesti was put into operation in 1982;
- the railway section between the railway stations Popesti and Copaceni was put into operation in August 1986;
- the railway section between the railway stations Copaceni and Berbesti was put into operation in December 1986;
- the railway section between the railway stations Berbesti and Alunul was put into operation in 1987.

When it was put into operation the maximum running speed of the line was of 50 km/h. In 2006 the running speed was limited to 30 km/h and in 2009 to 15 km/h.
The main causes of the running speed limitation were the continuous degradation of the embankments condition, of the works of consolidation of the embankments and of some bridges and footbridges.
The decrease of the rail quality over time is highlighted by the annual evolution of the number of dangerous points and of the embankment failures occurred over time.
So, if in 2002 in the records of Section L3 Ramnicu Valcea were listed as reviewed a number of 7 dangerous points, in 2010 their number reached 12. The maximum number of the dangerous points since the line was put into service was registered in 2006, when the in the records of Section L3 Ramnicu Valcea on this line were listed a number of 14 dangerous points. Most of these dangerous points are due to degradation of the embankments condition, of the supports and footbridges.
Area of km 18+890
On the interval km 18+980-19+155 the line was built, according to the geotechnical study that led to the line design, in very large fillings, of 2-9 m, over the profile of a valley where was built also a footbridge at km 18+825 with the opening of 2 m.
According to the geotechnical study in October 1991, that led to the design of the works of consolidation of the embankment from the km 18+600 to km 19+300 the area is characterized by phenomenon of instability consisting of the embankment sliding, plains of the rail platform and rail displacements to right or left. These deformations occurred during rainfall and were due to improper compaction of the embankment.
For this area ISPCF prepared the technical project no. 8-973-2-1991.
Area of km 21+900
During 25th of December 1996 - 5th of December 1996 between the km 21+850 and km 22+400, occurred landslides that led to rail vertical compactions of over 1 meter and to the line displacement to the left with values bigger than 1 meter, that led to the closure of the line for several works of consolidation and restoration of the embankment. During the execution of geotechnical study that led to the design of rehabilitation works of the embankment was found that the existing embankment was built of sandy clays and clayey sands susceptible to wetting which were proposed to be replaced with drainage material. The basic plot that is the embankment support is composed of clays covered with layers of coarse sands.
On the 6th of June 2005 until the 19th of September 2006 was closed the line Popesti-Copaceni to rebuild the footbridge from the km 22+563 and for RK works on embankments on the area of km 22+ 500 - km 22+800.

In November 2010, on the line Babesti-Alunul were recorded a number of 12 dangerous points of which 5 are of I grade and 7 of II grade. 11 of these are due to the embankment degradation by compactions, erosions or landslides.
None of the two areas where occurred the two derailments is mentioned in these records. On both areas was found the existence of sterile deposit result of the sifting process that together with the banquet uncut and clogged of the embankment impede the rain water discharges from the rail platform to ditches or slopes.
Checking the points where occurred the derailments, the investigation commission also viewed the condition of the dangerous points between the railway stations Popesti-Copaceni.
A dangerous evolution was found on two areas listed as dangerous points at I grade as follows:

- area from km 18+150 to km 18+450 where the line is affected by sliding of the slope on the left of the rail that led to the braking and deformation of the support wall, of the reinforced trench and the deformation of the direction and of the profile along of the line on a distance of about 300 meters. To improve the quality of this area is prepared a technical documentation no. 8-263-99 by ISPCF Bucharest since 1999, but the work to date has not been executed.

photo no.9

photo no.10

photo no.11

- area from km 26+000 to km 26+015 where the line is affected by the sliding of a part of the slope on the right of the embankment and by a landslide on a length of 10 m.

photo no.12

It was also found the obstruction of the waters access to the fall chambers of the footbridges due to the clogging and to the vegetation growth of all waste water ditches.

photo no. 13 - km 21+900

photo no.14 - km 21+900

Expertise and projects carried out

On the railway section between the flag stations Popesti Valcea - Copaceni, due to frequent occurrence of defects immediately after being put on service, especially during rainy periods, were ordered by CF Craiova Regional Branch technical documentations of expertise and design for 11 area affected by the instability and the deformation of the embankments and slopes. Since 1988 has been prepared by ISPCF Bucharest a number of 8 documentations and by SC CONSIS PROIECT Bucharest a number of 3 documentations. Of these only for 3 were started and performed the designed works.

The achieved technical documentations show that the rail embankment on the embankment areas has to be partially replaced with draining material and the rail platform to be reinforced. This confirms that the rail embankment was damaged by the storm waters non-discharged from the embankment platform level which led to the deformation of the embankment over time and the creation of broken stone bags, defects enhanced by basic nature of the soil of the embankments consisting of sandy clay susceptible to wetting.

B.6. Analysis and Conclusions

B.6.1. Conclusions on the technical condition of the rail superstructure and of the embankment

Conclusions on the technical condition of the rail superstructure at the time of the derailments

The compaction of the rail embankment under load led to:

- exceeding the rail twisting value admitted by the provisions of the art.7, point A, paragraph 4 of the Instruction no. 314/1989 of standards and tolerances for the construction and maintenance of the rail - standard gauge lines, for the speed V=15 km/h;
- exceeding the tolerance of 10 mm for the cross level, in the point previous to the derailment, admitted by the provisions of the art. 7, point A, paragraph 1 of the Instruction no. 314/1989 of standards and tolerances for the construction and maintenance of the rail - standard gauge lines, for lines with V_{max} of up to 50 km/h.

Conclusions on the condition of the embankment after the derailments

By visual checking carried out on the 9th of November 2010 by the members of the investigation commission on the condition of the prism of broken stone, of the rail banquets, of the drainage ditches were found the following:

area of km 18+890

- width of the prism of broken stone was provided, but the broken stone was not compacted and reinforced and the clogged banquet and the sterile resulted from the sifting process were impeding the waters discharge from the rail platform.

photo no.15

area of km 21+900

- width of the prism of broken stone was provided, but the broken stone was not compacted and reinforced and the clogged banquet and the sterile resulted from the sifting process were impeding the waters discharge from the rail platform;
- rail banquet towards the drainage ditch on the right clogged and the drainage ditch was full of vegetation.

photo no.16

B.6.2. Analysis and conclusions on the derailments occurrence

Conclusions

1. In both situations the embankment compactions has as result rail twisting bigger than those admitted by the provisions of the. 7, point A, paragraph 4 of the Instruction of standards and tolerances for the construction and maintenance of the rail - standard gauge lines no. 314/1989, which led to the derailment of the railway vehicles on the 15th of October and on the 24th of October 2010.
2. The gauge values show that they were within the tolerances admitted by the provisions of the art. 1, point 13 and art.1, point14.1 of the Instruction of standards and tolerances for the construction and maintenance of the rail - standard gauge lines no. 314/1989.

3. The over-elevations normal on the circular curves calculated for the speed of 50 km/h have values bigger than those corresponding to the limited speed of 15 km/h, their effect being the overloading of the inner wire, increasing of the embankment platform load and the accelerated degradation of the sleepers and of rails clamping on the sleepers.
4. Non-execution of periodic repair works of the line leads to the progressive degradation of the rail condition, which resulted in the progressive limitation of the running speed.
5. Non-execution of works of cutting the banquets and evacuating the soil resulted from the stiffing of the broken stone, as provided at chapter II, letter B, point 4b) of the Instruction for the execution of radical repair of the railway line nr.302/1986, favors increasing soil moisture by retaining water in the embankment body particularly during periods of heavy rainfall.

B.7. Causes of the structural subsystem failure

B.7.1. The direct cause of the technical failure of the structural subsystem infrastructure was the uneven compaction of the embankment under load, which caused a twisting of the rail and led to loss of guidance of the rail on the right in the running direction followed by the escalation of the rail on the right in the running direction by the appeal wheel of the railway vehicles, its fall outside the rail (on the right in the running direction), followed by the fall inside the rail of the wheel on the left.

Contributing factors to the compaction of the rail embankment were:

- saturation of the ground in the embankment body after heavy rainfall, which resulted in a decrease of the bearing capacity of the ground in the embankment body by the emergence and amplification of residual deformations in its body. This was possible because there was not insured the draining capacity of the prism of broken stone by works of cutting the banquets for storm water discharge from the embankment platform, contrary to the provisions of chapter II point B.4, letter b of the Instruction for the execution of radical repair of the railway line nr.302/1986 (reprinted in 1997);
- existence of an effective super-elevation of the line in curve, bigger than the one corresponding to a maximum running speed of 15 km/h, led to the overloading of the inner wire of the curve, which had as consequence the increase of the vertical forces transmitted by each fastener of the sleepers on the inner wire of the curve. This resulted in increasing the vertical stress on the layer of broken stone, ballast and on the ground in the embankment body, resulting the increase of the residual deformation of this layered system, manifested on the running surface of the rail by rail defects in transverse and longitudinal profile.
- failure to ensure the proper elasticity of the prism of broken stone, which resulted in the transmission of higher pressures on the surface of the embankment platform, causing strains in the body of the embankment. This was possible because it could not be achieved the appropriate thickness of the layer of broken stone under the sleepers sole, because at periodic repair works with full screening of broken stone prism was not provided all of the necessary broken stone for this work, in contravention with the provisions of the Chapter II point B.2a of the Instruction for the execution of radical repair of the railway line nr.302/1986 (reprinted in 1997);

B.7.2. Underlying causes

- noncompliance with the provisions of the art. 66 letter b) and letter d) of the Instructions on the capital repair works of railway lines no. 303/2003 on the restoration of the embankments and of the works of its protection-consolidation and with the provisions of Chapter 2, point 2.10. of Railway Technical Norm 72-003/2004 on the types of intervention on the embankments depending on the classification of the defects in levels of priority;
- noncompliance with the provisions of the Annex no.8 to the Instruction on the maintenance of the railway lines no. 300/1982 by partial execution of the works of the technological process of periodic repair with full screening of the broken stone.

B.7.3. Root causes

None.

D. SAFETY RECOMMENDATIONS

The addressees of the safety recommendations are the Romanian Railway Safety Authority and the National Railway Company "CFR" S.A as administrator of the railway infrastructure.
The safety recommendations aim to solve the next issues:

1. The National Railway Company "CFR" S.A will conduct a geophysical survey to identify the actual thickness of the layer of broken stone under the sole sleepers, the ballast bags and areas in which are formed slip plans in the embankment body of the line CF Babeni-Alunu. Depending on the results will be established the technical documentation for the execution of the works to ensure thickness of broken stone under the sole sleepers and remove the sliding effect of the embankment.
2. The National Railway Company "CFR" S.A will analyze how to reduce the aggressiveness of the rolling stock on the railway superstructure and infrastructure on the line CF Babeni-Alunu.

This investigation report will be sent to Romanian Railway Safety Authority - ASFR, to the public railway infrastructure manager - The National Railway Company "CFR" S.A, to the freight railway undertaking - SNTFM "CFR Marfa" SA and to the passenger railway undertaking - SNTFC "CFR Calatori" SA.

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