Office of the Chief Investigator
Transport Safety

Rail Safety Investigation
Report No 2011/07

Derailment
Freight Train
Warracknabeal
5 June 2011

TABLE OF CONTENTS

THE CHIEF INVESTIGATOR

The Chief Investigator, Transport Safety is a statutory position under Part 7 of the *Transport Integration Act 2010*. The objective of the position is to seek to improve transport safety by providing for the independent no-blame investigation of transport safety matters consistent with the vision statement and the transport system objectives.

The primary focus of an investigation is to determine what factors caused the incident, rather than apportion blame for the incident, and to identify issues that may require review, monitoring or further consideration. In conducting investigations, the Chief Investigator will apply the principles of 'just culture' and use a methodology based on systemic investigation models.

The Chief Investigator is required to report the results of an investigation to the Minister for Public Transport or the Minister for Ports. However, before submitting the results of an investigation to the Minister, the Chief Investigator must consult in accordance with section 85A of the *Transport (Compliance and Miscellaneous) Act 1983*.

The Chief Investigator is not subject to the direction or control of the Minister in performing or exercising his or her functions or powers, but the Minister may direct the Chief Investigator to investigate a transport safety matter.

EXECUTIVE SUMMARY

On the evening of 5 June 2011, all four wagons of an empty El Zorro freight train travelling towards Hopetoun derailed at an unsealed level crossing near Warracknabeal. There were no injuries.

The derailment was the result of a fractured rail at the level crossing. There had been a pre-existing, long-term, horizontal fracture in the web of the rail, leading to the separation of the rail head. A number of transverse rail fractures had also developed prior to the incident and the rail subsequently suffered catastrophic failure at the time of the incident, creating a gap of over 800 mm in the rail head running surface.

The investigation concluded that the rail had been weakened by corrosion that had caused a reduction in material thickness and that track inspections had not identified the deteriorated condition of the rail. In 2009, ultrasonic testing had identified indicators of what was thought at that time to be corrosion. The investigation concluded that, in fact, a horizontal web fracture of about 600 mm probably already existed at this time. This fracture subsequently grew to a length of 1400 mm in the following 22 months leading up to the incident.

The investigation makes recommendations in the areas of track condition monitoring and standards for the construction of level crossings at unsealed roads.

1. CIRCUMSTANCES

On 5 June 2011, El Zorro train № 9765 departed Murtoa at 2135 destined for Hopetoun in north-west Victoria. The train was comprised of a single locomotive and four empty wagons.

At about 2225, all wagons derailed at the Mellis Road level crossing, about five kilometres south-east of Warracknabeal. The locomotive did not derail and there were no injuries.

At the time of the incident the weather was fine and cool. There had been no measurable precipitation during the day of the incident, and a small amount of precipitation on the preceding day.

Figure 1 – Mellis Road level crossing and the derailed wagons in the background

2. FACTUAL INFORMATION

2.1 Train crew

2.1.1 Overview

The train was crewed by a locomotive driver and a second driver undergoing route knowledge training. Both were qualified for their respective duties and had been assessed as medically fit for duty. Following the incident, both crew members were breath tested and no alcohol was detected.

2.1.2 Train crew observations

The train crew reported that as they passed over the level crossing they felt a heavy impact. The locomotive lurched and the crew reported losing brake pipe air and coming to a stop. When they looked back they observed that the freight wagons had derailed. The crew returned to the crossing and identified a broken rail.

2.2 The train

2.2.1 Consist

The train had an overall length of about 90 metres with locomotive and wagon designations as shown at Figure 2. The leading wagon (CHBY 7075) was comprised of two permanently-coupled hopper wagons.

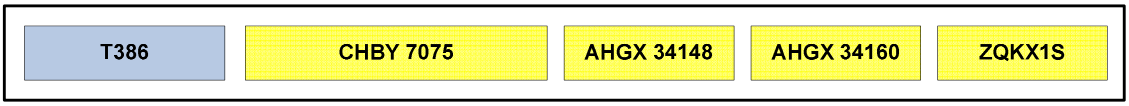

Figure 2 – The train consist, locomotive T386 leading

According to V/Line Circular *S.11/5134*, the train was scheduled to be running with the locomotive and one CHBY wagon only. The three additional wagons were not listed. This is not considered to be of significance to the incident.

Prior to the incident, the consist had been inspected in accordance with El Zorro pre-departure inspection procedures and was certified as fit-to-run. Following the incident, vehicle inspection at site did not identify any matters which may have contributed to the derailment.

2.2.2 Locomotive and wagon permitted speeds

The V/Line *Train Operating Data* for Murtoa to Hopetoun specified a permitted speed of 50 km/h for the T-Class locomotive. In accordance with the V/Line *Network Service Plan*, all freight wagons were approved to operate on the V/Line network and all with a permitted maximum speed of 80 km/h.

2.2.3 Locomotive speed recorder

The locomotive speed recorder indicated a train speed of about 45 km/h before dropping to zero at the time of derailment.

2.3 Infrastructure

2.3.1 Murtoa to Hopetoun

The section of track between Murtoa and Hopetoun was managed by V/Line. It was designated a Class 4 freight line with a permitted track speed of 50 km/h and at the time of the incident there were no other speed restrictions applicable to the incident location. Traffic on the line was low, with about three trains per week in each direction. Empty wagons would be hauled to Hopetoun and loaded with grain for the return journey south towards Murtoa and beyond to port.

The last train to traverse this section of track before the incident was on the day prior. It was travelling towards Murtoa having been loaded at Hopetoun earlier in the day. The train was carrying grain and was recorded as being comprised of 44 vehicles, with a length of 695 metres, and a mass of 3105 tonnes. The crew of this train did not report there being any issue with the Mellis Road level crossing.

Planning had commenced to use the rail network to freight mineral sands from Hopetoun via Murtoa to a processing facility at Hamilton and the train involved in the incident was proceeding to Hopetoun as part of this project.

2.3.2 Mellis Road level crossing

Mellis Road is an unsealed road used predominantly by local traffic, including farm machinery. It intersects the rail track at an angle of about 40 degrees with the road sloping down on either side of the crossing. The rail head was slightly proud of the road surface with roughly formed flangeways for wheel flanges. The rail web and foot and all rail supports were covered by road materials and not visible.

Figure 3 - Mellis Road level crossing

The rail track through the crossing was tangent, with no cant. The track had a slight rising grade on the approach to the crossing and falling grade on the departure. Rails were 80 lb/yd[1] and had been manufactured in 1908. Rails were secured using dog spikes onto double shoulder plates and timber sleepers.

---

[1] About 40 kg/m.

2.3.3 Incident site inspection

A section of the right hand rail (in the direction of train travel) was found to be severely damaged. The road surface was disturbed by the derailment although there had been minor restoration of the road surface prior to the investigation team arriving on site. Near the fracture, there were indications either side of the track of ‘holes’ in the road that contained loose, uncompacted materials (see Figure 4).

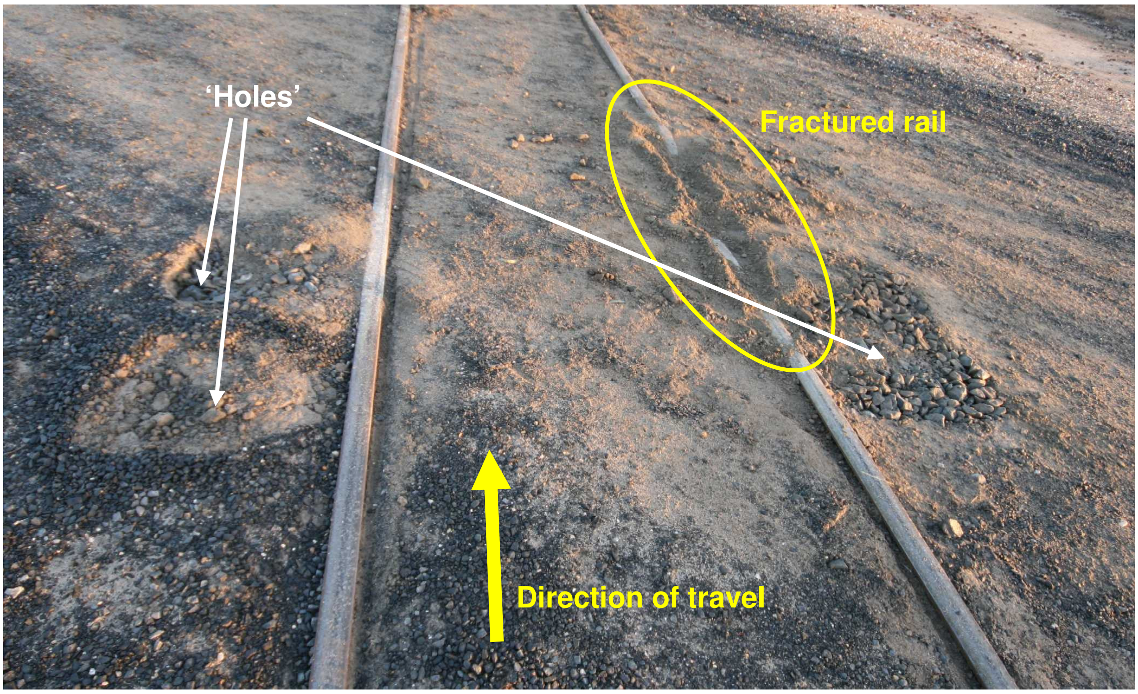

Figure 4 – Condition of level crossing on arrival at site

Road materials were removed from the area of the damaged rail. The rail was found to be fractured into several pieces, with a horizontal fracture in the web extending for about 1400 mm. There was a gap of 830 mm between the intact ends of the rail head. There was no evidence of a bituminous or other coating on the rail.

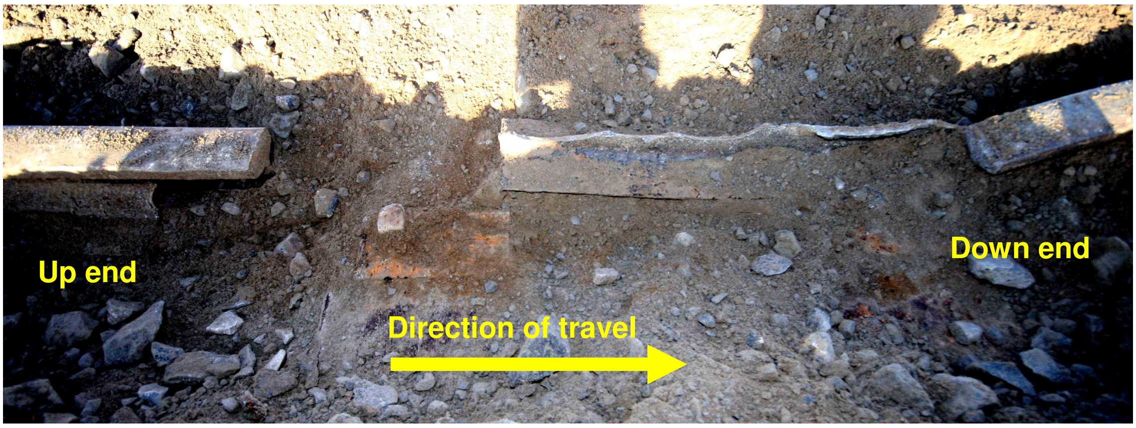

Figure 5 - Damaged section of rail after excavation and removal of fractured pieces of rail

Figure 6 – Up end of fracture, in-situ (note continuation of horizontal web fracture)

At the Up[2] end of the damaged rail, just beyond the web fracture, the sleeper had dropped by about 50 mm and was not providing effective support to the rail.

Figure 7 – Gap between sleeper support and rail at the Up end of the fracture

While on site, local residents advised the investigation that the area had been affected by floods in early 2011 and that the plains adjacent to the rail formation had been covered in water. Low lying areas adjacent to the track remained water-logged. The local residents also commented that the rails were sometimes struck by farm machinery traversing the level crossing.

---

[2] Towards Melbourne

2.3.4 Rail metallurgical inspection

A detailed metallurgical examination was made of the damaged rail (see Figure 9).

Material

The material tests performed on the rail established that the material was suitable for the application and that material defects had not contributed to the rail fractures that had occurred. Deep etching of the rail revealed the rail material was homogeneous with no evidence of significant segregation of non-metallic inclusions in the rail web.

The chemistry of the rail was found to be consistent with *AS 1085.1-1977* 41 kg/m or 47 kg/m Nominal Rail Size material. The rail chemistry indicated that the rail had been produced prior to 1985, the year when rail chemistry was upgraded. The rail head hardness and rail microstructure was also found to be typical of rail material produced pre-1985 in Australia or earlier non-Australian produced rail.

Corrosion

The broken rail was heavily corroded. The external surfaces of the rail foot and the web had been wasted by corrosion. The web had been reduced to a minimum thickness of approximately 5.5 mm after removal of the surface oxide layer. The minimum thickness of the new rail would have been in the range of 13 to 14 mm. As a result, the reduction in web thickness for the section examined was considered to have been between 7.5 and 8.5 mm.

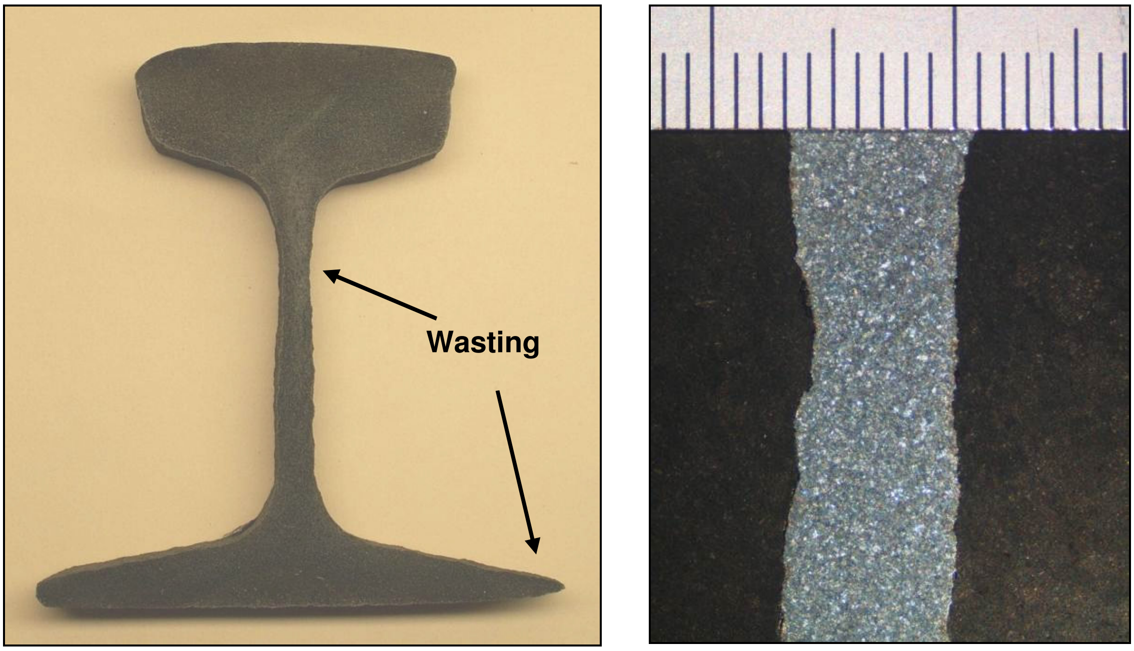

Figure 8 - Rail cross section, indicating wasting of the foot and web (shown right with 1 mm scale)

The presence of a band in the web where the corrosion was worst suggested the presence of a localised interface between moisture and air where corrosive conditions were at a maximum. The rail web was wasted in a horizontal band approximately 15 mm wide and about 50 mm below the top of the rail head, along the full length of the rail examined.

Figure 9 - Side elevation of the broken rail subject to metallurgical inspection

Published data on unprotected carbon steel indicates that pitting corrosion can occur at up to 1 mm per annum. These rates suggest that the external corrosion of the rail is likely to have been occurring over at least the last four years to produce an 8 mm loss of web thickness (4 mm from each side of the rail web). Corrosion rates may vary downwards if corrosion conditions do not represent unprotected steel with an adequate moisture supply at all times. For example, if moisture were only present for the three winter months each year, the amount of time required to produce pitting to the depth observed in the rail web would be expected to increase to 16 years.

Fractures

The rail fractures were inspected visually. Transverse rail head fractures between rail pieces 6 and 7; 7 and 8; 8 and 9; 9 and 10; and 10 and 4 were new and had occurred at the time of the incident. These transverse rail head fractures were consistent with instantaneous overload failure. Surface or internal metallurgical defects which could be interpreted as stress concentrators were not detected in the vicinity of the fracture origins. Fatigue or other long term failure mechanisms were also not detected on these rail fractures.

The transverse rail head fractures between rail pieces 5 and 6 and 5 and 1 (see Figure 10) both showed light corrosion on the rail head fracture surfaces. Also, the mating surfaces of broken rail pieces 5 and 6 had been battered on the head by passing wheelsets.

The horizontal web fractures were all heavily corroded and had been mechanically damaged. This indicated that they had been present in the rail for an extended period of time. The web fractures were predominantly aligned with the wasted band in the rail web that was observed below the rail head transition radius.

The three transverse fractures of the rail foot (pieces 1–4) contained a mixture of heavily corroded, lightly corroded and bright metallic fracture surfaces.

The fracture surfaces between rail pieces 1 and 2 were heavily corroded in the web and lightly corroded in the foot, indicating that the web fracture had been present longer than the foot fracture. The light corrosion of these foot fracture surfaces suggested this fracture had been present for a short period of time prior to the incident.

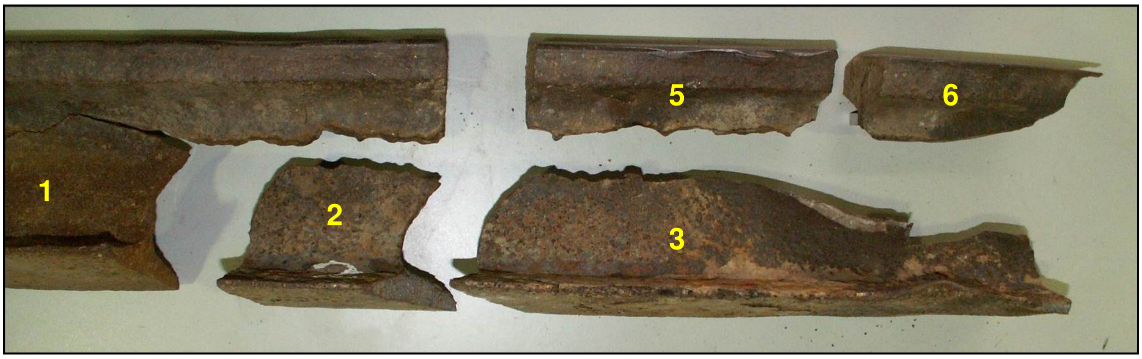

Figure 10 - Side elevation showing corroded web fracture

The fracture surfaces between rail pieces 2 and 3 were heavily corroded in the web and bright metallic in the foot indicating that the web fracture had been present for longer than the foot fracture. The bright metallic fracture in the foot region was consistent with instantaneous overload failure and was new and had occurred as a result of the incident.

The fracture surfaces between rail pieces 3 and 4 were heavily corroded in the web and the foot indicating that this fracture had been present for a significant period of time; sufficient to generate the corrosion that was present. The heavy corrosion of the fracture surfaces in this case indicated that this fracture had been occurring for sufficient time to generate the corrosion present, which could be 12 months or more.

The corrosion and mechanical damage obscured a number of the fracture surfaces and in many cases prevented positive identification of fracture modes. However, the pattern of damage suggested that the horizontal web fracture had occurred as a result of fatigue.

Ultrasonic testing

Ultrasonic testing confirmed that the rail did not contain intermittent indications consistent with non-metallic inclusions or segregation. The testing also revealed that the web cracking in the rail was detectable with normal (0 degree) and angle probes.

Conclusions from metallurgical assessment

The results of the metallurgical testing and inspections indicate that the initial rail failure had occurred by fatigue that originated at a horizontal band of corrosion in the rail web. The corrosion had produced a reduction in web thickness and pitting in the rail web surface, which had acted as a stress concentration in the fatigue mechanism.

2.4 Track condition monitoring

2.4.1 Standards

For Class 4 freight lines, V/Line procedures specify a range of inspections including:

Type	**Frequency**	**Latitude**
Track patrol (hi-rail)	1 week	2 days
Front-of-train	3 months	14 days
Walking inspection	1 year	30 days
Track geometry (recorder car)	1 year	30 days
Ultrasonic testing	3 year	182 days

2.4.2 Track Patrol

The most recent track patrol inspection of the Mellis Road level crossing was undertaken by hi-rail on 31 May 2011, which was within the required inspection frequency. The inspection did not identify any faults at the Mellis Road level crossing.

2.4.3 Walking Inspection

The most recent walking inspection of the Mellis Road level crossing was undertaken on 18 January 2011, which was within the required inspection frequency. The inspection report recorded that the rail head was in a sound condition but that the rail foot and fastenings and sleeper/foundation conditions were not visible. The report noted that the crossing was renewed on 15 October 2008.

2.4.4 Track geometry

The most recent measurement of track geometry was on 11 February 2010, which was outside the required inspection frequency by about three months. The records indicated that there were no geometric faults identified at the Mellis Road level crossing.

2.4.5 Ultrasonic testing

Ultrasonic rail testing is conducted in Victoria using a hi-rail vehicle travelling at speeds of up to 38 km/h. Ultrasonic testing is generally a reliable means of identifying rail defects and its limitations are well understood. Level crossings can sometimes present difficulties for automated ultrasonic testing because of differing rail size within the crossing and the presence of corrosion on the underside of rails that can disrupt return signals from the base of the rail foot. Either of these scenarios can create continuous alarms in inspection vehicles during the testing of crossings.

The testing vehicle is equipped with a range of transducers and incorporates multiple levels of detection logic to construct a composite picture of a rail defect. The data is analysed and assessed in real time against alarm parameters set by the operator. Defects are presented on a screen display in the vehicle and also saved for later review.

The most recent ultrasonic inspection of this section of rail was conducted by Speno Rail Maintenance Australia Pty Ltd (Speno) on 3 August 2009, which was within the required inspection frequency. The recorded data available for review was limited to responses from 0 and 37 degree transducers (probes). There were no records of back wall[3] response at the defect location.

Review of ultrasonic testing records by Speno

Speno commented that the replay of the 2009 test showed that corrosion indicators were detected at the broken rail location, intermittent along about 600 mm of rail. Speno concluded that the response from the transducers suggested the corrosion had not yet penetrated the full thickness of the web or propagated to any continuous length along the rail section and that all indicators appeared to be less than the reportable size of 20 mm.

Speno commented that the propagation rate for this type of defect was dependent on a number of factors such as moisture and acid content of the material surrounding the rail; drainage; train axle loading; and frequency and weight of road traffic. Speno recommended a review of testing frequency for freight lines and the introduction of a corrosion code for this type of discontinuity. Speno also stated that they would instruct their operators to conduct ground examinations on all corrosion indicators, evaluate the indicators, and record outcomes in the test report.

---

[3] The ultrasonic reflection from the foot of the rail.

Independent review of ultrasonic testing records

An independent review of the 2009 test records identified that there was insufficient detail to enable rigorous assessment of the defect responses. The lack of records of back wall response from the rail foot prevented positive assessment of the defect. Similarly, the responses from the 0 and 37 degree transducers alone were insufficient to confirm with certainty the extent of corrosion penetration of the rail web. Speno advised that the back wall response data could not be recovered for the 2009 tests.

For comparative purposes, ultrasonic examination of the damaged rail was undertaken post-incident using 0, 45 and 70 degree probes. In those parts of the rail where there was corrosion but not web separation, a back wall response was detected from the rail foot and there were no indicators from the corrosion above reference level. Whereas, in those areas where there was web separation, there was no back wall response but there were intermittent responses from all probes similar to those identified in the 2009 inspection, probably due to the variability of the orientation of the web separation.

The independent review noted that while the indications from the 2009 tests may have been less than 20 mm and so unreportable, there were several indications within the 600 mm length of rail where the failure occurred that had triggered responses from multiple probes. Some of the signals were close together, raising the question of whether the intermittent indications may have been connected by unfavourably orientated sections of the defect that were undetectable using automated ultrasonics.

The independent review concluded that, on balance, it was likely that the defect detected in 2009 was in fact a horizontal separation, about 600 mm long, which subsequently progressed to 1400 mm in length over the two years to final failure. The intermittent return signals obtained from the web split at the time of the 2009 inspection were likely to have been misleading and could have led to interpretation of the defect as corrosion rather than web separation. This is particularly so if back wall response from the rail foot had been switched out, preventing detection of a loss of response. This is known to occur in automated ultrasonics in situations like road crossings where back wall responses from the rail foot are often inconsistent, which can generate continuous alarms in the testing car.

The independent review also commented that inspection of crossings should be upgraded if web separations are to be minimised. It was suggested that when there are multiple adjacent indications from multiple probes over a distance of 200 mm or more in the web of rails in crossings, it may be prudent to introduce a requirement to perform ground testing even though the individual signals do not trigger reporting requirements. The use of hand scanning has the potential to improve inspection, subject to operator skill, and should enable the difference between corrosion wasting of the web and web separation to be readily detected. Hand scanning is particularly applicable in situations like crossings where probes used to detect back wall indications may be switched out to permit automated inspection without continuous alarms.

2.5 Level crossing construction

At the time of the incident, the V/Line standard for level crossings specified construction details for road crossings with paved (sealed) surfaces, but did not include a similar level of detail for crossings at unsealed roads.

The standard did include some generic requirements that would have been applicable to the Mellis Road level crossing. These included the requirement that when crossings are opened for inspection, the rail should be checked for corrosion, including loss of web thickness, and that rail that is corroded or otherwise defective should be replaced. The standard also specified that bituminous paint was to be applied to the web and foot of rail that would be in contact with fill material. For crossings that were being renewed, the standard specified a minimum size of rail of 47 kg/m.

3. ANALYSIS

3.1 The incident

On the day of the incident, the rail was already significantly degraded and finally collapsed with multiple fractures. The final catastrophic collapse probably occurred during the passage of the locomotive. Then, with a gap in the rail head of over 800 mm now present, all wagons derailed.

The features of the rail defect included a 1400 mm horizontal web fracture along the rail, leading to head separation. There were also three long-term transverse fractures in the web towards the foot of the rail, one of which had progressed through the foot. Another of these transverse fractures had progressed through the foot a short time prior to the incident, perhaps in the preceding weeks. The final transverse foot fracture occurred at the time of the incident.

All rail head fractures had occurred recently or during the incident. Two transverse fractures of the rail head had occurred shortly prior to the incident and five occurred at the time of the incident. These fractures were a result of a loss of web support for the rail head.

3.2 Infrastructure condition

The horizontal fracture in the web and subsequent transverse fractures were a direct result of the wastage of metal, loss of rail strength, and the cyclic loading by rail traffic.

The extent of wasting suggests that the rail has been deteriorating for a long period of time, probably many years, although it is impossible to identify the exact period. The rate of corrosion would have varied due to changing environmental conditions and, within the web, was found to be worst at the moisture-air interface. Floods earlier in 2011 would have increased moisture levels in the local environment and potentially promoted corrosion, but given the short time period before the incident, this effect is likely to have been minimal.

Site evidence of a loss of sleeper support on the Up end of the horizontal web fracture and ‘holes’ with loose fill in the adjacent road surface suggest that there may have been some pumping of the track around the defect location.

3.3 Infrastructure maintenance and condition monitoring

3.3.1 Crossing renewal

At the time the crossing was opened for sleeper renewal in October 2008, it is probable that the rail was already wasted. However, it is apparent that this deterioration in the rail was not detected at this time nor corrective action taken. Given the absence of any residual coating material on the rails, it is also probable that prior to reinstating the crossing a protective bituminous coating was not applied to the rails as required by the V/Line standard. The 40 kg/m rail in the crossing was also less than the minimum of 47 kg/m specified for crossing renewal.

3.3.2 Ultrasonic testing

It is probable that a 600 mm fracture already existed at the time of the 2009 ultrasonic testing, but the presence of a rail defect was not identified. It appears likely that the ultrasonic indicators detected during this testing were interpreted as corrosion, and of insufficient extent to be reportable.

The testing organisation has since advised that operators of the testing vehicle have been instructed to undertake ground inspections where there are indicators of corrosion. This action is consistent with the independent review of the ultrasonic testing undertaken by the investigation. It is probable that hand inspections would have identified the extent of the rail degradation in 2009 and initiated corrective action.

The testing organisation has also made a number of recommendations with regard to testing frequency and the development of a corrosion code. Given the high reliance on ultrasonic testing to detect subterranean defects, a review of the ultrasonic testing regime is considered warranted.

3.3.3 Other inspections

Subsequent to the 2009 ultrasonic testing, no other track inspection identified the defect in the rail web and its growth during the 22 months prior to the incident because the rails and track support were covered by road materials. It is probable that the first visible features of the defect were two transverse head fractures, which probably occurred shortly prior to the incident during the passage of other freight trains. Noting the light corrosion on these fracture surfaces, it is possible that one or both formed after the most recent track patrol five days prior to the incident.

The most recent close visual inspection was at the walking inspection about five months before the incident. This inspection specifically noted that track support and parts of the rail were not visible. It also noted that the crossing had been renewed just over two years prior. This would have created an expectation that the condition of the track had been fully inspected at that time, and perhaps lessened any concern at the inability to visually inspect some parts of the track.

The track geometry inspection was about three months overdue. However, prior to the actual collapse of the rail, the track geometry may not have been significantly affected by the defect and the exceedence of this inspection frequency requirement is not considered contributory to the incident.

3.4 Crossing construction

The V/Line standard for level crossings provided limited guidance on the construction of level crossings at unsealed roads and should be expanded to better address design considerations for such crossings. Road materials such as gravel, sand and dirt in combination with moisture can promote the existence of a corrosive environment. Coverage of the track also inhibits the ability to visually inspect the condition of the track, including rails.

4. CONCLUSIONS

4.1 Findings

1. The condition of the locomotive and wagons did not influence the derailment.

2. The operation of the train did not influence the derailment.

3. Inspection of track geometry was about three months overdue.

4.2 Contributing factors

1. At the time of sleeper renewal at the crossing in October 2008, the opportunity was not taken to adequately inspect, renew and protect the rail.

2. Ultrasonic testing in 2009 identified possible rail degradation but no further action was taken to more closely inspect the site.

3. The rail was heavily wasted leading to a loss of strength, long term fracture development and ultimately, catastrophic failure.

5. SAFETY ACTIONS

5.1 Safety Actions taken since the event

Speno Rail Maintenance Australia Pty Ltd has advised that it will instruct its operators to conduct ground examinations on all corrosion indicators and record outcomes.

V/Line has advised that it has reviewed its method of capturing asset information and would use collected data to complete a prioritisation of crossing works.

5.2 Recommended Safety Actions

Issue 1

The rails were not adequately inspected when opened for sleeper renewal in 2008 and there was no apparent attempt to enhance longevity of the rail by applying a protective coating.

RSA 2012017

That V/Line reviews the implementation of its procedures for the conduct of renewal works at level crossings with unsealed roads.

Issue 2

The V/Line standard for level crossings provides only limited detail on the construction requirements for unsealed level crossings. The nature of a crossing such as that at Mellis Road provides a potentially corrosive environment and limits the ability to inspect the condition of the track including rails and support structures.

RSA 2012018

That V/Line reviews its standard for the construction of level crossings at unsealed roads.

Issue 3

Ultrasonic testing detected the presence of possible rail degradation almost two years prior to the event. Action has been taken to improve follow-up manual inspections, but there remains doubt as to the adequacy of ultrasonic inspection frequency and criteria.

RSA 2012019

That V/Line conducts a review of ultrasonic testing protocols in light of the outcomes of this investigation.

Issue 4

There is a heavy reliance on ultrasonic inspection to detect rail defects of this type. When this inspection failed to identify the defect in this instance, the remaining suite of inspections used to monitor the condition of this Class 4 track did not identify the existence of a significant rail defect. The visual inspections of track patrols and walking inspection were compromised by the nature of the crossing construction.

RSA 2012020

That V/Line holistically reviews the condition monitoring of track at level crossings with unsealed roads in light of the outcomes of this investigation.