RAILWAY OCCURRENCE REPORT

SUBGRADE FAILURE

CANADIAN PACIFIC RAILWAY
TRAIN NO. 935-06
MILE 44.8, PARRY SOUND SUBDIVISION
POINTE AU BARIL, ONTARIO
07 APRIL 1997

REPORT NUMBER R97T0097

The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

Railway Occurrence Report

Subgrade Failure

Canadian Pacific Railway
Train No. 935-06
Mile 44.8, Parry Sound Subdivision
Pointe au Baril, Ontario
07 April 1997

Report Number R97T0097

Summary

On 07 April 1997, at approximately 0200 eastern daylight time, Canadian Pacific Railway (CPR) northward freight train No. 935-06 encountered a roadbed slump near Pointe au Baril, Ontario, Mile 44.8 of the Parry Sound Subdivision, derailing 14 cars and the locomotive consist. Approximately 45,000 litres (10,000 gallons) of diesel fuel leaked from damaged locomotive fuel tanks; the diesel fuel ignited and burned until it dissipated into the subgrade material. One crew member sustained serious injuries and the remaining two sustained minor injuries.

The embankment collapse is attributable to a build-up of pore pressure in loose sand fill. The pore pressure was the result of the head of water created by a beaver pond along the west slope of the embankment. Contributing to the head of water was the rapid melting of snow during the two weeks preceding the derailment.

Ce rapport est également disponible en français.

Other Factual Information

The train departed MacTier, Mile 0.0 of the Parry Sound Subdivision, at approximately 0058 eastern daylight time (EDT)[1], travelling northward destined for Romford (Mile 121.7). The trip between Mile 0.0 and Mile 44.8 was without incident. The train was proceeding on a clear signal indication displayed on the Automatic Block System (ABS) signal at Mile 43.5.

As the train entered the three-degree curve, at Mile 44.8, the train crew observed that the roadbed had collapsed. The tracks were suspended above the depression. The locomotive engineer immediately initiated a brake application, but the 4 locomotives, 10 residue sulphuric acid tank cars, 1 loaded gondola car and 2 boxcars plunged into the void in the roadbed and came to rest in various states of upset. The 14th car, another residue sulphuric acid tank car, was derailed but upright at the edge of the depression. Although all the fuel tanks on the four locomotives were punctured, the fire burned in the area of the second locomotive. Thirty tonnes of lead sulphide, an environmentally hazardous material (powder), spilled from the derailed gondola car. (It was completely recovered in the site clean-up.)

The train crew consisted of a conductor, a locomotive engineer and a trainman. During the derailment, the conductor was rendered unconscious upon hitting the locomotive windshield. The locomotive engineer and trainman sustained minor injuries. The two conscious crew members immediately exited the locomotive cab, with a portable railway radio, and contacted the rail traffic controller (RTC) requesting emergency assistance. They then re-entered the locomotive to rescue the conductor. They carried the conductor to the top of the embankment and covered him with their coats and an emergency blanket from the locomotive to await the arrival of the first responders.

The RTC first contacted the ambulance service in Parry Sound (approximately 25 miles south of the derailment site) at approximately 0213. Local CPR employees were then notified, as were police and the fire department in Nobel (approximately 19 miles south of the derailment site). At approximately 0334, after a 15-minute delay was experienced while the RTC unsuccessfully attempted to determine if loaded dangerous good cars had derailed, first responders accessed the track from a crossing at Mile 48.9 and proceeded southward in a CPR Hi-rail vehicle. At approximately 0522, the three crew members were admitted to the hospital in Parry Sound.

The train was hauling 2 loaded cars and 46 empty cars, including 14 residue cars. It was approximately 3,000 feet long and weighed about 2,380 tons.

The roadbed collapse occurred on a section of track (circa 1914) where an embankment, consisting of loose sand fill, stretched over muskeg between two rock slopes. The embankment was approximately 140 m long, 15 m high (to the base of the fill), 90 m wide (at the base), with side slopes of 1.5:1.0 (horizontal to vertical). A rock drainage tunnel (1.2 m wide, 1.8 m high and 75 m long) was located at the south end of the fill to allow water to flow through the

---

1 All times are EDT (Coordinated Universal Time (UTC) minus four hours) unless otherwise stated.

embankment. A beaver dam was located on the west side near the inlet of the tunnel, creating a pond on the west side of the embankment. Water was observed to be flowing freely from west to east through the tunnel.

A large amount of subgrade material slumped to the east into the muskeg. The embankment sunk at an angle of approximately 40 degrees, and shifted about 10 m to the east. The water level was noted to be 9.08 m below the top of the rail on the west side of the embankment and 11.15 m below the top of the rail on the east side. The surface of the east side of the embankment was covered with ice and snow over a 0.6 m-thick frozen crust of fill. There were no indications that the water level on the west side of the embankment had recently changed nor were there signs of erosion evident.

During the two weeks before 07 April 1997, the average daily temperature had been gradually increasing. The maximum temperature had been above freezing and the minimum daily temperature had been predominantly below freezing. On 06 April 1997, the maximum temperature was approximately 20 degrees Celsius and dropped to approximately minus 6 degrees Celsius at the time of the derailment.

The track structure consisted of 115-pound continuous welded rail, laid on double-shouldered tie plates on hardwood ties and fastened with six spikes per tie. The ballast consisted of crushed slag and the cribs were full with 16-inch shoulders. All track components were in good condition.

The Parry Sound Subdivision is a single main track. At Mile 44.8, train movements are governed by the Occupancy Control System (OCS) authorized by the Canadian Rail Operating Rules and the ABS signals, and supervised by an RTC located in Calgary, Alberta. At Mile 44.8, the maximum speed for freight trains is 50 mph.

The event recorder data indicated that the train was travelling at 41 mph when braking was initiated. Within 1.4 seconds and 84 feet of travel, recorded speed suddenly dropped to 35 mph. Recorded forward motion ceased 4 seconds and 200 feet after the brake application.

The CPR geotechnical investigation of the failure circumstances concluded that:

> . . . a combination of build up of pore pressure within the embankment as a result of a beaver dam flooding the west side of the embankment, the rapid melting of snow which was equivalent to a heavy rain fall during the two weeks that preceded the derailment and the presence of frozen soil and ice at the lower portion of the east slope face may have triggered the slide. The loose state and uniform nature of the sand fill and the dynamic loading of the embankment by the trains may have also contributed to the slide.

The TSB Engineering Branch observations (report No. LP 053/97[2]) were as follows:

1. The embankment fill was loose sand (fine and uniformly graded) with traces of some silt and gravel, possibly with cobbles and boulders at the bottom. The structure was constructed with relatively steep side slopes on a saturated peat layer (with sand and silt underlying this layer) across a swamp in a rock depression.

2. It is considered likely that the build-up of ice and the creation of a frozen (impermeable) crust on the east slope of the embankment can in part be attributed to the north-north-west alignment of the structure coupled with environmental effects.

3. On the day before the failure, the maximum temperature was near its highest close to 20 degrees Celsius, the total daily equivalent precipitation was one of the largest (10 mm), and the snow melt reached its maximum (40 cm). The temperature plunged to sub-zero values during the hours immediately before the failure.

4. The beaver dam found near the inlet of the rock tunnel on the west side of the embankment impeded water drainage. The height of the dam, coupled with the frozen (impermeable) condition of the east slope, elevated the water level on the west side, created a load imbalance and a build-up of pore pressure within the structure, causing failure.

5. It is considered likely that, if the beaver dam had not existed, the failure would not have occurred even with the high precipitation and run-off conditions that were encountered in this case.

6. The flow pattern, long run-off distances, and shallow angle of the displaced material from the slide indicate that the embankment probably failed suddenly and that it was a rapid event.

7. The estimated factor of safety for the high water condition referenced was so marginal that the presence of a train load is not considered to be a prerequisite condition for failure to occur. The passage of the previous train may or may not have initiated the failure.

8. The trajectory and scatter pattern of train wreckage indicate that the failure occurred before the subject train crossed the embankment.

The track supervisor had last inspected the track by Hi-rail on 04 April 1997 and no irregularities were observed. A track geometry car had evaluated the location on 14 March 1997 with no exceptions noted. The beaver dam air reconnaissance patrol had last assessed this area on

---

[2] This report is available upon request from the Transportation Safety Board of Canada.

21 May 1996. The beaver dam located at the failure site did not require attention at that time. Local track maintenance personnel, supervisors and managers as well as a CPR geotechnical expert were aware of the beaver dam and did not consider it a threat to roadbed stability.

Track inspection personnel are trained to identify water management problems during routine inspections and are not trained to evaluate geotechnical conditions.

Southward freight train No. 404 passed this location approximately four hours before the derailment. The train crew did not observe any irregularities at or about Mile 44.8 at that time.

Analysis

The method of train operation played no role in the derailment. There were no physical manifestations of the impending failure for track inspection forces to discern during routine track inspections. The limited range of vision available to the crew while in the curve in night-time conditions did not allow them sufficient distance to even slow their train before plunging into the depression.

The subgrade collapse is attributable to a build-up of pore pressure in a loose sand fill as a consequence of the head of water created by the beaver pond. Contributing to the head of water was the rapid melting of snow during the two weeks preceding the derailment. The frozen crust on the east slope and the differing thaw rates on the east and west embankments may have affected the failure mechanism in some way and is similar to the manner of failure of the subgrade at Mile 89.7 of the Canadian National Kinghorn Subdivision on 25 April 1994, near Orient Bay, Ontario (TSB report No. R94W0101).

The presence of loose fill in the embankment is a consequence of both the limitations of construction capabilities and the understanding of soil characteristics at the time of construction. Many sections of Canadian railways are built with such fills and require protection from unusual water events to ensure safe train operation.

While no physical manifestations of the latent subgrade weakness were evident (i.e., soft areas, track geometry problems), it is noted that the involved track maintenance employees did not view the beaver pond, which created differing water levels on the embankment, as a hazard. Since railway subgrade collapses can be traced to the effect of standing water on the subgrade, such a situation should have provoked concern.

In Centralized Traffic Control (CTC) and ABS territory, subgrade collapses often leave the track unbroken, with the signal circuits functioning as intended. Systems could be developed to identify subgrade failures and cause an immediate “stop” indication on wayside signals. Systems could also be developed to activate alarms in locomotive cabs to protect areas of OCS operation not governed by ABS signals.

The remoteness of the derailment and the darkness complicated the rescue effort. While it is recognized that the first responders took approximately 1.5 hours to reach the accident location, the response was as timely as possible.

A significant amount of diesel fuel was released and created a fire that endangered the train crew. Locomotive fuel tanks are vulnerable to impact damage and do not resist puncture to the extent possible nor does their design restrict the amount of fuel released.

Findings

1. The method of train operation played no role in the derailment.

2. The subgrade collapse is attributable to a build-up of pore pressure in loose sand fill.

3. The build-up of pore pressure was the result of the elevated water level from the beaver pond.

4. The rapid melting of snow during the two weeks preceding the derailment contributed to the elevation in water level.

5. The frozen crust and ice on the east face of the embankment may have contributed to the failure, but their role is not known.

6. The latent subgrade weakness was not evident to track maintenance employees.

7. The head of water along the embankment created by the beaver dam was not viewed as a potential hazard.

8. Subgrade collapse often leaves wayside signal systems intact, and functioning as intended.

9. Although the night-time conditions and remote location complicated the rescue effort, first response was as timely as possible.

10. Locomotive fuel tanks are prone to puncture and release of fuel at derailment.

Causes and Contributing Factors

The embankment collapse is attributable to a build-up of pore pressure in loose sand fill. The pore pressure was the result of the head of water created by a beaver pond along the west slope of the embankment. Contributing to the head of water was the rapid melting of snow during the two weeks preceding the derailment.

Safety Action

Action Taken

Detection of Destabilized Railway Roadbeds

The investigation into this occurrence (and another at Conrad, British Columbia, in March 1997 (R97V0063), where a freight train encountered a large roadbed depression and derailed, causing fatal injuries to two crew members) identified safety deficiencies with respect to the early detection of destabilized railway roadbeds. To address this concern, in an Interim Railway Safety Recommendation, the Board recommended that:

> The Department of Transport, in collaboration with the Railway Association of Canada:
>
> a) evaluate the effectiveness of current track continuity warning systems vis-à-vis roadbed failures;
>
> b) evaluate alternative methods for confirming the integrity of the roadbed during high risk periods; and
>
> c) sponsor research to develop more reliable technologies for monitoring the integrity of both the track and the roadbed.
>
> (R97-02, issued April 1997)

In response, Transport Canada met with railway industry representatives on 08 May 1997 to discuss the following track continuity warning systems and the evaluation of these alternative measures for confirming the integrity of the roadbed:

1. level beam detectors using electro-level beam sensors to detect movement;
2. time domain reflectometry using existing buried fibre-optic cable sheath to sense washout or ground slip conditions;
3. guided radar system using coaxial cables and radio frequency to detect disturbance;
4. seismic trigger (accelerometer) used to detect ground movement;
5. slump/washout detector used in conjunction with existing track circuits to initiate stop signals, RTC notification, and a broadcast message.

The railway industry has decided that the guided radar system would be the best option for detecting rail discontinuities. Test sites have been established to test aspects of system performance. The finalization of the production version is expected by the end of November 1998. This is to be followed by a verification period of 12 weeks. The system monitoring and optimization process should be completed about March 1999. Transport Canada has a direct involvement with the development of this new technology through its Transportation Development Centre.

Transport Canada is modifying its track monitoring program by requiring that culvert and drainage conditions on specific territories be included in the monitoring activities of regional inspectors.

In addition, Canadian Pacific Railway and Canadian National have cooperatively developed a training program entitled "Geotechnology for Railroaders." This program outlines the circumstances leading up to geotechnical problems with railway roadbeds and is based on recent accident case histories.

Crashworthiness of Locomotive Fuel Tanks

Crashworthiness of railway locomotive fuel tanks is now covered by the *Railway Locomotive Inspection and Safety Rules*, which came into force on 18 March 1998. These rules stipulate that fuel tanks on new locomotives must be of high impact-resistant design and have gauges protected against accidental breakage where loss of fuel would be incurred. The rules do not apply to the existing 3,000 locomotives that will remain in service on the Canadian railways for approximately another 17 years.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 15 October 1998.