Rail Accident Investigation Branch

Rail Accident Report

Derailment of a train at Croxton Level Crossing
12 September 2006

Department for Transport

Report 11/2008
May 2008

This investigation was carried out in accordance with:

- the Railway Safety Directive 2004/49/EC;
- the Railways and Transport Safety Act 2003; and
- the Railways (Accident Investigation and Reporting) Regulations 2005.

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Contents

Introduction

1 The sole purpose of a Rail Accident Investigation Branch (RAIB) investigation is to prevent future accidents and incidents and improve railway safety.

2 The RAIB does not establish blame, liability or carry out prosecutions.

3 Access was freely given by Network Rail, HoldFast Level Crossings Ltd, Rosehill Polymers Ltd, the PDM Group and 'one railway' to their staff, data and records in connection with the investigation.

4 Appendices at the rear of this report contain the following glossaries:

- acronyms and abbreviations are explained in Appendix A; and
- technical terms (shown in *italics* the first time they appear in the report) are explained in Appendix B.

5 All times in this report refer to 12 September 2006, and are converted, where necessary, to that used by the CCTV recording system at Croxton level crossing.

6 All references to left and right are given from the point of view of a person facing in the direction of travel of the derailed train, or a car, as appropriate.

Summary of the Report

Key facts about the accident

7 At 06:03 hrs on 12 September 2006 the leading bogie of the 05:33 hrs train from Norwich to Cambridge, running number 1K55, derailed at 87 mph (140 km/h); the train ran for 463 m before the driver brought it to a stop. There were no casualties.

8 The immediate cause of the derailment was the train striking a HoldFast *level crossing panel* which had been dislodged by a tanker trailer lorry less than ten minutes earlier.

9 Causal factors were:

a. the lack of support under the Thetford end of crossing panel B4 due to incorrect sleeper spacings

b. the lack of support under the Thetford end of crossing panel B4 due to the panels being less than their manufactured lengths;

c. the panels had shortened in length whilst in service;

d. the loadings at Croxton caused the panels to shorten; and

e. Network Rail (NR) not taking earlier action in response to the many reports of problems on the crossing in the five months prior to the derailment.

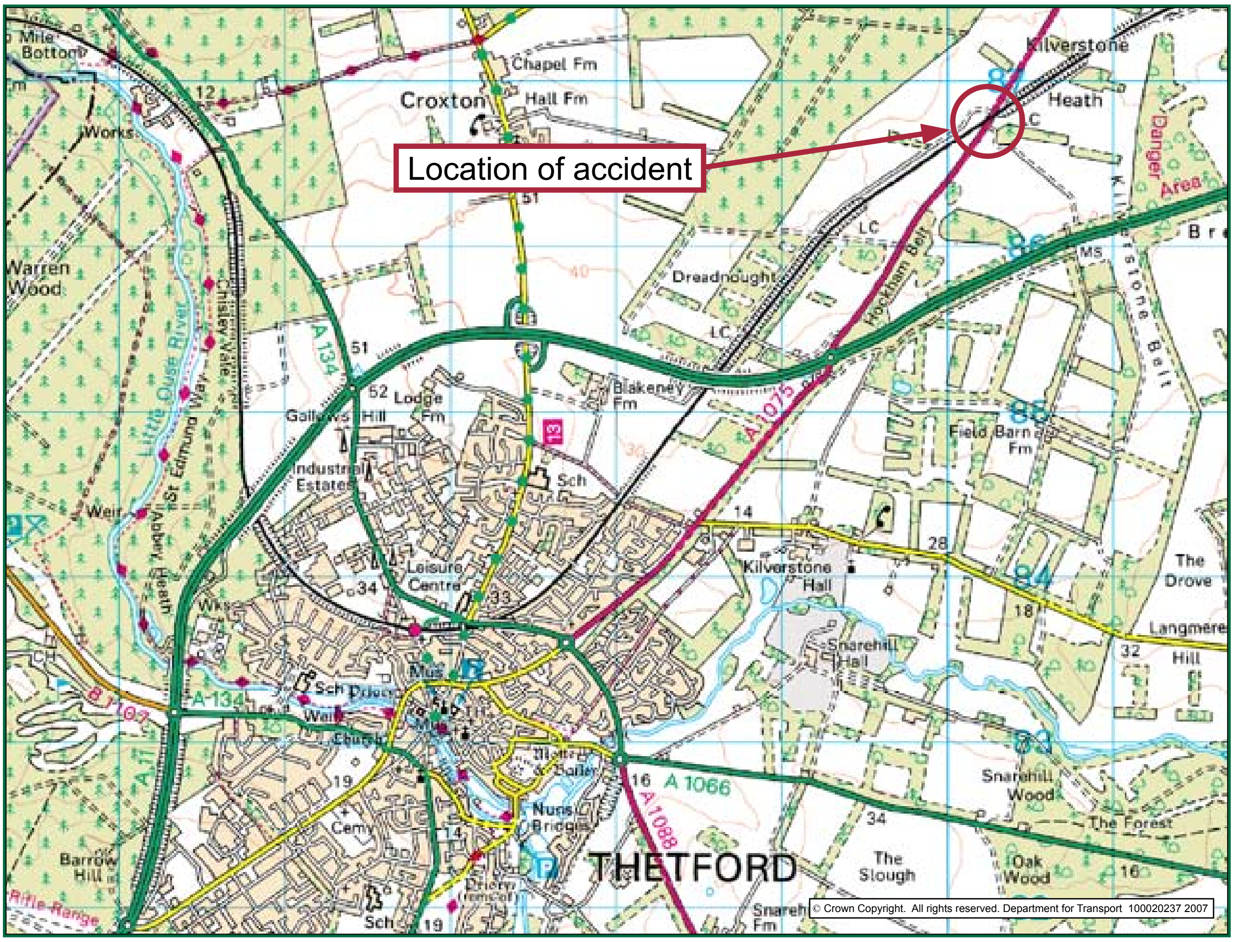


Figure 1: Extract from Ordnance Survey map showing location of accident

10 The following factors were considered to be contributory:

a. the sleepers were not maintained in their correct positions when last refitted;

b. there was a lack of understanding of the requirement to have the sleepers at the correct positions;

c. the effect of panels shortening in service was not appreciated; and

d. there was no perception of risk that the panel could come out.

11 The underlying causes were:

a. no provision of information to personnel involved with the crossing of the need to ensure correct sleeper spacings;

b. lack of specification and assurance of the duty to which level crossing panels are exposed;

c. lack of adequate control of the design and application of the HoldFast level crossing system; and

d. lack of a thorough risk assessment and monitoring of the behaviour of the product in service.

12 The RAIB has made four observations on matters that were not related to the derailment. These concern the installation and component identification of the HoldFast level crossing system, supply of the HoldFast level crossing system to rail authorities other than Network Rail, and use of Bowmac level crossing panels at Croxton.

13 Recommendations can be found in paragraph 432. They relate to the following areas:

- manufacture, installation and maintenance of HoldFast level crossing panels;
- standards and risk assessment concerning the installation of panel level crossings; and
- provision of information to staff responsible for panel level crossing systems.

The Accident

Summary of the accident

14 At 05.54 hrs on 12 September 2006 a tanker trailer lorry crossed over the Norwich to Ely railway line at Croxton *automatic half barrier level crossing* heading north-east on the A1075. In doing so the lorry dislodged a level crossing panel of the level crossing surface so that it was proud to both road and rail traffic.

15 Between 05:55 hrs and 05:59 hrs five cars crossed the level crossing heading north-east. Two of these struck the panel and one of these was diverted by it into the roadside ditch beyond the crossing. Two motorists returned to the crossing and tried to move the panel clear, but found it too heavy to lift or otherwise move.

16 At 06:03 hrs the 05:33 hrs train from Norwich to Cambridge, running number 1K55, struck the panel at 87 mph (140 km/h); the leading bogie of the train derailed.

17 The train ran for 463 m after it derailed until the driver brought it to a stop. The train remained close to the line of the track, but foul of the opposite running line (Figure 2).

18 One of the motorists mentioned above suffered whiplash injuries; there were no injuries to persons on the train.

19 The Norwich to Ely railway line was closed until 23:59 hrs on 12 September 2006 whilst investigation and repairs took place.

Figure 2: Derailed train after coming to a stop

The parties involved

20 Network Rail own, maintain and operate the railway infrastructure at Croxton, including the level crossing panels, the level crossing barriers and their control equipment. Prior to 2002 ownership and operation of the infrastructure rested with Railtrack, and prior to 1994 with British Railways (BR).

21 From 1996 to 2004 maintenance of the track and the level crossing at Croxton was carried out by contract, but major decisions with regard to renewal of the crossing were taken by Railtrack / Network Rail.

22 London Eastern Railways Ltd, trading as 'one' railways operated train 1K55.

23 HoldFast Level Crossings Ltd (HoldFast) designed and supplied the panels used in the *up* and *down four foot* at Croxton.

24 Rosehill Polymers Ltd manufactured the level crossing panels.

25 PDM Group owned the trailer of the lorry that crossed the line at 05:54 hrs.

Location

26 The railway line from Norwich to Ely is a two track line, mainly carrying passenger traffic between Norwich and various destinations to the west, as far as Liverpool. The *line speed*, and the permissible speed at Croxton, is 90 mph (145 km/h).

27 The line is generally flat, running across the East Anglian fen land. As a result, the line was built with many level crossings over roads. Most of these level crossings remain in use.

28 At Croxton, between Thetford and Attleborough, the railway line crosses the A1075 road from Thetford to East Dereham in an area known locally as Kilverstone Heath. The road is 'de-restricted', meaning that it is subject to the national speed limit for a single carriageway road of 60 mph (97 km/h).

29 Both the road and railway are approximately in the middle of mile long straight sections at the Croxton level crossing, and both run approximately south-west to north-east. The angle of intersection between the road and the railway at the crossing is 27 degrees (where a road crossing the railway perpendicularly would be 90 degrees).

30 In view of the straight and generally flat nature of the road, traffic crosses the railway at, or even above, the national speed limit.

External circumstances

31 At around 06:00 hrs on 12 September 2006 the weather was light drizzle and the ground was damp due to either earlier light rain or dew. Visibility was good, albeit through light mist. However, it was not fully light, dawn being at 05:51 hrs.

Train(s)/rail equipment

32 The derailed train, running number 1K55, was the 05:33 hrs from Norwich to Cambridge and it consisted of a two carriage class 170 *diesel multiple unit*. It was maintained as laid down in its schedules, no related technical faults were found with it after the incident, and it was being driven in accordance with the speed restrictions for the line.

33 The level crossing at Croxton has been in place since the Norwich to Ely line was built in the 19th century. For many years it was operated by a signalman working a set of gates, but in 1967 it was converted to an automatic half barrier crossing, as part of BR's general programme of conversion of manned crossings to unmanned types.

34 The crossing has been subject to misuse, with road vehicles zig-zagging the barriers, and as a result Network Rail fitted it with a closed circuit television recorder (CCTV) with time logging, so as to be able to record details of misuse by road drivers. The crossing was also fitted with a data logger so as to be able to demonstrate whether the crossing was working correctly, should that be necessary. The crossing was operating as specified, and without any faults, on the morning of 12 September 2006.

35 The crossing was also equipped with two telephones, one on each off-side road approach, which connected directly with the signaller at Thetford. Both telephones were tested and were working correctly on the morning of 12 September 2006.

Events preceding the accident

36 BR upgraded the crossing surface from time to time. It is not known what surface was installed historically, but by 1993 the crossing surface had been converted to a panel construction. The panels used were made of concrete, and known as Bowmac panels.

37 Panel level crossings are used so that the panels can be removed to allow maintenance of the track. The Bowmac design of panel was the standard product used by BR for most of the 1970s and 1980s.

38 Bowmac panels for use in the four foot are single panels that span the whole width of the four foot and locate on the *webs* and *feet* of the running rails, with clearance between their undersides and the sleepers. Each panel is nominally 600 mm long. This longitudinal dimension is set by the standard spacing between centre lines of adjacent concrete sleepers so that the ends of each panel are mid-way between sleepers.

39 Bowmac panels for use in the *six foot* and *cess* are nominally 1200 mm long. They are mounted on the rail web and foot on one side, and on a concrete edge beam on the other. The longitudinal dimension of these outer panels is a multiple of 600 mm to match the centre line span between three sleepers above which they lay.

40 BR and Railtrack found the performance of the Bowmac crossing surface at Croxton to be unsatisfactory over a period of time. The A1075 takes heavy traffic, with many cars and lorries using it, and the combination of the high speeds (paragraph 30), the vertical profile, (paragraph 261) and the acute angle of the crossing (paragraph 29) was particularly aggressive for the level crossing surface.

41 By the 1990s the crossing was subject to constant attention. Between 15 October 1993 and 14 October 2000 the local maintainer was able to show thirteen reports referring to loose or broken panels in the crossing. Staff who worked in the area stated that they had to replace panels every few months.

42 Local Railtrack management decided, after discussions with HoldFast, to install HoldFast panels in the four foot at Croxton, but to retain the Bowmac panels for the outer panels. Witness evidence indicates that this decision was driven by the higher damage rate of the four foot panels relative to those in the cess and six foot and in consideration of the cost of replacing the edge beams where the six foot panels meet the road (Figure 3).

43 The HoldFast level crossing system consists of rubber panels that sit directly on top of the sleepers. The panels are nominally 1800 mm long; this being a multiple of the 600 mm sleeper centre line spacing, allowing each panel to lay on four sleepers.

44 The HoldFast four foot panels are half the width of the track *gauge*, with two panels being used to fill across the four foot. These panels can be either opposite each other, or staggered by a multiple of 600 mm (ie offset by one or more sleeper intervals) in either direction, depending on the skew of the crossing.

45 HoldFast had supplied earlier designs of panels for other level crossing from 1987 onwards. From this date to the fitting of the HoldFast panels at Croxton, the design had changed (paragraph 121). By the time the panels were fitted at Croxton Railtrack had given the HoldFast level crossing system product acceptance. There were conditions applied to the approval (paragraphs 141 to 143).

46 Railtrack installed HoldFast panels in the four foot of the down line at Croxton during July or August of 2000. They ordered a second delivery of panels for the four foot of the up line, which they fitted over the weekend of 22/23 August 2001. They installed the panels with a stagger of 600 mm on the down line and 1200 mm on the up line, with the most north-easterly and south-westerly panels in each line leading by these respective amounts (Figure 3).

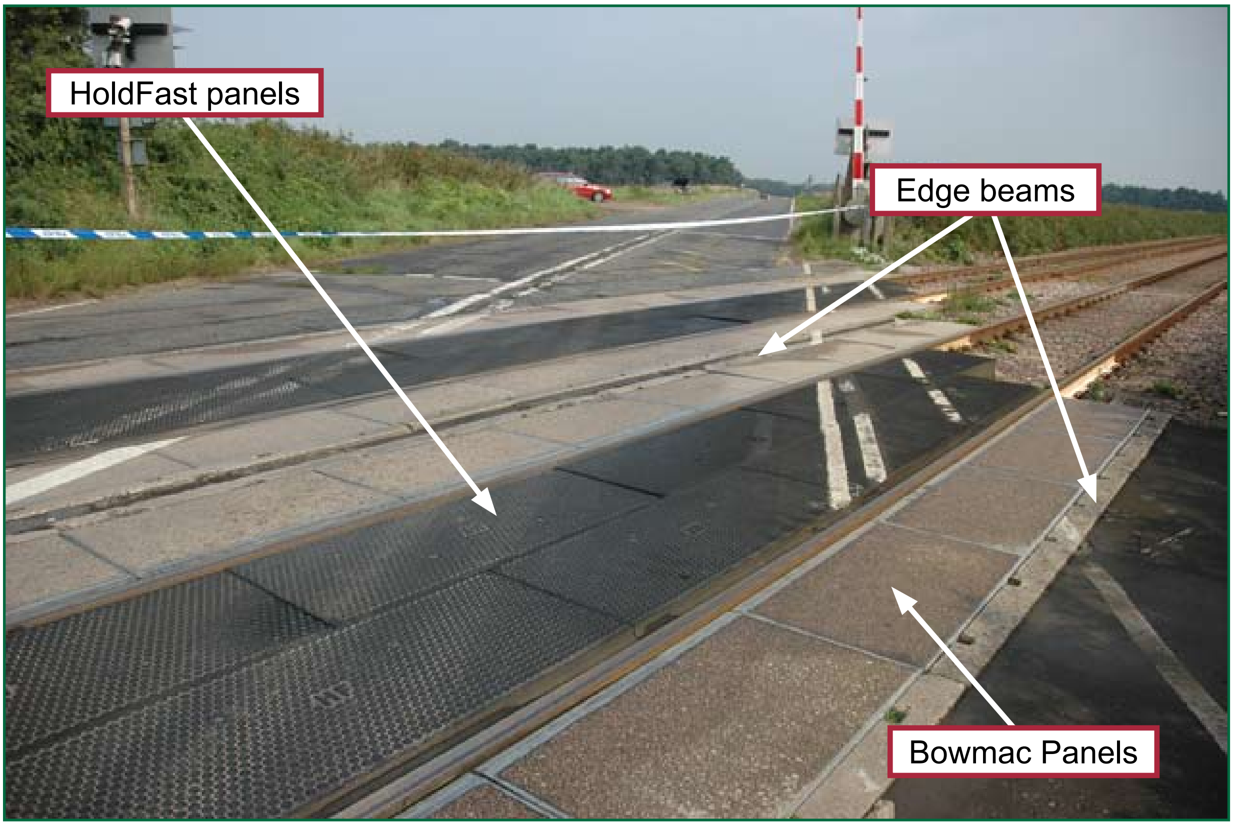


Figure 3: Croxton level crossing looking in a north-easterly direction

47 Whilst the RAIB has not found a full record of the maintenance of the crossing after the HoldFast panels were installed, Network Rail's records show that eight of the twenty six four foot panels in the down line were renewed in November 2004. This replacement was carried out following a car crash and fire on the crossing in October 2004. The RAIB has no evidence that these events were related to the derailment.

48 Between November 2004 and February 2006, Network Rail's records indicate that their staff identified various crossing repairs, including road surface repairs and the refitting of the Bowmac panel end restraints. Network Rail had also identified Croxton for an upgrade under a capital expenditure plan during this time, but had not created a specification of work. It appears that they undertook some, but not all, of the repairs identified, as directed by the level crossing supervisor responsible for Croxton.

49 During this period the records also indicate that Network Rail planned work to address the levels of two six foot edge beams which were reported to have dropped. The level crossing supervisor identified this work in 2004 and the level crossing assistant re-prioritised it several times, with the planned date at the time of the accident being October 2006.

50 In June 2005 Network Rail lifted the crossing surface for renewal of the rails through the crossing, renewing the up line rails on 18 June 2005 and the down line rails on 25 June 2005.

51 Network Rail *tamped* the down line of the crossing on 21 August 2005, which would again have required the removal of all panels on that line.

52 At some time between August 2005 and early 2006, and possibly related to the tamping in August 2005 Network Rail carried out track maintenance to correct *wet beds* on the down line at the crossing. During this work the staff carrying out the work accidentally lifted a concrete edge beam on the Thetford end of the down line. This was not corrected at the time and resulted in the edges of two of the six foot Bowmac panels being higher than the rest of the crossing surface (Figure 4).

Figure 4: Raised six foot Bowmac edge beams (circled)

53 A Network Rail Mobile Operations Manager (MOM) identified this during a regular inspection on 30 April 2006 and reported it to the Network Rail infrastructure fault control (IFC) at Cambridge, where it was entered into the Network Rail fault reporting system known as FMS.

54 In April 2006 Network Rail revised their method of inspecting level crossings, creating a dedicated level crossing team (paragraph 231).

55 On 27 June 2006 permanent way staff recorded a fault via the IFC onto the FMS system, following an inspection around the Croxton area. The fault was reported as ‘Rubber Bowmac on both roads (meaning lines in this case) has dropped inwards’. The IFC notified the level crossing supervisor, who dispatched an inspector that same afternoon to examine the crossing for a loose panel. The inspector found nothing untoward and reported back to the level crossing supervisor, who closed the fault with the IFC.

56 On the 7 July 2006, the same inspector undertook a planned crossing inspection and reported that there were uneven footpath beams, ie the concrete edge beam (paragraph 52) and that there were ‘very uneven Bowmacs with loose panels’. He gave a priority to these two defects that required attention within seven days.

57 At 17:05 hrs and then at 17:09 hrs on 7 August 2006, Norfolk Constabulary received reports from two different members of the public. One of the reports stated that the surface of the crossing between the two tracks ‘has risen about four inches above the railway track almost like a ramp’. It also mentioned that ‘cars are swerving to go around this’. The reports were passed on to IFC. Given the times of the logged telephone calls, these two reports are very likely to be related to the same event.

58 Network Rail responded by dispatching a MOM to inspect the crossing.

59 At 20:23 hrs on 8 August 2006 the police received a report from another member of the public reporting ‘material like asphalt sticking up from the track’. This report was again passed on to Network Rail IFC.

60 Network Rail responded by dispatching a MOM (the same one as the previous day) to inspect the crossing. During both inspections he found no raised panels. However, he noticed the raised six foot concrete edge beam and, considering it to be a trip hazard to pedestrians, verbally informed the level crossing supervisor. The level crossing supervisor responded that he was aware of it.

61 On 18 August 2006 a verbal report attributed to the route manager was received by the IFC who recorded that ‘one side of the rubber Bowmac has come off and is sticking in the air’. IFC recorded a fault in the FMS system, and notified the level crossing assistant.

62 As a result, on 23 August the level crossing supervisor sent members of the level crossing team to visit the crossing. They noticed that a panel was rising a few inches when lorries travelled over it, and undertook a non-recognised repair. They inserted some timber strips, about 25 mm in thickness, between panel B4 and panels A4 and A5 of the crossing (Figure 5). They did this by forcing open a gap between the panels and hammering the timber down into the gap created. The team leader reported the finding of the loose panel, and the repair, to the level crossing supervisor and suggested that a road closure should be obtained to undertake a full inspection.

63 Following this repair the level crossing supervisor instructed two of his team to inspect it regularly on their way from home to their place of work. Verbal reports were given to the level crossing supervisor that, although the panel seemed to be moving less than it had done prior to the repair, it needed a road closure to correct. During these inspections the road was in use, requiring the two team members to adopt a safe position that made it impossible to tell whether the timber strips were still in place. These inspections continued up to, and including, 11 September 2006.

64 At 08:27 hrs on 8 September 2006 the police received a report from another member of the public that at Croxton there was a ‘concrete block sticking out of the track and that it is possible that a train may hit it’. They passed the report on to Network Rail IFC.

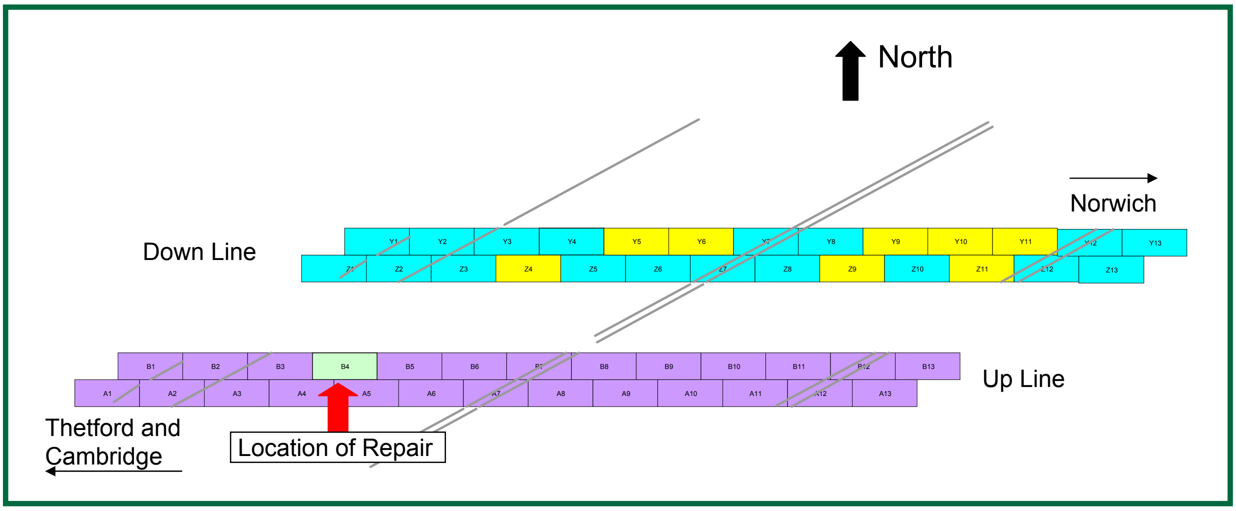


Figure 5: Position of panel B4 and region of repair on 23 August 2006 (arrowed)

65 Network Rail reported back to the police that trains would be approaching the crossing at caution, but not stopped, and that an engineer was to be dispatched to site. Police who arrived at the crossing reported again to Network Rail Fault Control that the block was not concrete and that 'it looks like this has been like this for some time'. Network Rail confirmed that an engineer would still attend.

66 The same MOM who had attended on both 7 and 8 August 2006 visited the crossing on 8 September 2006 around 09:30 hrs. He inspected the crossing and reported that he had found no loose panels. He noted on this visit that a tarmacadam repair had been made to the raised six foot concrete edge beam (paragraph 52) to reduce the tripping hazard it presented to pedestrians using the footpath. However, the MOM was concerned that this had not been fully attended to following his previous report. He reported the fault to IFC to record it within the FMS system. IFC notified the fault to the level crossing supervisor that morning. The level crossing supervisor telephoned the MOM and said that he would instruct some of his team to look at the crossing on their way to work.

67 Around mid-morning the local operations manager and the area level crossing manager visited the crossing as a result of the MOM's concern. They noted the raised six foot concrete edge beam and told the MOM that this was only a temporary repair. Nothing was reported about the condition of the crossing panels.

68 Around midday on 8 September 2006 the level crossing assistant instructed one of the team working in the area to take some photographs of the raised six foot concrete edge beam. Whilst at the crossing the team member noticed that one of the HoldFast panels in the four foot of the up line 'had dropped on the centre line of the panels'. He then telephoned the level crossing supervisor to report this.

69 At 08:36 hrs on 11 September a member of the public reported to the police that a 'large lump of rubber was stuck up from the centre of the track.' The police passed this on to Network Rail IFC, who in turn notified the level crossing supervisor.

70 The level crossing supervisor instructed the two members of the level crossing team who had been undertaking the regular inspections since the repair with the timber strips to inspect the crossing. Although they found that the panel was not in an elevated position, it appeared to them that the timber strips were no longer in position as the panel was lifting as it had done before the repair on the 23 August 2006.

71 At around 10:30 hrs on 11 September one of the team contacted the level crossing supervisor and stated that the timber strips were no longer in position. The RAIB has conflicting evidence and cannot say for certain whether he advised the supervisor that the crossing needed attention that night.

72 At 13:44 hrs the level crossing supervisor began to arrange for repair work during the week beginning 18 September 2006. This was recorded within the FMS system as a response to the fault report raised on 8 September 2006, although he had not arranged a road closure by the time of the accident.

73 At 15:08 hrs on 11 September the Police received a report from another member of the public about a 'large piece of foam that has lifted up'. The report also mentioned that it was on the road area of the crossing 'so possibly nothing to do with the railways and just debris'. The police attended the crossing and found no obstruction to the road; they did not contact Network Rail.

Events during the accident

74 The times in the following sequence are mainly recorded from the CCTV log of the crossing. All times in this section refer to 12 September 2006. All road vehicle movements referred to are heading north-east over the crossing unless stated otherwise.

75 At 05:33 hrs train 1K55 left Norwich en route to Ely. Norwich is 27.5 miles (44 km) from Croxton level crossing.

76 At 05:51:55 hrs a car passed over Croxton level crossing without problem.

77 At 05:54:34 hrs a tanker trailer lorry passed over the crossing (Figure 6). Examination of the CCTV image taken at 05:54:38 hrs shows that an object was present in the four foot of the up line, which had not been visible prior to the lorry's passage.

78 At 05:54:57 hrs a car passed over the level crossing. It struck the object and was lifted up on its nearside to an angle of around 30 degrees (Figure 7). The driver lost control of the car and it spun and came to a halt in the nearside road ditch some tens of metres north of the crossing, facing south-west. It was subsequently found that as a result of the collision with the object, two tyres had been punctured.

79 At 05:55:05 hrs a further car passed over the crossing. The driver swerved to the right to avoid the object.

80 At 05:55:30 hrs the driver of the first car that had hit the object and been forced to a stop walked to the crossing to examine the object that his car had hit. The object was a dislodged HoldFast panel which he attempted to move. During the time he was at the crossing a car passed over the crossing with its brake lights illuminated, but did not hit the panel.

81 At 05:56:00 hrs the car driver left the crossing and walked back to his car to retrieve his mobile phone. He then made an emergency phone call on his mobile phone and was transferred to Norfolk Constabulary control room.

82 At approximately 05:57 hrs train 1K55 passed Harling Road signal box, 5 miles (8 km) to the east of Croxton. The signals here were the last ones that could have been used to stop the train, although it might have been possible to stop or slow the train by making a radio broadcast to the driver had a message reached a signaller within the next few minutes.

Figure 6: CCTV image of tanker trailer lorry passing over the crossing

Figure 7: CCTV image of car striking dislodged HoldFast panel

83 At 05:57:37 hrs a 4x4 vehicle passed over the crossing. The vehicle struck the panel and was lifted up on its nearside by some ten degrees. This vehicle slowed down close to the car that had spun off the road before continuing its journey.

84 At 05:59:29 hrs a van passed over the crossing, again with its brake lights illuminated, but without incident.

85 At 06:01:42 hrs the van driver who had most recently travelled over the crossing, entered the level crossing and attempted to move the panel.

86 At 06:02:08 hrs both men left the crossing area; the driver of the first car that had hit the panel was still in communication with the police.

87 Neither driver attempted to use the telephones at the crossing that connected directly to the signaller at Thetford.

88 At 06:02:49 hrs train 1K55 activated the level crossing control sequence as it approached the crossing, and the yellow lights on the crossing illuminated.

89 At 06:03:23 hrs the train entered the crossing (Figure 8) and struck the dislodged panel. The collision derailed the leading bogie, but the rest of the train remained on the track. The train driver applied the emergency brake after realising that the train was running derailed, and the train ran 463 m before coming to a halt (Figure 2).

Figure 8: CCTV image of 1K55 approaching Croxton level crossing

90 The dislodged panel was found in the four foot of the down line 83 m towards Thetford from the point of impact (Figure 9).

91 The dislodged panel had come from the six foot side of the up line four foot, and was the fourth panel from the Thetford end of the crossing. This panel is referred to as panel B4 (Figure 5).

Figure 9: Dislodged HoldFast panel looking towards Croxton level crossing

Consequences of the accident

92 The driver of one of the cars (paragraph 78) suffered whiplash injuries when his car was diverted off the road following the impact with the displaced crossing panel.

93 In addition to the train driver there were four other staff and eight passengers on the train; none were injured in the accident. However, the train was running, at speed, foul of the other line; if another train had been passing there would have been more serious results.

94 The damage to the train was relatively minor, and it was capable of being towed at 30 mph once re-railed.

95 The car referred to in paragraph 78 was written off by the driver's insurer as a result of the damage it sustained. None of the other road vehicles were at the scene when the police arrived.

96 There was limited railway infrastructure damage. Most of the sleepers between Croxton level crossing and the point where the train came to rest were grooved by the running of the train's derailed wheels, and many *rail clips* were knocked out. There were two rail fractures. The fractured rails and some of the sleepers were replaced.

97 The railway line from Norwich to Thetford was closed from the time of the accident until 23:59 hrs on 12 September 2006. The A1075 was reopened to road traffic during 13 September 2006.

Events following the accident

98 The Norfolk Constabulary despatched a considerable team of officers to the level crossing. The first officers arrived at 06:10 hrs, and by 06:17 hrs had established that there were no casualties on the train. The Fire and Rescue Service arrived at approximately 06:25 hrs.

99 Officers of the British Transport Police attended the site shortly afterwards, taking over control from Norfolk Constabulary and holding the site until the arrival of the RAIB's inspectors.

100 The train driver applied *track circuit clips* to the up line, and telephoned Thetford signal box to inform the signaller of the collision and derailment. The Thetford signaller informed the signaller at Harling Road at 06:10 hrs, after which time the line was closed to traffic.

101 The passengers and crew walked from the derailed train, and continued their journeys by road. This was facilitated by 'one' railways.

102 Network Rail tested the level crossing operating mechanism and telephones under the supervision of the RAIB, and found them both to be operating satisfactorily.

103 Following initial examination by the RAIB the train was re-railed and removed to Norwich Crown Point depot for further examination and repairs.

104 Network Rail immediately installed one new HoldFast panel to permit the re-opening of the A1075 and the railway. In addition they made a temporary repair by adding timber sleepers under the panels between the concrete sleepers. They also added end restraints.

105 Thereafter they maintained a continuous presence on site to monitor the crossing until 30 September 2006, when the level crossing was replaced with new rails, sleepers and ballast. The complete crossing surface was replaced with Bowmac panels.

106 The RAIB was present during the installation of the new crossing surface. Measurements were taken of sleeper intervals and the panels and base plates were secured for further examination.

107 RAIB issued an *Urgent Safety Advice* (USA) on 8 November 2006. This was sent to all UK users of rubber level crossing panels, as well as safety authorities in Europe via the European Rail Agency (ERA). This alerted users to the visible signs that may be present that would indicate a possibility of panels becoming dislodged. The USA is included as Appendix D to this report.

The Investigation

Investigation remit

108 The RAIB's remit was:

- to understand why the level crossing had been converted from Bowmac to HoldFast panels;
- to understand how it had been subsequently maintained;
- to understand how level crossing panel B4 became dislodged so as to cause the derailment; and
- to consider if there were transferable lessons from this incident to other level crossings in the UK and overseas.

Sources of evidence

109 The RAIB used the following sources of evidence:

- witness statements;
- CCTV recordings;
- supplier and manufacturer drawings, specifications and product acceptance documents;
- examination of the derailed train, the lorry tractor involved, a tanker trailer of the type involved, the track and the level crossing;
- level crossing records;
- Norfolk Constabulary records of reported incidents at the crossing;
- data logs from the derailed train and the level crossing control system;
- a specially commissioned report from the Rubber and Plastics Research Association (RAPRA); and
- measurements of HoldFast panels on other level crossings.

Key Information

The derailment of the train

110 Witness and CCTV evidence confirm that the train was derailed by striking the level crossing panel B4.

111 Evidence from the witnesses, CCTV pictures and examination of the damage to the dislodged panel and the train all indicate that the panel was lying across the six foot rail of the up line, with one end remaining in or over the gap left by its displacement, and the other elevated over the six foot Bowmac panels of the crossing when the train hit it (Figure 10).

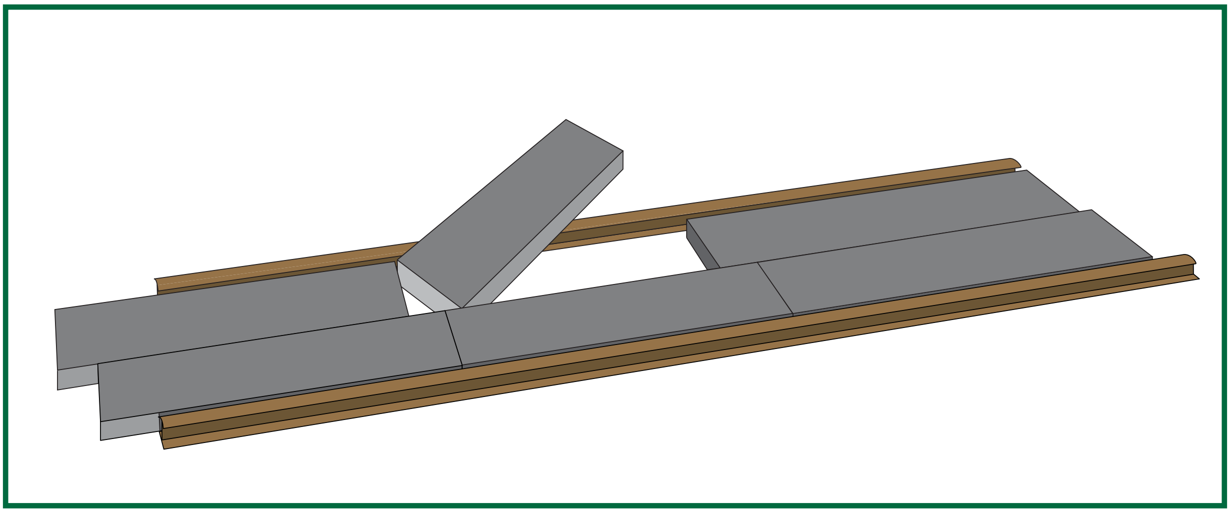


Figure 10: Likely position of panel B4 immediately before train impact

112 The most likely mechanism of derailment was that the bogie *lifeguard* of the leading six foot side wheel on the train and its mountings struck the dislodged panel. This lifted the wheel so that it was partially unloaded. The collision also created a yaw force, forcing the partially unloaded wheel to the right in the direction of travel. The partially unloaded right-hand wheel climbed the head of the rail, mounting onto it 6.1 m after the initial impact; the wheel then ran on the rail head until it derailed into the six foot after a further 6 m. The yaw angle of the bogie was sufficient to cause the wheels on the second axle to run into derailment.

113 Although the wheels were partially unloaded, marks on the rail head show that they did not lose contact with the rail at any time, indicating that total unloading of the wheels did not take place.

114 The lifeguard was distorted backwards towards the body of the train (Figure 11) and prevented the panel from passing under the leading right-hand wheel. It created a deep groove in the dislodged panel (Figure 12), and the lifeguard's mounting bolts and its upper plate also made contact with the panel. These impacts imparted considerable kinetic energy to the panel, so that it was moved towards Thetford by 83 m.

115 The derailed train veered to the right as it moved away from the crossing, towards and then foul of the up line. There was a considerable pile of ballast in the six foot in the path through which it ran derailed, and this helped it to remain upright and assisted retardation. In addition the back faces of the cess-side derailed wheels ran up against the six foot rail, preventing further deviation of the train from the line of the track.

Figure 11: Distorted lifeguard on leading right-hand (six foot) side of derailed train

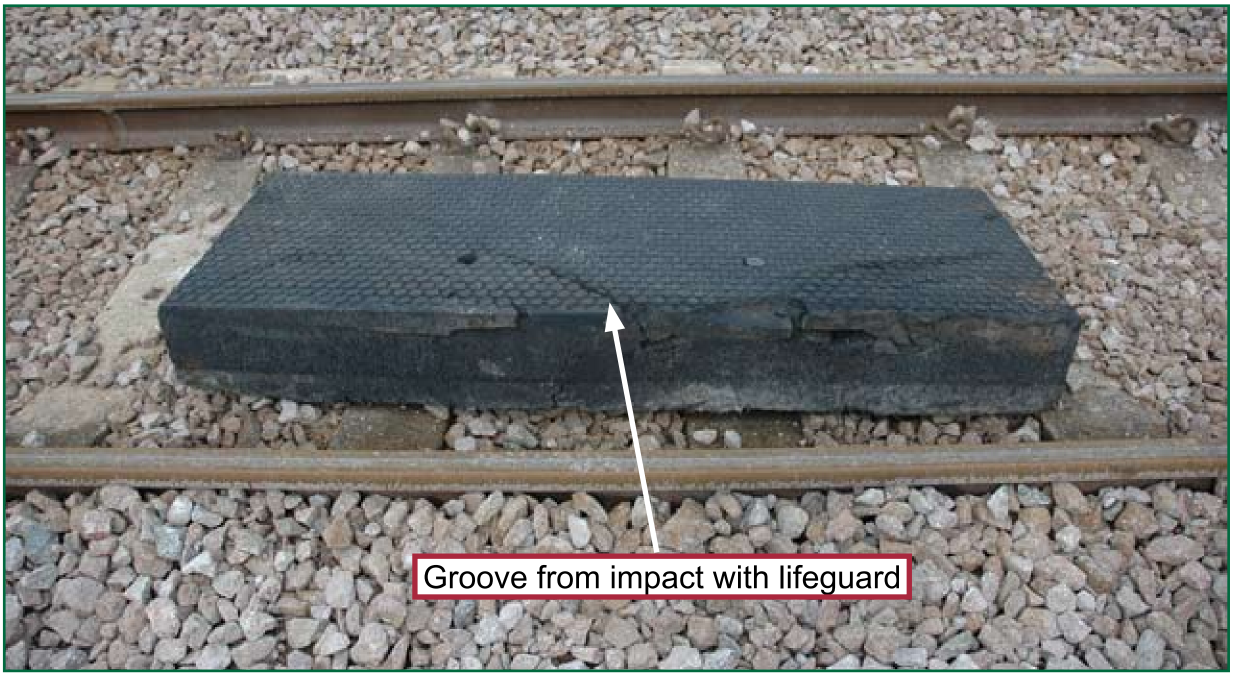


Figure 12: Impact marks to panel B4

The HoldFast level crossing system

Acceptance of design for use on Railtrack / Network Rail system

116 The Railtrack product acceptance process involved ensuring that any product proposed for use on the infrastructure did not introduce unacceptable risks and met the requirements of any relevant specifications.

117 The specification governing level crossing systems was RT/CE/S/040 – Level Crossing Surface Systems, Issue 1. This was authorised in 1997, and remained valid at the time of approval of the HoldFast level crossing system, and during its installation at Croxton. Before this time, however, the surface of Croxton level crossing had been converted to Bowmac panels.

118 Railtrack created this specification for public vehicular level crossing surface systems in order to ensure that manufactured level crossing surface systems were fit for purpose and had an adequate life expectancy. Road traffic loading was defined from an existing British Standard for bridges and the crossing's skid resistance was by reference to an existing guidance for highways works.

119 RT/CE/S/040 defined the normal operating conditions for a panel level crossing:

- the system should be capable of performing with an acute angle between the road and the railway of between 60 and 90 degrees;
- the gradient on either side of the crossing should be shallower than 1 in 20 for at least 100 m either side of the crossing; and
- traffic should be less than 2 500 commercial vehicles per lane per day.

120 RT/CE/S/040 did not state what should happen if 'normal operating conditions' did not apply, and did not define 'a commercial vehicle'.

<u>History of design and supply to the UK</u>

121 The HoldFast level crossing system fitted at Croxton was derived from a North American product known as OMNI. OMNI crossing panels were supplied into the UK by HoldFast following a trial installation in 1987 conducted by BR at Inverness. A timeline of OMNI and HoldFast developments and the fitment of panels at Croxton level crossing is given in Appendix F.

122 Unlike the Bowmac system, in which the four foot panels are supported on the rail webs and feet, the HoldFast/OMNI panels were designed to sit on the sleepers with their vertical support dependent upon this.

123 The original North American OMNI panels were manufactured from rubber that was cast within moulds using a high temperatures process. The panels were designed for installation upon timber sleepers at 450 mm centres. The first OMNI crossings supplied to the UK were fitted to timber sleepers. It has not been possible for the RAIB to establish at what centres the sleepers were installed for the initial trials, but the eventual normal service sleeper spacing was set at 600 mm by the specification in order to give access for tamping the ballast beds. The RAIB has not been able to establish whether any assessment of the effect of the increase in sleeper spacing was undertaken, other than unmonitored in-service experience.

124 HoldFast's installation instructions, submitted at the time of their application for product acceptance in 1999, state that "If a particular and exceptional level crossing takes a high level of fast and heavy traffic it may be considered worthwhile placing sleepers at 450 mm centres'.

125 OMNI subsequently designed a base plate system for use with concrete sleepers. This design developed into two further versions over subsequent years, in order to overcome problems that were found through in-service experience with the panels in Europe. The detail of these changes can be found in paragraph 164.

126 Many panels were supplied to the UK and worldwide until OMNI ceased supply in January 1997. This followed quality issues with the rubber bonding process after changing the method of manufacture.

127 HoldFast then began development work with Rosehill Polymers Ltd in the UK for the production of panels. This was a different method of manufacture to the original OMNI panels and used polyurethane binders as a means of bonding the granulated recycled rubber together.

128 Rosehill Polymers undertook some tests of the material during this development, one of which was a test of the material's permanent set. Permanent set is the permanent loss in length following application and removal of a load. It is usual that rubber materials both deform under load and that permanent loss in length occurs. The test conducted was a standard industry test that is used for comparisons between different rubbers. The test does not predict the performance of the rubber under the actual conditions in service. The test, conducted at a temperature of 70 degrees Celsius, yielded a permanent set of 10 % of the original sample's length.

129 Rosehill Polymers did not consider the effects of any permanent set on the performance of the product in its intended service. However, they made the panels slightly oversize to allow for a small amount of shrinkage following their removal from the moulds. Both this, and regular checking of the dimensions of finished panels and measurements of process parameters, enabled Rosehill Polymers to despatch panels with a tolerance of +/- 10 mm from the nominal length of 1800 mm.

130 There were a range of panel cross-sectional profiles available, the selection of which depended upon the type of sleeper and rail for its intended application. The panels used at Croxton were designated 00324, identifying them suitable for use with F27S sleepers and BS 113A FB rail section. This number related to the mould design in which the panels were made and therefore all the panels were of the correct type for the sleeper and rail type fitted at Croxton.

131 HoldFast applied for Railtrack product acceptance in July 1998. At this time OMNI had ceased supply and Rosehill Polymers were developing their manufacturing process for the panels. The OMNI crossing system had been given '*grandfather rights*' on account of its service experience. Railtrack informed HoldFast that acceptance for service trials could be granted to the new panels if evidence was presented that they were the same as the OMNI panels in respect of their performance.

132 No product acceptance application form was available to the RAIB, although correspondence from Railtrack to HoldFast indicates that Railtrack requested HoldFast to complete this form and provide evidence of compliance to the specification in RT/CE/S/040.

133 The records available from Network Rail indicate that Railtrack raised issues concerning the skid resistance of the panels' surfaces and Rosehill Polymers made changes to the moulded patterns on the surface to address this. Tests were also conducted to confirm the panels' electrical insulation properties in order to maintain the continuity of *track circuits*.

134 In March 1999 Railtrack undertook a product acceptance review of the HoldFast level crossing system, and it was rejected based upon the lack of evidence that it conformed to the specification requirement of deflection under load.

135 The specification required a maximum deflection of 10 mm under a defined static load. The intent of this was to limit the degree of road traffic wheel contact with the heads of the rails; the load criteria having originated from standards associated with concrete structures, especially roads and bridges.

136 HoldFast and Rosehill Polymers undertook static deflection tests and reported they had achieved a deflection of 13.5 mm under the specified load. Railtrack considered this acceptable given that this level of load would be seen infrequently.

137 HoldFast supplied Railtrack with a maintenance manual as part of the requirements of the specification. This is discussed in detail in paragraph 252.

138 There was a requirement within the specification for level crossing systems to have a minimum service life of fifteen years.

139 Although a temporary non-compliance was approved by Railtrack on 2 November 1998 in respect of the difficulty of demonstrating that the skid resistance would be sufficient during the required service life, it was still required that evidence be provided that this fifteen year service life was achievable.

140 Railtrack documented that this requirement for service life had been satisfied by HoldFast's general guarantees supplied to them in written correspondence from HoldFast. The guarantee covered wear, protectiveness to rail fixings, dynamic load resistance and chemical resistance. The guarantee period was stated as five years for 'fair use' from the date of installation. The term 'fair use' was neither defined nor qualified. HoldFast also stated that they would welcome discussions prior to ordering for 'exceptional conditions'.

Conditions on use of HoldFast system

141 Railtrack approved the HoldFast system for use on 24 May 1999. The certificate of acceptance was signed on behalf of the Professional Head of Track Engineering.

142 The certificate allowed the use of the HoldFast system in the following circumstances:

a. new public vehicular crossings;

b. as replacement for entire level crossing surface systems on an existing public vehicular level crossing; and

c. for new / replacement private vehicular, footpath or bridleway crossings.

143 The certificate also required that:

a. any change to the product is liable to a demonstration that risk arising from the change has been assessed and is negligible;

b. a change in product configuration shall be notified to Railtrack; and

c. HoldFast supply a user manual with each complete crossing.

HoldFast applications and development of the design

144 HoldFast and Rosehill Polymers also supplied panels outside the UK, to European countries and others.

HoldFast panel types

145 Applications for HoldFast panels, other than to highway crossings, included farm level crossings, pedestrian crossings and track access points (TAP). TAPs are strategic locations on the rail network that are used by rail plant and equipment for accessing the railway. The use of TAP panels provided a flat and level platform for the mounting and dismounting of road/rail equipment.

Figure 13: Continuous relief area on underside of panel B4

146 The Railtrack specification and certificate of acceptance did not include application to TAPs; Network Rail granted HoldFast TAP panels, still branded as 00324 (paragraph 161), acceptance for use in TAP applications in February 2005, although both Railtrack and Network Rail used HoldFast TAP panels widely prior to that date.

<u>*Panel relief*</u>

147 On the underside close to the rail foot, there is an arch-shaped recess known as the relief (Figure 13). This recess is required in order to give clearance for the rail clips.

148 Two styles of relief were available:

- Continuous relief, where the relief was for the full length of the panel (Figure 13).
- Discontinuous relief, where the relief was restricted to short lengths over the length of the panel. The areas that were not relieved were solid and integral with the rest of the panel (Figure 14).

149 The relief style was altered for panel manufacture by the use of inserts with the mould.

150 The use of continuous relief gave the installer the time and cost benefits of not having to ensure that the sleepers were at such regular intervals. TAP panels had continuous relief .

151 With discontinuous relief, although it was possible to install the panels without having their ends over a sleeper (as there is adequate clearance between the rail clips and the sides of the pockets to allow this) the panel had to be placed so that the 'pocket' was situated above the rail clip.

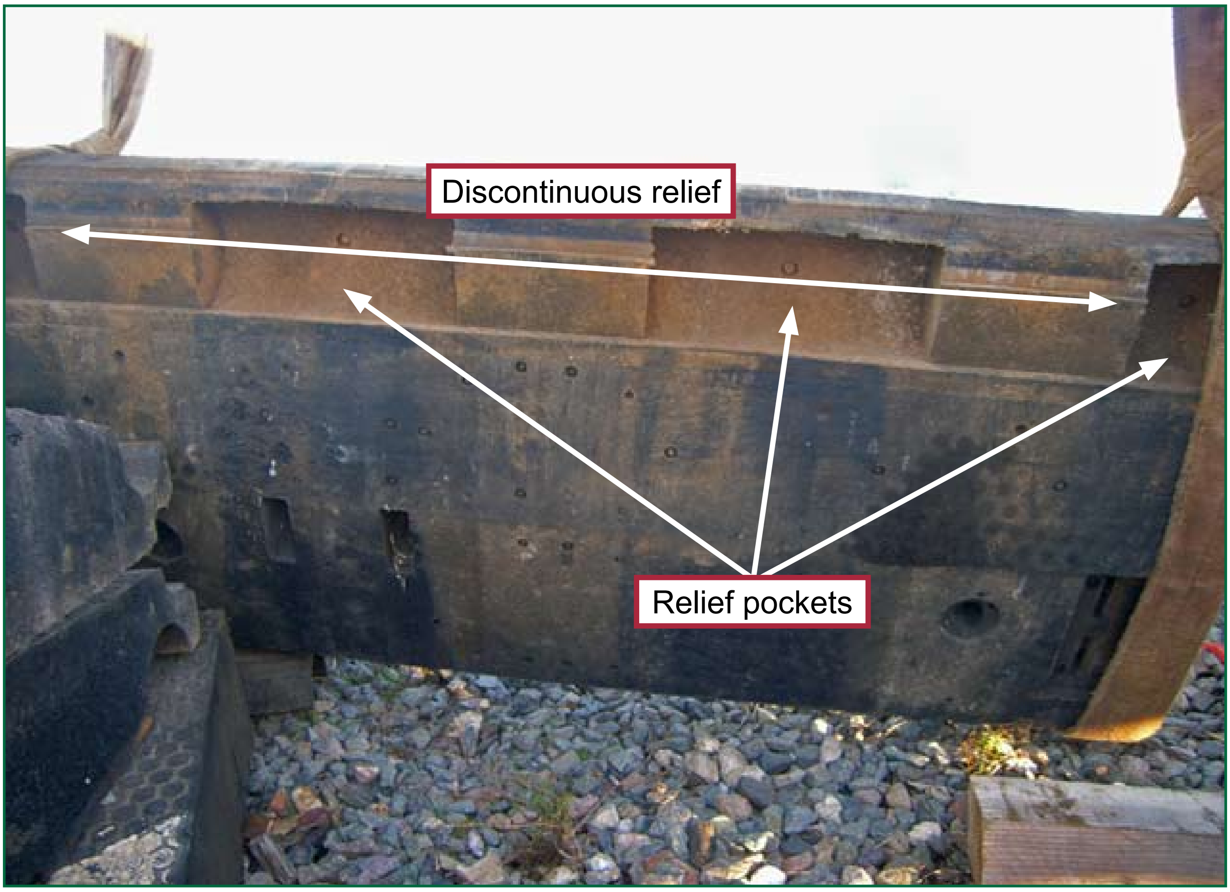


Figure 14: Discontinuous relief area on HoldFast panel underside

152 HoldFast did not distinguish between the two relief styles in terms of service performance. They have acknowledged that the continuous relief panels require less attention to the correct sleeper spacing than those panels with discontinuous relief.

153 It has not been possible to establish which type of relief system was tested during the time that acceptance by Railtrack was being considered; the documentation submitted does not define the design in this respect.

154 The panels originally installed at Croxton in 2000 and 2001 (paragraph 46) were of the continuous relief type. The eight panels installed as replacement panels in 2004 (paragraph 47) were of the discontinuous relief type.

155 The material in the relief area was relatively thin in comparison to the rest of the panel (Figure 15). As well as the relief on the underside, the upper surface had a channel close to the rail to provide clearance for train *wheel flanges* to pass through. This gave a relatively flexible area, known as the nose, as compared to the rest of the panel.

Panel composition

156 The Rosehill Polymer production method is now such that the composition, and hence material properties, of a panel can be selected. Since November 2002 two grades have been available.

157 The ‘normal’ grade panel used a layered construction which consisted of a different composition of rubber for the upper surface compared to the rest of the panel’s depth.

158 A ‘heavy duty’ panel was developed in November 2002 that used this top surface mix of the normal panel throughout its depth.

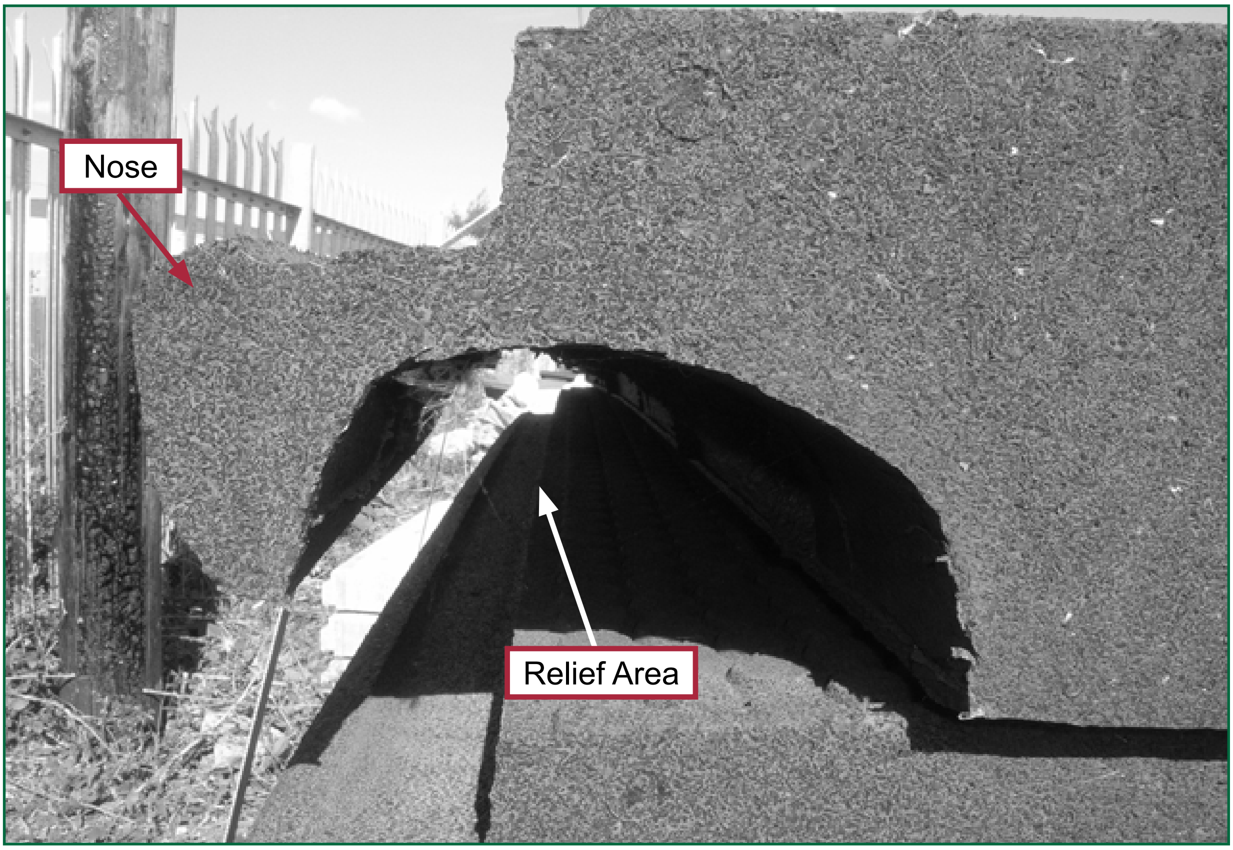


Figure 15: End view of panel nose area

159 All of the panels installed at Croxton were of normal grade, including those replaced following the fire in November 2004.

Panel identification

160 Identification of a panel's design was moulded into the upper surface of the panel in the area of the flangeway close to where the panel meets the running rail. This identified the design shape to the mould in which it was made.

161 All of the panels at Croxton had the same identifier ie 00324, and there was no means of inspectors determining the relief type, or the ages of the panels, once they were installed in position.

162 There were also differences between the three supplies of panels to Croxton in respect of vertical holes in the panels to assist with panel installation and removal. This is not considered relevant to the accident, but this feature did assist the RAIB in identifying panels and their likely dates of supply for the purposes of the investigation.

163 Rosehill Polymers also used white paint markings on the vertical ends of the panels as a means of recording production information. Examination of the removed Croxton panels showed that the markings were either not present or indistinguishable. Either some of the markings were not present originally, or they had been worn away due to rubbing contact between panels. Even if present, this information would have been of no use with the panels in place as it would not be visible to inspectors.

Vertical retention

164 The original OMNI panels were fastened down vertically to timber sleepers at 450 mm centres by screws that passed through moulded holes in the panels (Figure 16). The vertical retention of each panel was from the direct connection of the screw into the timber sleeper.

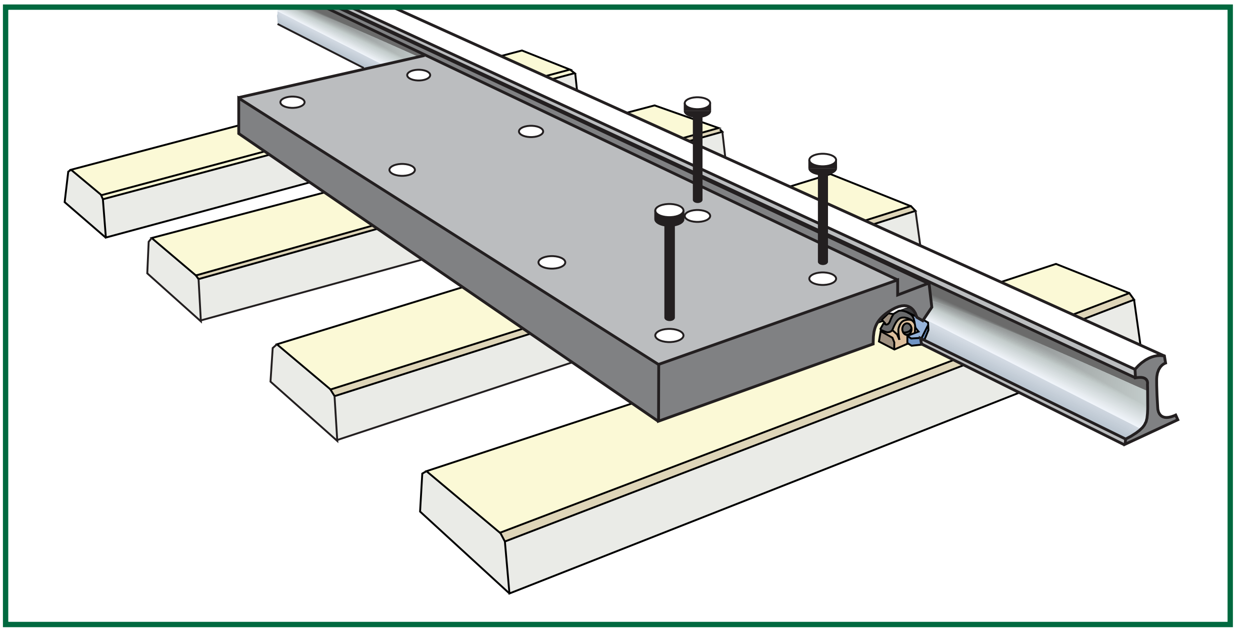


Figure 16: Original screw fixing of panels to timbers

165 Additional retention to resist possible movement was present from the panel's self weight and any friction present by the interference of mutually contacting panels and their fit against the webs of the running rails. This would have been variable in nature as it would have been in part a function of the dimensions of the panels relative to the dimensions of the spaces into which they were fitted.

166 OMNI supplied a base plate for use with panels on concrete sleepers. The base plate sat upon the top of the concrete sleeper, but was not attached to it. The first design of base plate had four bosses on its upper surface that were internally threaded (Figure 17). The bosses located into recesses at the underside corners where four adjacent panels met. Screws were then added through the moulded panel holes and into the bosses.

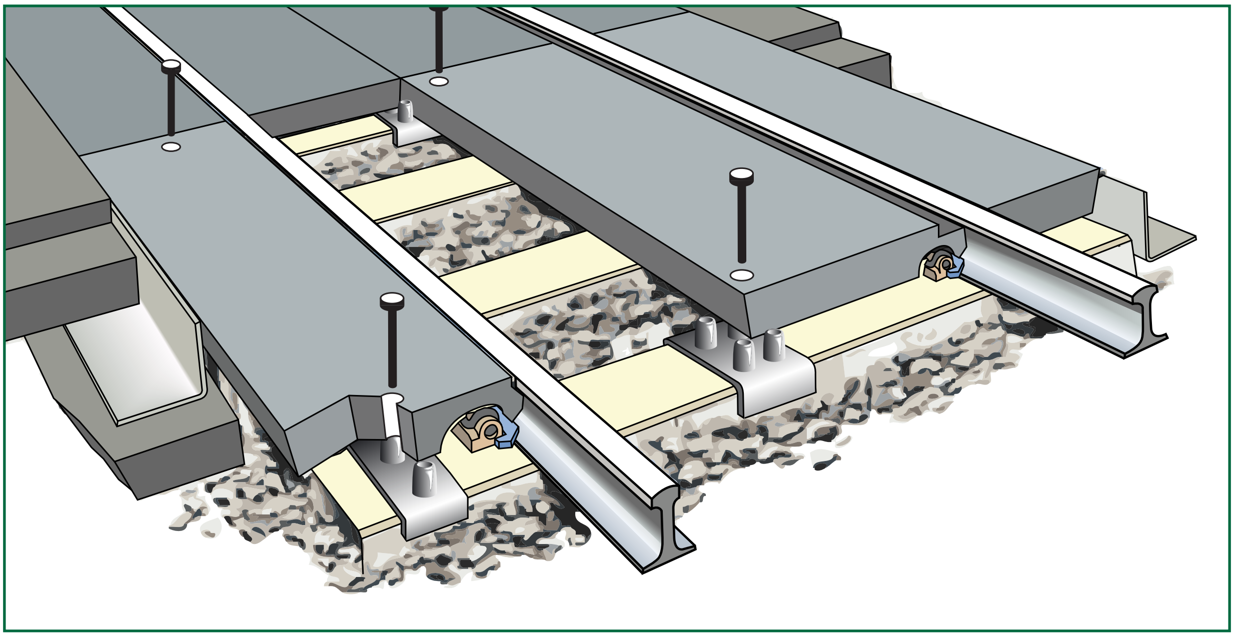


Figure 17: First version of base plate with threaded bossess

167 With this base plate vertical retention ceased to be from the direct fixing to the sleepers and relied more upon the other factors mentioned at paragraph 165, assisted by the fasteners between the panels and the base plates.

168 The relative dimensions of the panel recesses to the base plate bosses, where the four panel corners met, would have influenced the degree of compression of the rubber and hence the frictional forces created between panels.

169 BR and Railtrack fitted many panels of this design but the supply was discontinued following service experience of fretting of the screws and associated problems in removing them during panel lifting operations for track maintenance work.

170 Around 1990, OMNI / HoldFast developed a second design of base plate to overcome this problem. This incorporated four unthreaded bosses on the base plate, known as 'grip-tight nuts' (Figure 18). These were 'bulb' shaped bosses that located in recesses in the underside of the panel. The sizes of the bulb and the recesses were such that an interference fit between the boss and the recess was created when assembled. This base plate also incorporated four bosses on a single base plate to locate the corners of four adjacent panels.

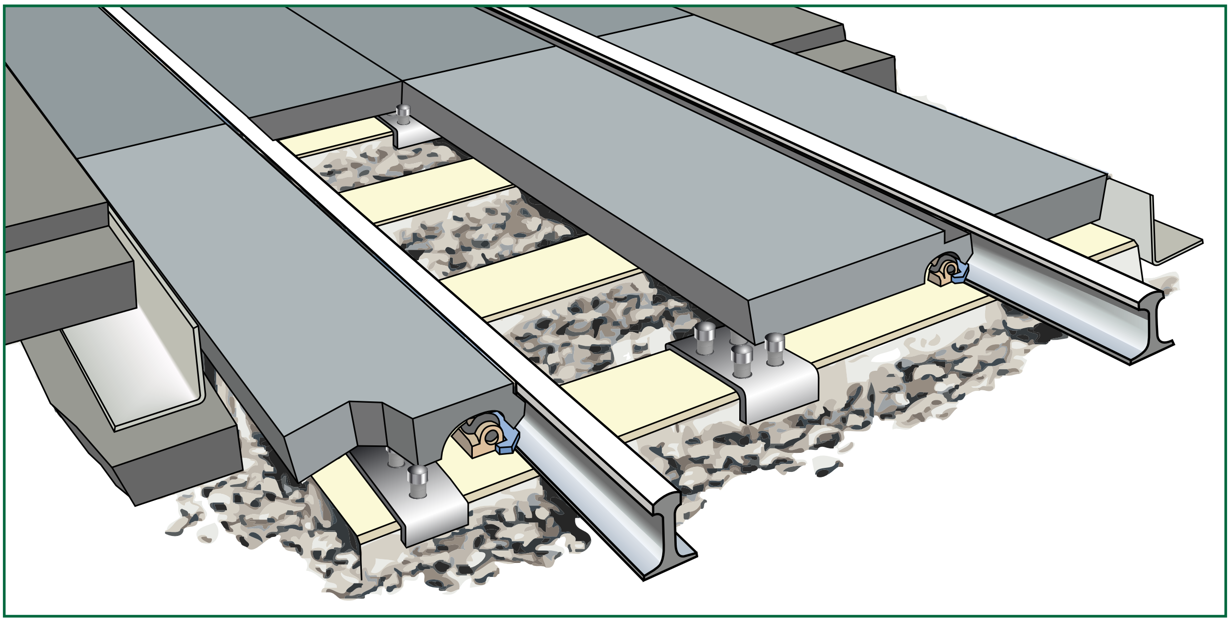


Figure 18: Second version of base plate with 'grip-tight nuts'

171 The vertical retention was no longer from fasteners but came from the panel's self weight, and contact friction generated by the compression of the fit of the grip-tight nuts to the panel recesses. The relative sizes between the panels and the cavity into which they fitted created retention from rubber compression between adjacent panels and rail webs.

172 HoldFast submitted this design of base plate when they applied to Railtrack for product acceptance in mid-1998.

173 Subsequently HoldFast and Rosehill Polymers redesigned the base plate following reports received of panel ends splitting in the region of the 'grip-type nut' recesses.

174 This third design, known as a 'turreted' base plate, was a pressed steel plate with two uprights at each of its ends. HoldFast and Rosehill Polymers made an associated change to the recess in the underside of the panel into which these uprights engaged, changing it from a circular cavity to a parallel-sided slot (Figure 19).

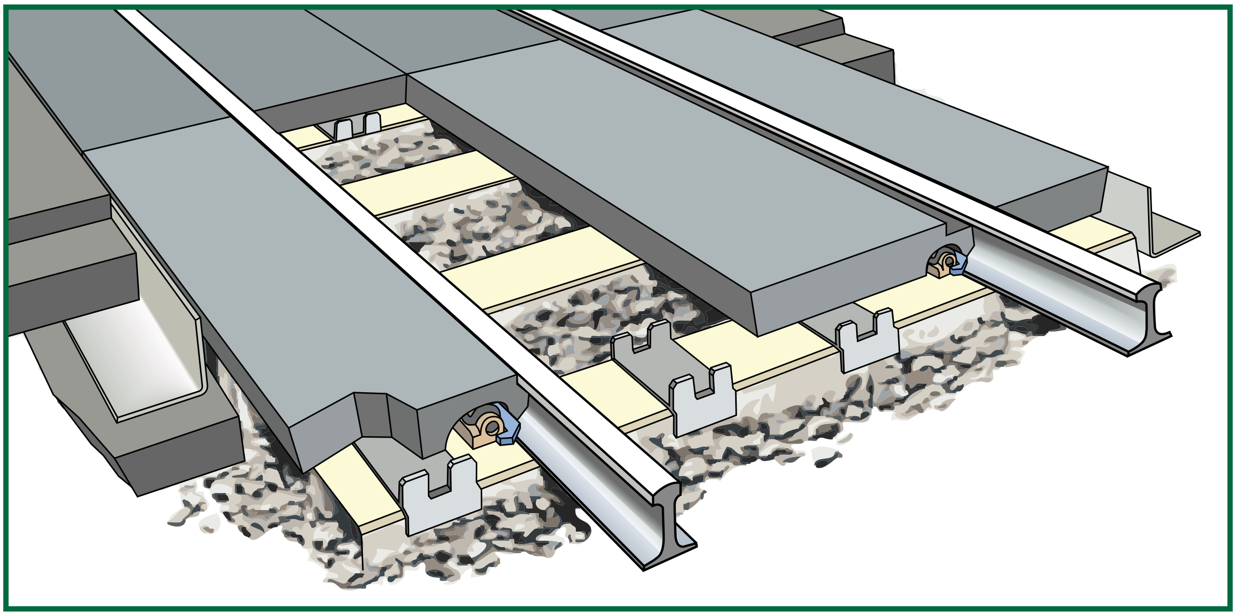


Figure 19: Turreted base plate design

175 HoldFast also moved this recess away from the panel's corner; the intent of the design change was to increase the contact area of the base plate's engagement with the panel and so reduce the risk of splitting to the panel's ends found with the approved design.

176 With this design, the former single base plate that located the corners of four adjacent panels was replaced with two base plates; one being required between panels for each row. This base plate now located only two longitudinally adjacent panels relative to each other; whereas the previous design had located four.

177 Also this base plate employed a rubber pad bonded to its underside to reduce attrition damage to the top of the concrete sleeper from the underside of the base plate.

178 The vertical retention now relied on self-weight and friction due to interference contact between panels from the compression of the rubber in this direction, as there was no positive locating between adjacent panels across the four foot.

179 The use of base plates for individual rows of panels also allowed panels to be staggered, ie offset by a sleeper spacing which reduced costs as less panels were required on skewed crossings.

180 It has not been possible to establish when this change took place, but it was certainly after Railtrack product acceptance had been given in May 1999. The first supply of this design of crossing panels with the revised design of base plate was in January 2000.

181 This change was neither submitted to, nor accepted by, Railtrack as required in the conditions of the certificate of acceptance (Appendix E) and the RAIB has found no evidence that any risk associated with this change was assessed.

<u>*Longitudinal retention*</u>

182 There were two distinct types of base plate for each of the three versions developed, the first of which was known as a legged base plate (Figure 20).

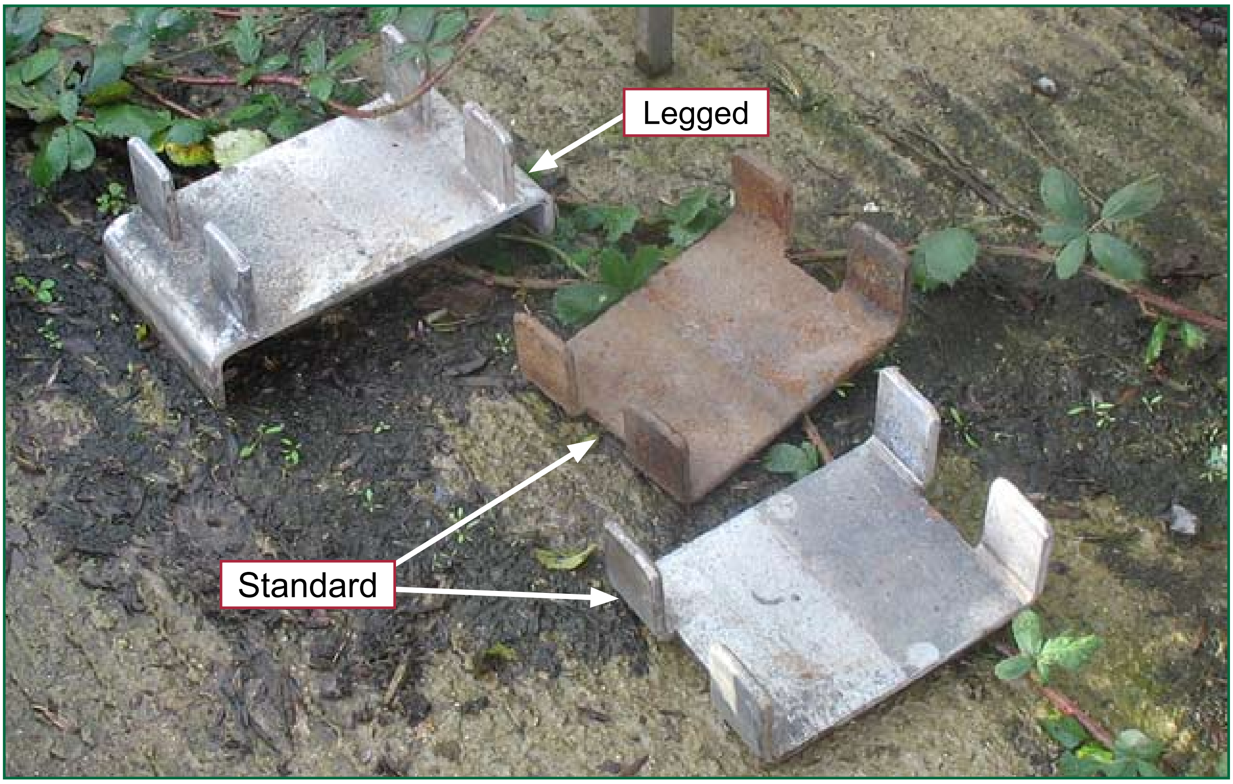


Figure 20: Legged turreted base plate (top) and two standard turreted base plates

183 This base plate had downward pointed legs at each of its ends which located either side of a sleeper; HoldFast recommended these to be fitted at the centre panels of a crossing to give longitudinal retention of the panels to the sleepers. This was required to prevent the panels from sliding along the track through forces induced by road traffic attempting to move the panels. The other function it provided was to give a reference of the panel to which it was attached to the sleeper over which it was located.

184 The second base plate type was known as a 'standard' base plate (Figure 20). This base plate had no legs and rested on the top a sleeper. Therefore, it gave no longitudinal retention, or reference of the panels to the sleepers. This was developed as it was found through previous experience that it was impractical to use 'legged' base plates throughout a crossing as this required the sleeper centre line intervals to be at, or very close to, 600 mm or the multiples thereof.

185 HoldFast submitted literature to Railtrack in support of their application for product acceptance, which included reference to an 'end restraint plate'. This was similar to the 'legged' base plate but was intended to locate the panels at the outer ends of the crossing to the sleepers. HoldFast ceased to offer this option after they changed the design to the 'turreted' base plate.

186 The Railtrack specification RT/CE/S/040, required the use of chain guards. These are steel plates angled at 45 degrees which attach to either the end panels, or the sleepers, in the four foot at the ends of the crossing's surface. The purpose is to deflect any object hanging centrally across the width of trains which may damage the end crossing panels.

187 The HoldFast design of chain guard consisted of an angled plate attached to the outer ends of the two adjacent end panels. No chain guards were present at Croxton at the time of the accident and it is likely that they were not fitted when the panels were installed, as the chain guard design is not compatible with staggered panels. Although this does not comply with the specification requirements, the chain guards' contributions to the panels' longitudinal retention is thought to be small, as the lower ends of the chain guards sit in the ballast bed and are not attached to a sleeper.

Method of installation

188 HoldFast submitted literature to Railtrack as part of their application for product acceptance. This states that every fourth sleeper should be placed at 1800 mm centres and that the intermediate sleepers are not so critical.

189 It also states that if a crossing takes a high level of fast and heavy traffic, that it may be considered worthwhile placing sleepers at 450 mm centres. The terms 'fast' and 'heavy' were not defined.

190 The HoldFast literature recommended that panel installation should start at the centre of the crossing, using a legged base plate (paragraph 182), with panels being added towards the crossing's outer end. The reasons for this were to 'reduce error', ie minimising cumulative effects of any inaccuracies in sleeper spacing towards the ends of the crossing's surface.

191 The four foot panels were to be added as pairs, either by adding one panel first, with the other being pushed down by mechanical means, or by adding both at the same time.

192 In this latter method, the panels were added with their 'noses' located in the webs of the rails, with both panels being elevated towards the centre of the track (Figure 21). A downwards force was then applied to the raised ends of the panels to push them into their final position – for example by using an excavator backactor.

193 There is a moulded profile on the vertical panel face at the centre of the four foot (Figure 21 inset). This gives some clearance to the panels' lower edges when installing them in the latter method described above to assist in their fitting.

194 HoldFast recommended that soapy water be used between panel mating surfaces and also between the base plates and the panels. This would have allowed the panels to slide relative to one another to assist in their fitting.

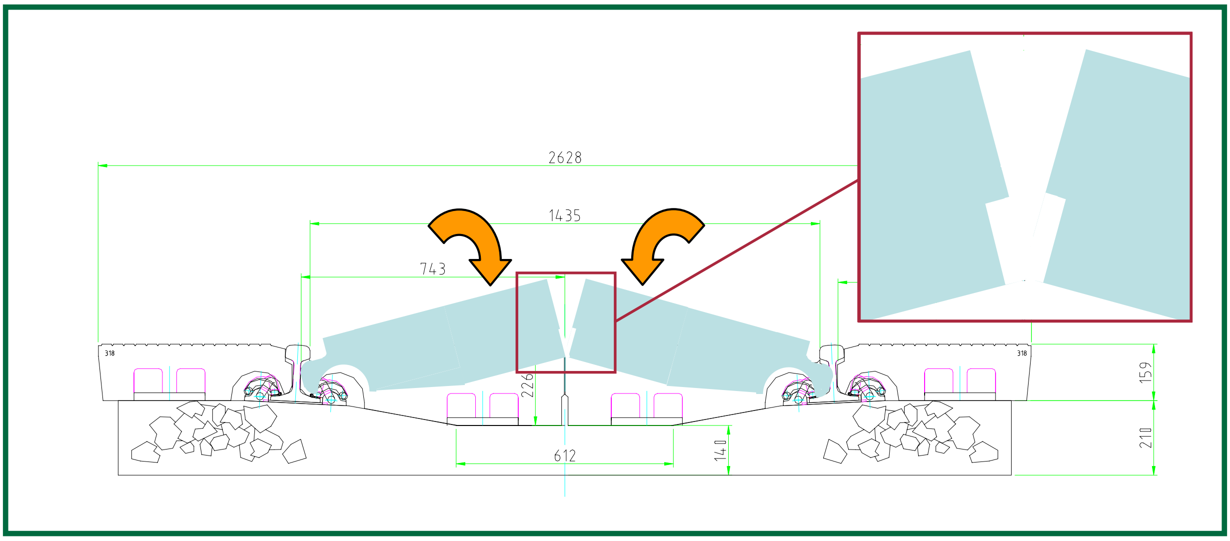


Figure 21: Installation method of HoldFast four foot panels and moulded profile on lower edge (inset)

Supply and Installation of the HoldFast level crossing system at Croxton

195 The Bowmac crossing panels at Croxton had given Railtrack problems over a number of years (paragraph 41), and in 2000 Railtrack local area management decided to replace the panels in the four foot at Croxton with the HoldFast system. This decision was driven by the higher damage rate of the four foot panels relative to those in the cess and six foot and in consideration of the cost of replacing the full crossing surface.

196 Railtrack's installation contractor ordered the panels from HoldFast, who were then approved to supply level crossing panels. HoldFast visited the site and undertook the specification of the type of panel and base plates in February 2000, placing the order on Rosehill Polymers in March 2000. The documentation from HoldFast to Rosehill Polymers requested the 'new style base plates'; these would have been the 'turreted' plates (paragraph 174).

197 HoldFast did not notify Railtrack local staff, or Railtrack Product Acceptance Services, that the holding down system was different from that approved by Railtrack the previous year.

198 In documents accompanying the order, HoldFast indicated that Croxton was a fast and heavy duty crossing and had a skew of around 45 degrees. The actual skew angle was 27 degrees, and both this and the 45 degree angle, as wrongly stated by HoldFast, were outside the 60 degree limit stated in RT/CE/S/040 (paragraph 119).

199 There is no evidence that HoldFast recommended the installation of sleepers at 450 mm spacing, as recommended by their literature for 'fast and heavy traffic' (paragraph 124).

200 The RAIB has found no evidence that either local Railtrack personnel or HoldFast were aware of the normal limit of crossing angle stated in RT/CE/S/040 of between 60 and 90 degrees. Railtrack did not consider undertaking a design review of the application of the panels to Croxton.

201 The first order requested 26 panels to replace only the panels in the four foot of the down line. HoldFast had specified that the panels were to be staggered. It appears that the decisions to stagger and to only replace the four foot panels may have been taken with a view to minimising costs.

202 There is no evidence that local Railtrack personnel were aware of the requirement to replace an entire level crossing surface system when a HoldFast system was to be installed (paragraph 142). HoldFast did not tell them of this, although at the time of the accident, the product certificate of acceptance, including this requirement, had been posted on their web site.

203 The order from HoldFast quoted the panel type as 00324 GPN, in order to suit F27S sleepers and 113A FB rail section. The letters 'GP' indicated that it was a *gauge panel* and the letter 'N' indicated that it was of 'normal' grade composition (paragraph 156).

204 Rosehill Polymers completed the production of the panels in June 2000. The delivery advice note states the panel type as 00324GPCN; the 'C' indicating that the panel was of the continuous relief type.

205 The HoldFast quotation to Railtrack's contractor for the second order for panels for the up line in 2001 quoted for 'exactly the same crossing that was installed in April 2000'. The traffic conditions are documented as 'fast and heavy although the duty is quite light'. It was also recognised that the road profile in one direction was poor and led to 'driving down into the crossing'. It also mentioned that the angle of the railway to the road was 'approximately 45 degrees' and that the panels were for the four foot only.

206 As with the first order there was no recognition of the requirements of RT/CE/S/040, or of the product acceptance certificate in respect of the crossing angle (paragraph 119) and partial panel replacement (paragraph 142).

207 There was also no record that the road profile was checked, although the order does identify that the crossing surface was lower than the road. The order gives an assurance that the panels would be suitable for this location.

208 For this second order, the Rosehill Polymer production documentation indicates that the relief is to be of the discontinuous type, and that the composition grade was 'normal'. This documentation also confirms that the base plates were to the new design, ie 'turreted' base plates.

209 Rosehill Polymers' delivery note to HoldFast for this second order quotes the panels as being of the type 00324GPN, ie discontinuous relief, and yet all of the panels delivered had continuous relief.

210 The third order from HoldFast to Rosehill Polymers for the replacement of panels damaged in the fire (paragraph 47), requests that the panels are the same as supplied previously. Rosehill Polymers supplied these from stock; they were of type 00324GPN, that is of the discontinuous relief type.

211 It is not known why the continuous relief panels were supplied to Croxton on the first two orders; neither the supplier nor the manufacturer have offered an explanation for this. However, HoldFast did not recognise any performance differences between the two types of relief and Railtrack did not appreciate that there was a difference.

<u>Track and track components</u>

212 The railway track on both lines at and through the level crossing was of BS 113A FB *continuously welded rail*, laid on F27S concrete sleepers.

213 Network Rail's standard for condition of the track in September 2006 was NR/SP/TRK/001 Issue 2, 'Inspection and Maintenance of Permanent Way'.

214 Standard NR/SP/TRK/001 section 17 states that crossings should be lifted every three years to check for loose clips, slurried ballast and corrosion of the rails. As the rails were renewed at Croxton in 2005 (paragraph 50) the crossing was compliant with this requirement. However, the condition of the ballast found in September 2006 would indicate that the ballast condition not been attended to at the time of the rail renewal.

<u>Rails</u>

215 The rails had been renewed in 2005 (paragraph 50), and there is no evidence that their condition contributed to the derailment in any way.

<u>Sleepers</u>

216 There was no sleeper supporting the Thetford end of panel B4 (Figure 22).

217 RT/CE/S/040 specifies that a level crossing surface system shall allow any individual sleeper to be at +/- 10 mm from the nominal grid pattern. This effectively defines a limit in variation from an absolute datum for each sleeper and its intent is to control any cumulative inaccuracies in sleeper spacing. HoldFast also state in their literature that every fourth sleeper is to be at 1800 mm centres.

218 Measurements of the sleeper intervals on 30 September 2006 (paragraph 106) found that of the twenty five intervals on the up line in the location of panels B2 to B9, twelve were not in the correct positions as defined within specification RT/CE/S/040.

219 The centre line spacing of the first and fourth sleepers at the ends of panel B4 was 1853 mm which is outside of the HoldFast recommended four interval spacing of 1800 mm.

220 One of the sleepers under panel B4 was cracked, and the cast iron housing into which the *Pandrol clip* locates was loose and at an angle to the rail. There was no clip present and even if it had been present it could not have functioned correctly.

<u>*Fastenings*</u>

221 The rails were fastened to the sleepers by Pandrol clips. The Pandrol clip is a spring clip that has been used, with various developments, since the early 1960s. It holds the track firmly to the sleepers, but has sufficient resilience to allow movement. In order to function both mechanically and electrically a plastic insulator is placed between the toe of the clip and the foot of the rail, and a pad is placed between the rail and the sleeper (Figure 22).

Figure 22: Pandrol rail clip and insulators

222 Standard NR/SP/TRK/001 recognises that there will be occasions when clips will be missing from the track, and sets a limit as to how many may be missing. For a line with a line speed of between 65 mph (105 km/h) and 100 mph (161 km/h) there is an allowance of three defects, such as missing clips, in a single 60 ft (18 m) length of rail, with at least two sound fastenings between any defect.

223 Of the six sleepers under panels B3 and B4 none had all four Pandrol clips in position. Some had broken ends of Pandrol clips corroded into the housing. The sleeper closest to the unsupported end of panel B4 had no Pandrol clips in any of its housings (Figure 23).

<u>*Ballast*</u>

224 The ballast under the sleepers in the up line was eroded, with slurry having formed around the ballast (Figure 23).

Figure 23: Six foot rail and sleepers under dislodged panel B4

225 The Track Section Manager (TSM) at March identified that wet areas of slurried ballast (wet beds) needed attention on the up line at Croxton. He entered this work onto Network Rail's work database (*Ellipse*, formerly known as MIMS). Although this work was outstanding on 12 September 2006, it was not connected with the exact location of the derailment.

<u>Track geometry</u>

226 Network Rail's track recording train had last run on the up line from Norwich to Ely on 29 June 2006. The vertical alignment of the track for the 1/8 mile (200 m) through the crossing was recorded as being in the 'very poor' and the 'poor' categories for 70 m and 35 m wavelengths respectively. It is not clear what the state of the track through the crossing itself was, and whether the defects identified in paragraph 225 and would have contributed to the readings. However, given the inherent ability of level crossing panels to follow vertical deflections in the track, it is unlikely that the track geometry contributed to the derailment.

Installation, inspection and maintenance of Croxton level crossing

<u>Installation</u>

227 AMEC Rail Limited, Railtrack's subcontractor, had installed the HoldFast panels at Croxton (paragraphs 195 to 211). Many of the personnel involved had been employed by BR prior to 1996, when their work involved them with installation and maintenance of infrastructure, including bridges, buildings and level crossings. They continued to install and maintain level crossings until Network Rail took the responsibility for maintenance in house in 2004.

228 None of the personnel involved had been given training or formal instruction on the installation of the HoldFast system, other than that which they had learnt from experience, supplemented by the literature HoldFast supplied (paragraph 185) and on occasions, by the presence of HoldFast staff on site during installation.

229 Although not required to be present at installations, it was not uncommon for HoldFast to choose to be present during the installation of their level crossing systems. Witness evidence suggests that they were not present during any installation activity at Croxton.

Inspection requirements

230 Prior to April 2006, the inspection of public level crossings formed part of the duties of personnel within the Operations function of Network Rail. Procedure C5 of the Operational Manual as issued in July 2002 specified how the inspections were to be conducted and reported.

231 In April 2006 an organisational change within Network Rail created dedicated level crossing teams responsible for both the inspection and maintenance of level crossings. In the Anglia area, there were three teams directed by a level crossing supervisor at Ely who reported to the service delivery manager at Tottenham. The supervisor had a level crossing assistant to support him in his duties.

232 This change was accompanied by the implementation of specification NR/SP/SIG/19608, Level Crossing Infrastructure (Inspection and Maintenance) Handbook, current at issue 2 from February 2006, up to and after the time of the accident. This reflected the use of the new system of dedicated level crossing inspectors. These inspectors were described as being specialised, non-technical personnel, with their duties being to carry out checks against the specification, along with certain repairs. These repairs included control of vegetation, timber/ballast deck repairs and the changes to signs.

233 Their inspections used a standardised checklist, included within the specification, which the inspectors were to complete for every inspection. Following all inspections, whether defects were found or not, the specification required the inspectors to complete an inspection record form, which they were to send up to the level crossing supervisor, eventually to be retained by the area services manager.

234 The inspection record form also reported the recommended priority that the inspector had assigned to the correction of defects. Specification NR/SP/SIG/19608 had a 1 to 4 rating with 1 being ‘immediate – rapid response’ and 4 being ‘rectification required within 6 months’. The rating was to be based upon the inspector’s assessment of the safety risk that the defect presented.

235 The specification provided guidance to the assigning of priorities to defects, and accepted that a degree of judgement was required by the inspector.

236 A defect described as ‘surface units not fitted / seated correctly’ was to be assigned a priority of 1 and a defect described as ‘road surface substandard’ was to be given a minimum priority of 4, although an accompanying note states that this item is particularly sensitive to the severity of the defect which may warrant increasing the priority if the defect could affect the safe use of the crossing.

237 The inspection checklist covered the many features of level crossings, including those associated with the quality of the crossing surface. Of particular relevance was the requirement to check that the surface of the crossing was in an acceptable and even condition with no gaps present. There was no requirement to observe the panels under road traffic, although the busy nature of the road over Croxton crossing was such that the effects under road traffic could be, and were, seen.

238 Also there was no requirement to lift the panels during these inspections as this would require one or both carriageways of the road to be closed.

239 Network Rail appointed inspectors under the new system and allocated them specific crossings to inspect. In February 2006, before the system changed, they provided a week's training to the nominated inspectors on the forthcoming inspection system. This training covered many aspects of the inspection requirements within the checklist and was general in nature. There was no specific training on the inspection of crossings using the HoldFast or OMNI panels.

240 The specification defined inspection frequencies depending on the type of level crossing. The maximum interval between inspections at Croxton was defined as seven weeks.

241 Defects found during inspections were required to be attended to; the details of which were recorded on a 'WAIF' (Work Arising Identification Form). This form was then used to record planned work in the Ellipse work planning system. The level crossing supervisor, or his assistant, was required to complete the WAIFs before planned work was assigned. The planning of the work and when to undertake it was decided by the level crossing supervisor.

<u>Inspection history</u>

242 On 30 April 2006, the last inspection under the previous inspection system was conducted at Croxton. This reported 'a poorly relaid deck' (paragraph 53). Further investigation has revealed that this was related to the raised six foot edge beam in the down line. This was reported as a fault within the FMS system. Other than this, nothing was reported in relation to the surface of the level crossing.

243 The RAIB has only found records for one of the three seven-weekly inspections that should have been conducted between April 2006 and the 12 September 2006. This took place on 7 July 2006.

244 Although the Network Rail Ellipse database indicates that all three were completed, no completed checklists or inspection record forms have been provided to support this.

245 None of the sections within the checklist had been completed for the inspection record of 7 July 2006, as the inspector believed that the checklist was for guidance, rather than as a means of recording the inspection detail. However, he had completed the inspection record form.

246 The inspection record form reported 'uneven footpath beams' (these being the raised six foot beams), excess vegetation, a broken fence and 'very uneven Bowmacs with loose panels'. The inspector has confirmed that he used the word 'Bowmac' for all level crossing panels, irrespective of type, and that he was referring to the HoldFast panels.

247 The inspector assigned a priority of 2 to both the defects relating to the raised six foot beam and the uneven crossing surface. This rating indicated that the inspector recommended the defects to be repaired within seven weeks. He returned the completed form to the level crossing supervisor for onwards work identification and planning.

248 The RAIB has found no records that the defects identified, and reported to the level crossing supervisor following the inspection on 7 July 2006, were planned to be addressed within the timescales that the inspector had allocated in his prioritisation.

249 On 9 August 2006, the level crossing supervisor completed three WAIFs and made the associated entries within Ellipse. Two are of no relevance to this accident, but the other relates to crossing ‘pads’ needing replacement. However, witness statements indicate that this referred to the rubber wedges that hold the Bowmac panels to the cess and six foot, and not to the HoldFast panels. There was no reaction to the defects identified in the inspection of 7 July 2006.

250 Although there was a system of regular crossing inspections, other Network Rail personnel reported defects with the level crossing when they came across them, by means of the IFC and the FMS system (paragraph 53).

Maintenance requirements

251 The maintenance process specified within NR/SP/SIG/19608 refers to Issue 1 of NR/SP/TRK/040 (previously referred to as RT/CE/S/040), and NR/SP/TRK/001 ‘Inspection and Maintenance of Permanent Way’.

252 The section on maintenance within RT/CE/S/040, which was the basis for the acceptance of the HoldFast level crossing system, required the supplier to provide a maintenance manual. This was to include recommendations for the installation and maintenance of their system. The section also stated that the manual should include a list of recommended spares to be held by the maintainer.

253 HoldFast were required to submit a manual as part of their consideration for product acceptance and they submitted two documents during February or March 1999.

254 The installation instructions submitted specified the sleepers to be at 600 mm centres and made mention to the ‘grip-tight nut’ design of base plate (paragraph 170). It also detailed the installation method as discussed in paragraph 185.

255 The RAIB has found no evidence that indicates that these instructions were supplied to those directly involved with the installation, or with the subsequent inspection and maintenance activities, at Croxton. The RAIB found that many of those currently responsible for inspection and maintenance were not fully aware of the requirement to have the sleepers at 600 mm centres.

256 The maintenance instructions stated that there is no maintenance required for a HoldFast crossing, other than keeping the flangeways clear. It also stated that no spares had been previously been supplied for the OMNI system and recommended no spare parts.

257 There were therefore no instructions for staff at local level regarding the inspection and maintenance of the HoldFast panels and no guidance on looking for signs of deterioration.

Maintenance history

258 The relevant history of maintenance work undertaken at Croxton provided by Network Rail is outlined in paragraphs 47 to 52.

259 The sleepers were spaced outside of the tolerance band within RT/CE/S/040, and of HoldFast’s requirements (paragraph 217) at the time of the accident.

Condition of Croxton level crossing

The crossing approach and its surface

260 The road approach in both directions was generally flat and was within the RT/CE/S/040 specification requirement to be shallower than 1 in 20 for at least 100 m either side of the crossing (paragraph 119). However, Network Rail has indicated that this requirement relates to the average gradient.

261 There was a difference in levels between the road surfaces and the level crossing surface close to the crossing; the top of the crossing surface was approximately 100 mm lower than the road for some 1 m on both sides of the edge beams in the cess. HoldFast had recognised this local variation in the road profile at the time of the supply of the second delivery of panels in 2001 (paragraph 205).

262 Examination of the crossing surface after the derailment showed that it was irregular, with vertical steps between different HoldFast panels in the four foot of both up and down lines. Some of these steps were in the order of 15 to 20 mm (Figure 24).

Figure 24: Vertical differences between upper surfaces of adjacent panels at Croxton

263 White painted carriageway markings were present on the top surfaces of the panels. Some of the panels at the ends of the crossing had worn double line marking on their surfaces, indicating that it is likely that they had been in other positions at the centre of the crossing. Witness evidence has shown that the practice exists of changing panels from one position to another if they exhibit signs of wear to their top surfaces.

264 At the time of the derailment the six foot edge beam for the Bowmac panels at the Thetford end of crossing on the down line was in a raised position (Figure 4). This did not affect the road surface as it was in the area of the footpath; it had been left in this position following earlier maintenance work (paragraph 52).

265 There was a gap of the order of 30 mm between two panels on one row of the down line at the Thetford end of the crossing (Figure 25). This had been filled in at some earlier time with tarmacadam.

266 Contactors to Network Rail undertook a level crossing survey on 17 August 2006. This survey was to record the signalling infrastructure present at the crossing and was not related to the level crossing surface. A photograph from this survey, which was supplied to Network Rail by the contractor, shows a gap present between panels A5 and A6. This gap was in the order of 10 mm.

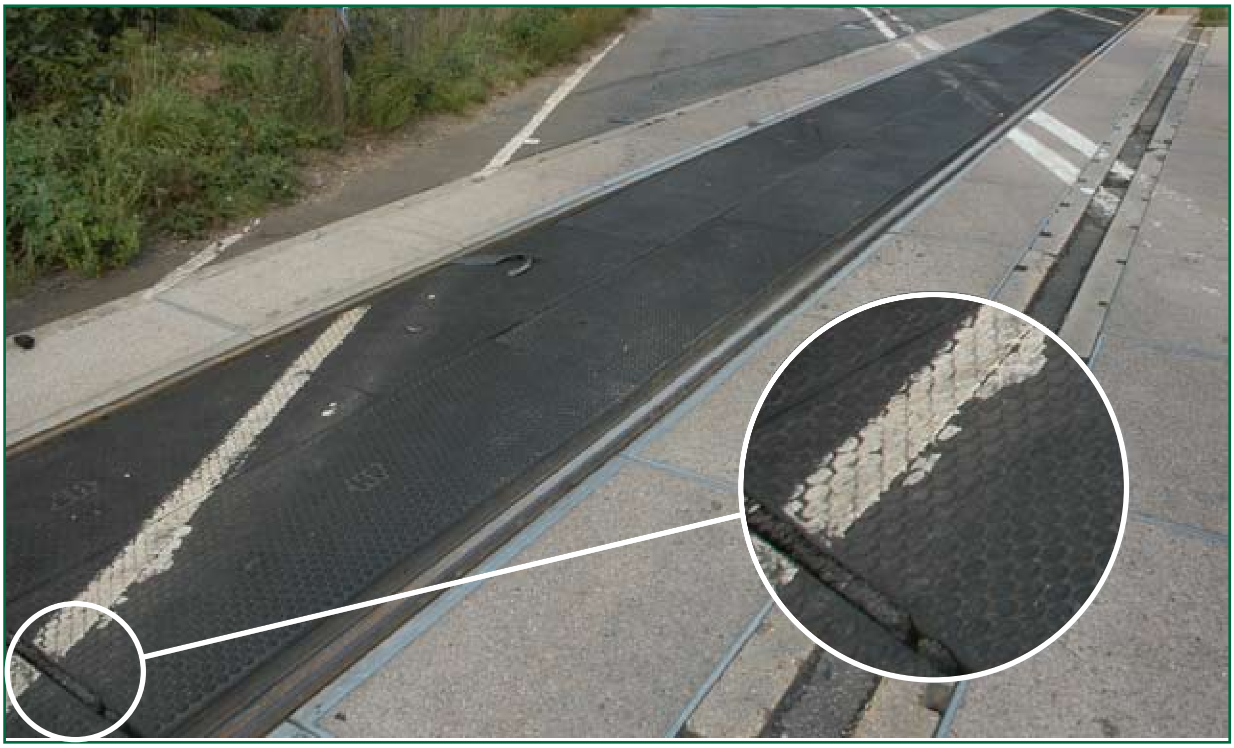


Figure 25: Gap with tarmacadam infill between panels in the down road (lower left corner)

Panel B4 – Condition prior to being dislodged

267 The deep groove in the upper surface of panel B4 was as a result of the impact with the lifeguard of the train that derailed (paragraph 114). Other scuff markings on the upper surface are likely as a result of impacts with road vehicles after it had become dislodged.

268 Panel B4 had continuous relief, as did all of the other panels installed in the up line (paragraph 147). The underside of the arch in the relief area was cracked throughout its length (Figure 26). There was substantial evidence of tearing on the upper side of the relief channel at the Thetford end of the panel, extending for approximately two thirds of its length.

269 The nose of the panel also had damage to its lower edge (Figure 26).

270 The length of panel B4 was 1775 mm which is 25 mm shorter than the nominal 1800 mm design length.

271 The underside of a new HoldFast panel is moulded with two level surfaces along its length. These are angled relative to each other to allow full contact between the respective horizontal and sloped surfaces of the sleeper.

272 On the underside of panel B4 there were three substantial indentations across its width, which coincided with the positions of the three sleepers that were supporting it at the time of the accident (Figure 27).

273 Each indentation varied in depth, from 25 mm on its sloped surface close to the relief area to 10 mm on its horizontal surface towards the centre of the track.

274 Panel B4 also had cracks in its lower surface which ran from the corners of the sleeper wear indentations and in to the arch.

275 There were also three other similar indentations to those in paragraph 272, but of a lesser depth. Some of these overlapped with those formed from the panel's most recent location leading to a wider area of wear than that solely of a sleeper's width.

Figure 26: Panel B4 underside showing cracking in relief area and damage to nose

Figure 27: Panel B4 underside showing indentations from sleepers and transverse crack (arrowed)

276 There was a crack running transversely across the panel's underside in an area which would have been approximately mid-span of the centre two sleepers supporting the panel (Figure 27).

277 There was damage on both ends of panel B4 in the areas of the underside recesses where the base plate located (Figure 28). This consisted of three distinct features, which were:

- wear to the slots on both ends into which the base plates uprights located;
- cracking through the side wall separating the two slots; and
- wear to the moulded square edge on the Thetford end of the panel under which the base plate locates. This had been worn into a curved surface (Figure 29).

278 The standard base plate fitted to the Thetford end of panel B4 had deformed through 45 degrees (Figure 30). This distortion permitted the end of panel B4 to drop below the surface of the sleeper on which it should have been resting.

279 There was no pad present under this base plate and the pad on the underside of the base plate at the Norwich end was badly worn.

Condition of other panels in the crossing

280 The RAIB instructed Network Rail to lift a sample HoldFast panel after the accident. The panel selected was in the down line, diagonally opposite panel B4 and situated next to the six foot rail (Figure 31). This panel was likely to have experienced similar road traffic loads to that of panel B4, albeit from road traffic travelling in the opposite direction. The RAIB selected the particular panel as it was the most uneven panel in the entire crossing's surface.

Figure 28: Panel B4 underside showing wear and cracking in the base plate location area


Figure 29: Panel B4 underside showing wear on panel edge in the base plate location area


Figure 30: Deformed base plate under Thetford end of dislodged panel B4

Figure 31: Diagonally opposite panel to panel B4 (in the down line of the other road carriageway)

281 The Norwich end of the selected panel was located on its intended supporting sleeper but only by approximately 20 mm, rather than in the order of 110 mm, ie half the sleeper's width. The standard base plate present had no pad on its underside.

282 Examinations of the other panels removed on 30 September 2006 (paragraph 105) found similar damage to that found on panel B4, although not to the same degree. The damage included:

- indentations from wear from their location on the sleepers;
- cracking in the relief area;
- splitting of side walls in the panels' base plate recesses (Figure 32);
- wear to the lower edges of the noses (Figure 32); and
- damage to, or loss of, the base plate pads (Figure 33).

283 Measurements of the panel lengths found that twelve were within $^{+}/\text{-}$ 10 mm of their nominal design length, two panels were oversize by 10 mm and the remaining twelve were between 10 mm and 25 mm shorter than their nominal design length.

284 These twelve short panels were shorter by more than their lower manufactured tolerance (paragraph 129).

285 The A row of panels in the up line at Croxton had one legged base plate present, between panels A10 and A11, but there were no legged base plates on the B row (Figure 34). All of the other base plates, the standard type, were present on all panel joints on the up line.

286 The RAIB also examined the panels that had been replaced following the fire in 2004 (paragraph 47). The panels had suffered damage to their upper surfaces as a result of the fire. These panels were of the continuous relief type. Two of the panels had sleeper related indentations, cracking in the relief areas and splits to the side walls in the base plate recesses to the same degree as panel B4.

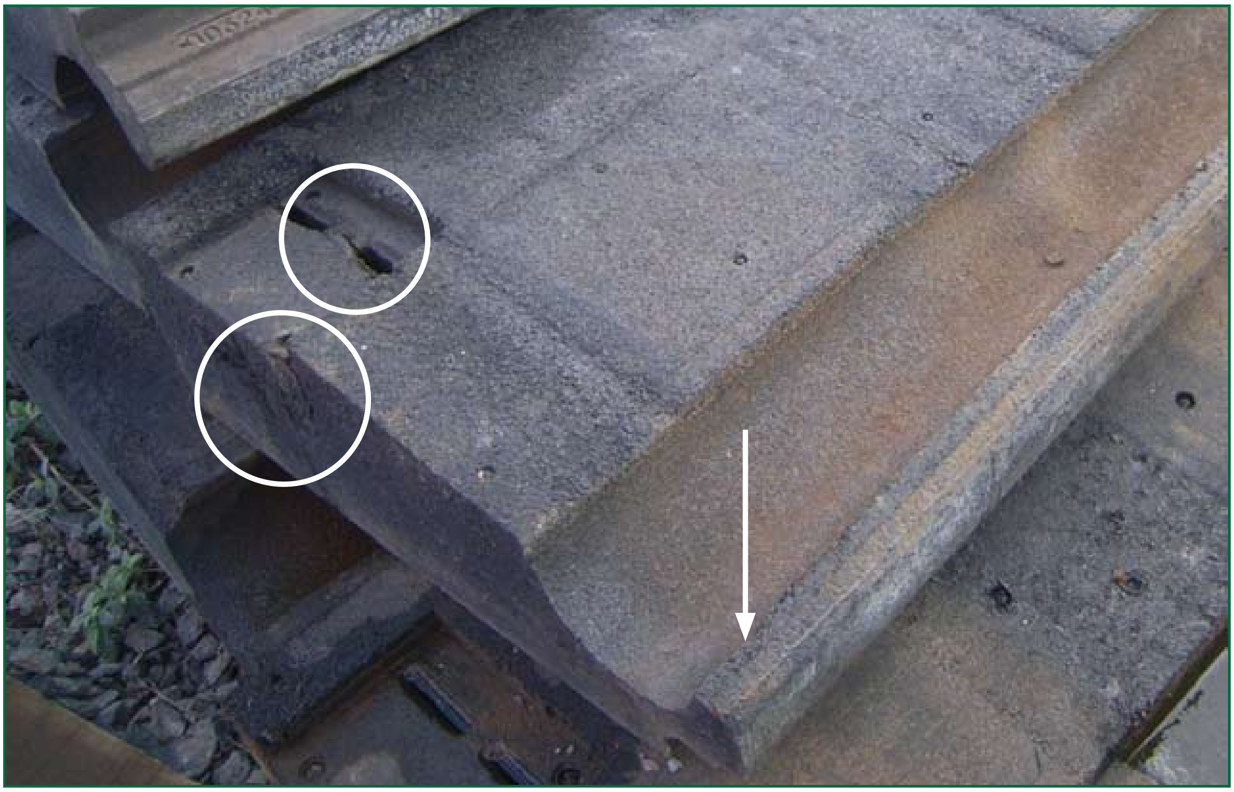


Figure 32: Side wall splits in panel base plate area (circled) and wear to nose (arrowed)

Figure 33: Loss of and damage to base plate pads

The dislodgement of the level crossing panel

<u>Initial dislodgement of panel B4</u>

287 The damage to the nose and the relief areas of panel B4 (paragraph 268 and 269) and other panels examined (paragraph 282) indicate that the panels were degrading under the forces from road traffic.

288 The nose and relief areas were under the highest stress when the panel is fitted. This is due to the compression fit between the adjacent four foot panels and the rail web at the 'nose' (paragraph 192).

289 This area was the least stiff section of the panel because of its reduced cross section compared to the rest of the panel. Under road traffic forces it flexed from both direct vertical forces and those induced by resisting road wheel traction forces attempting to move the panel towards and away from the rail web. The rubber resisted these movements by attempting to return the panel to its least loaded condition.

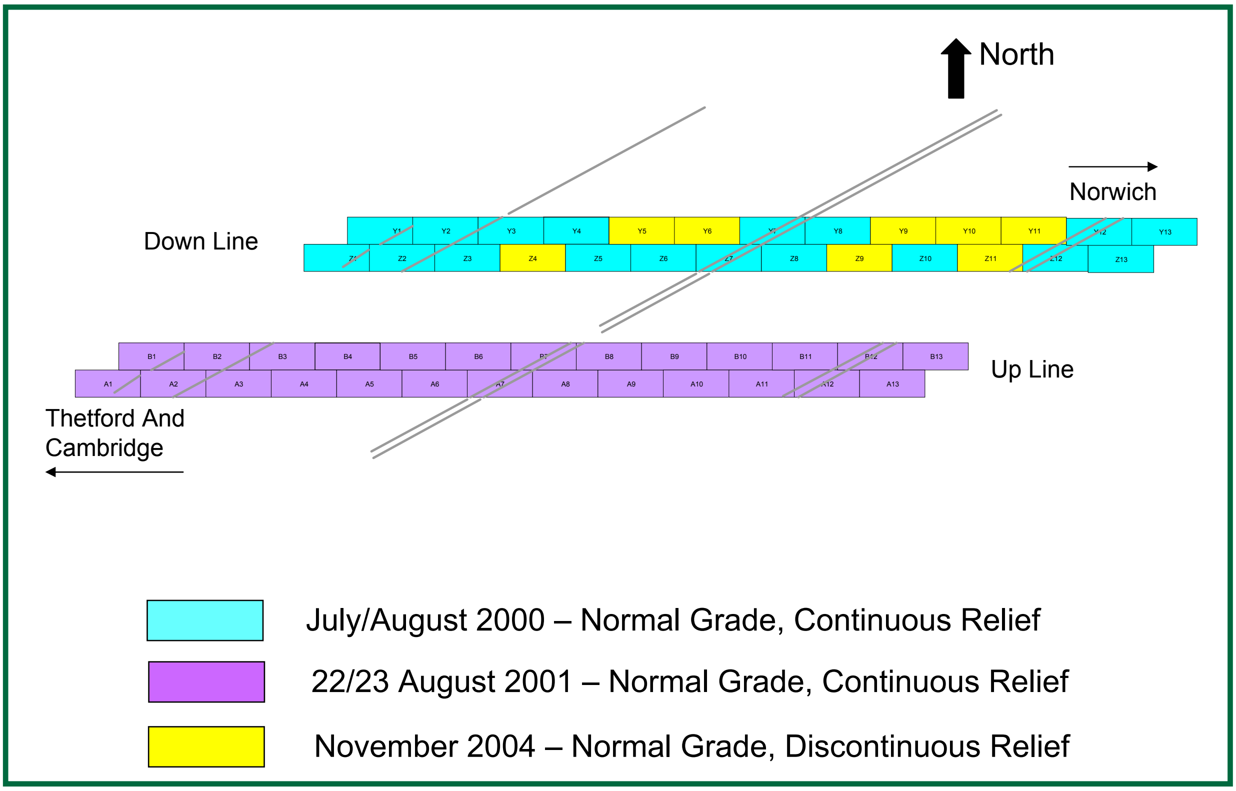


Figure 34: Panel types ages and positions fitted at Croxton at time of accident

290 This constant flexing caused *fatigue cracks* to develop and grow through the material in these areas of highest stress; as the cracks grew longer, the stiffness of the 'nose' section decreased and it became more flexible. The rate of this crack growth likely then accelerated and eventually the cracks grew to a length sufficient to overcome the material and a tear resulted.

291 The cracks present in Panel B4, which run from the corners of the sleeper wear indentations and in to the arch (paragraph 274), support the existence of high stresses in this area, and these cracks further reduced the stiffness of the relief area.

292 These cracks would have gradually reduced the compression forces retaining panel B4 tightly in its cavity and this explains why it took time for the panel to become fully elevated and dislodged.

293 The likely effect of the repair of 26 August 2006 (paragraph 62) was to force the arch closer to the rail web which would have stiffened the arch and increased the panel's retention in its cavity. Panel retention was subsequently reduced when the timber strips became removed (paragraph 70).

294 The indentations on the panels' undersides (paragraph 272) occurred through wear of these areas in contact with the sleepers. The varying depth of these indentations (paragraph 273) is indicative of the panels rocking by variable amounts, as the nose edge was pushed downwards, assisted by the higher flexibility in this area (paragraph 289). This action would have resulted in the four foot edge raising in the order of 30 mm with no allowance for deflection due to compression. The panels had been rocking in the direction of the prevalent road traffic for sufficient time to have caused this wear.

295 Further evidence of this rocking action was apparent from the wear present to the lip of the moulded profile on its four foot vertical face (paragraph 193); the wear of the lip is likely to have been from rubbing contact with its adjacent four foot panels as it rose and fell under the action of road traffic.

296 The other set of indentations on panel B4 indicate that at some other time panel B4 had been in a different position within the crossing. This is supported by the witness evidence that panels could have been in different locations at other times (paragraph 263). The distances between these other imprints indicate that the other end of the panel, ie its most recent Norwich end, may have been not fully supported when in this earlier location (Figures 35a and 35b).

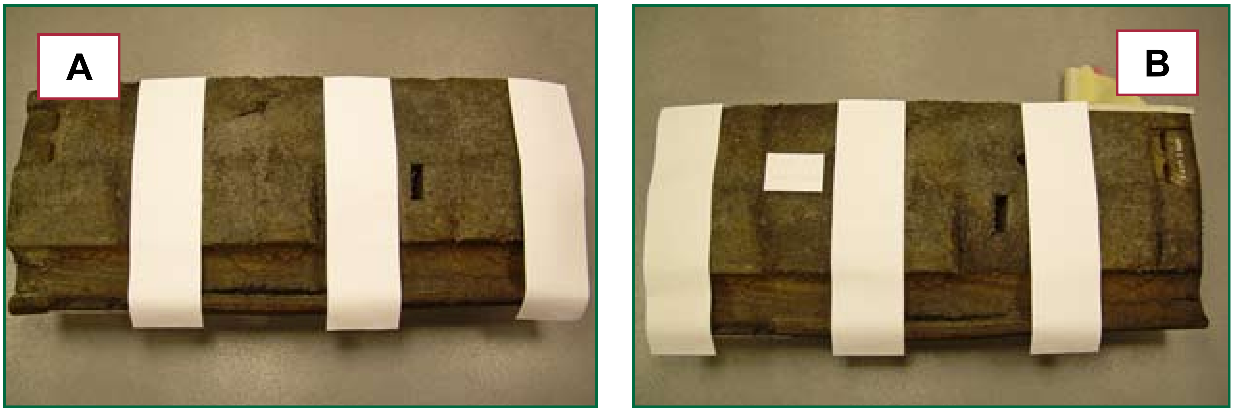


Figure 35: Panel B4 underside showing sleeper positions : A - at time of accident; and B - at some earlier time

297 The transverse crack found across the width of the underside of panel B4 (paragraph 276) was at the mid-span of the two central sleepers. The underside surface in this area of the panel would be under tension from vertical loads directly above it attempting to bend the panel.

298 Interaction between the base plate uprights and the panel slots caused the wear to the slots at both ends of panel B4 (paragraph 277). This indicates relative vertical movements between the panel and the base plate.

299 The absence of this wear on other panels indicates that this wear was as a result of panel B4 being repeatedly raised and lowered.

300 A common feature of panel B4 and many of the other panels was the cracking through the side wall separating the two slots (paragraph 277). Some of the other panels also had cracks running from the slots to the end faces of the panels (Figure 29).

301 A comparative test of the degree of tightness of the base plates in the slots between panel B4 and other panels, found differences in the forces applied to the base plate uprights by the slots. The slots in panel B4 gave little resistance to the removal of the base plate. Panels with no signs of damage held the base plate firmly.

302 The cracks in this area, together with the splitting of panel side walls found with the previous design of base plate (paragraph 173), indicate that high forces exist at the joints of longitudinal adjacent panels.

303 The standard base plate fitted to the Thetford end of panel B4 was deformed through 45 degrees (paragraph 278). This was because the base plate was not fully supported by the sleeper and therefore subjected to repeated loadings from road traffic.

304 The corrosion of the cracks present at the upper surface of the bend in the base plate indicates that the deformation had preceded the accident by some time. This is further supported by the curved surface worn on the moulded square edge on the Thetford end of the panel under which the base plate located (paragraph 277). This wear resulted from contact between this edge and the deformed base plate.

305 The deformation of the base plate was such that its unsupported half, under the action of road traffic, would have allowed this end of the panel to be deflected downwards in the order of 100 mm. This resulted in the other end becoming lifted.

306 The lack of a base plate pad at the Thetford end of panel B4, the damage to the pad on the base plate at the other end (paragraph 279) and the missing or damaged pads on base plates from other areas of the crossing are indicative of the high loads and relative movements that existed between the panels and the sleepers. Some of the pads had become unstuck from their base plates (Figure 33), others had been abraded by contact with the concrete sleepers.

307 The panels that had been removed following the fire in 2004 had similar damage to that previously observed; this damage was not as a result of the fire. The location of these panels was likely to have been as shown in Figure 34; as determined by the location of the replacement panels added in November 2004 and found at the time of the accident.

308 Markings on one of these panels indicates that this panel was supported at both ends and correctly positioned relative to the sleeper centre line at one end, but not at the other. This suggests that its first and fourth supporting sleepers had not been at the specified 1800 mm interval.

309 These observations on panels other than panel B4 are indicative that panels were degrading under forces from road traffic, which indicates that they had a finite safe life and therefore require periodic replacement.

310 The RAIB concludes that the damage present on panel B4 was not limited solely to it, and that damage on other panels had already taken place over the period between July or August 2000 and November 2004.

311 The many reports regarding the state of panel B4 indicate that it had been unsupported at its Thetford end for a period of at least 11 weeks.

312 Some of the reports record that the panel had lifted above the road carriageway. It is likely that panel B4's elevated position was not observed during the subsequent Network Rail inspections as the panel had either fallen back, or had been forced back by road traffic into its cavity by the time the inspection took place.

313 From analysis of the CCTV records the RAIB has traced the lorry that crossed over Croxton level crossing at 05:54:34 hrs on 12 September 2006.

314 The lorry was a tanker trailer design, carrying slurry to a factory some 2 miles (3 km) north of Croxton crossing.

315 The driver of the lorry tractor (who has since changed employment, and has not been traced) is not known to have made any report about problems when he delivered the trailer to the factory on the morning of 12 September 2006.

316 Records of the trailer's laden weight showed that it was within its allowable loading limit.

317 Analysis of the route of the lorry from the CCTV pictures indicates that its nearside wheels crossed panel B4 at its Thetford end, with the wheels crossing over the corner of the panel adjacent to the rail (Figure 36).

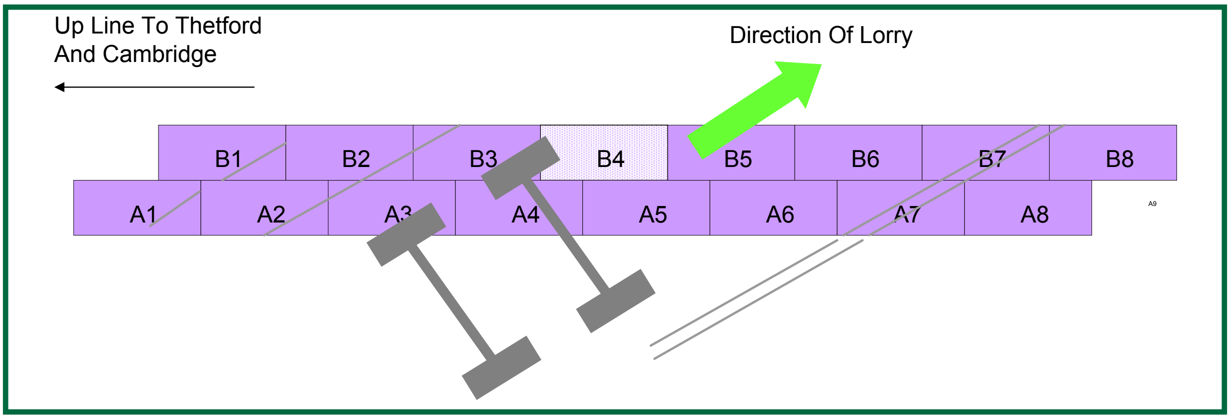


Figure 36: Likely path of lorry over panel B4

318 The Thetford end of panel B4 was not supported by a sleeper (paragraph 216) and the base plate at this end had been previously deformed (paragraph 278). The weight of the lorry forced the rail side edge of the panel down towards the sleeper, and it is likely that the four foot edge and the Norwich end lifted.

319 At the same time as the panel was lifted, with its Norwich end having to have been above its longitudinally adjacent panel, it is likely that longitudinal forces from the lorry's wheels moved the panel towards Norwich so that it could not fall back into its cavity. The panel is likely to have twisted, through distortions allowable by its flexibility that caused an anticlockwise rotation (when viewed from above) which left the Norwich end of the panel close to, or over the six foot rail of the up line.

320 Study of the underside of the lorry tractor and a similar tanker trailer unit showed that there were protrusions associated with the suspension that were 150 – 175 mm clear of the ground, and that could have struck the dislodged panel. However, there are no marks on the panel that are consistent with this having taken place, and the movement of the panel can be explained without such an impact.

321 These two mechanisms dislodged panel B4 out of its location within the crossing surface. Analysis of the CCTV pictures after the passage of the lorry indicates that the panel was left with its Norwich end resting on the six foot rail of the up line.

<u>Behaviour of panel B4 after initial dislodgement</u>

322 The subsequent collisions with the two cars (paragraphs 78 and 83) further rotated panel B4 in an anticlockwise direction when viewed from above, increasing the obstruction to any approaching train (Figure 10).

323 The mass of a HoldFast four foot panel is 263 kg. This is considerably more than two people can manipulate even in ideal conditions, and it is unlikely that the efforts of the two drivers (paragraphs 80 and 85) made any significant difference to the position of panel B4.

Previous occurrences of a similar character

324 The RAIB has been unable to establish any other instances where a level crossing panel has been dislodged to the extent that it caused a derailment of a train.

Analysis

Identification of the immediate cause

325 The immediate cause of the derailment was the train striking the fourth HoldFast level crossing panel from the Thetford end on the six foot side of the up-line four foot, after it had been dislodged by a tanker trailer lorry at 05:51 hrs, eight minutes and forty nine seconds before the derailment occurred.

Identification of causal and contributory factors

326 The RAIB is satisfied that the following factors made no contribution to the derailment:

- the condition or the driving of train 1K55;
- the control systems of Croxton level crossing;
- the vertical positions of the edge beams on the up line (paragraphs 49 and 52); and
- the actions of the road vehicle drivers who attempted to move panel B4 immediately before the collision.

327 From the evidence available to the RAIB it is unlikely that the driving or condition of any of the road vehicles involved is contributory to the derailment.

328 The RAIB considers that the issues associated with the support of the panels and the response to the reports of the crossing's condition are the causal factors that lead to the accident.

<u>Causal and contributory factors associated with the crossing (panel support)</u>

<u>*Causal factors*</u>

329 Panel B4 had been unsupported at its Thetford end prior to the lorry that dislodged the panel passed over the crossing and had been in a condition that allowed the passage of the lorry to overcome all means of the panel's retention and dislodge it from its location in the crossing (paragraphs 317 to 320).

330 It is likely that this had been the case for at least the time that reports were received that the panel was lifting and was the cause of the distorted base plate.

331 Twelve of the twenty five sleepers under panels B2 to B9 were incorrectly spaced (paragraph 218).

332 If the sleepers had been correctly spaced, and with the shortened panels installed as they were at Croxton, panel B4 would have been supported by at least 40 mm at its Thetford end.

333 However the Thetford end of panel B3 would have been be very close to being unsupported, albeit that this is at the edge of the road carriageway.

334 Twelve of the twenty-six up-line panels were shorter than their nominal lengths of 1800 mm (paragraph 284).

335 Had the panels been within the tolerance of their nominal design lengths, and with the sleepers in the positions as they were at Croxton, panels B2 to B8 would have had all their ends supported by sleepers.

336 The combined effect of both the incorrect sleeper positions and the panels being shorter in length than their manufactured tolerance was that the Thetford end of panel B4 was unsupported.

337 Therefore, both the incorrect sleeper intervals and the panels being out of tolerance from their nominal design length are causal factors to the accident.

338 There was no legged base plate present between any B row panels (paragraph 285). There should have been one at the centre of the road which was between either panels B6 and B7 or panels B7 and B8. Measurements showed that the joints between these panels were 14 mm and 9 mm from their respective supporting sleeper centre lines. This is close to where they would have been had a legged base plate been present. Although, this is indicative that the prescribed method of installation of the panels was not followed, the lack of a legged base plate is not contributory to the accident.

Contributory factors – incorrect sleeper spacings

339 Whilst the RAIB has witness evidence that states that the sleepers were in their correct positions when HoldFast panels were first installed, it is not able to confirm this with any certainty.

340 There were missing rail clips on some of the sleepers (paragraph 223) with the sleeper closest to the unsupported end of panel B4 having no rail clips present. The lack of rail clips is not compliant with standard NR/SP/TRK/001 (paragraph 222) and the possibility exists that the sleepers had moved from their original positions.

341 Sleepers can move either as a result of rail traffic or during tamping activity. The latter is more likely at Croxton, given that trains were probably running at a constant speed with no gradient over the crossing.

342 The panels were lifted for track maintenance work at least once since the original HoldFast installation (paragraph 50) and the RAIB has no evidence that suggests they were lifted since this activity in June 2005.

343 Although the RAIB is unable to establish with certainty the positions of the sleepers before June 2005, and how they came to be in the positions in which they were at the time of the accident, it is considered likely that in June 2005 the sleepers were not correctly positioned. At this time there was an opportunity to check that the panels were adequately supported.

344 Witness evidence indicates that the need for correct sleeper intervals was not widely understood by all personnel involved with level crossing inspection and maintenance. This is a contributory factor.

Causal factors – panel lengths

345 Evidence from Rosehill Polymers suggests that the panels were manufactured to lengths that were within the tolerance of 1800 mm +/- 10 mm (paragraph 129).

346 The majority of the shorter length panels were in a position within the road carriageway that subjected them to road traffic loads, whilst the lengths of the panels at the edges of the road carriageway were within the manufacturing tolerance.

347 The RAIB measured the lengths of 80 four foot HoldFast panels on four other crossings; the panels had been in service for a similar length of time as those at Croxton. The crossings' usages varied in speed, angle and load. All measurements were taken during a two hour period.

348 All but two of the panels were shorter than the lower manufacturing tolerance. The lengths ranged from 1775 mm to 1791 mm with an average of 1783 mm.

349 Those in the centre of the road at the crossing with the greatest angle of skew were as short as the shortest at Croxton.

350 The RAIB concludes that the panels had experienced a reduction in their lengths from loads induced through traffic causing them to become permanently compressed.

351 The change in length of the panels at Croxton during their time in service is a causal factor.

352 The angle of the crossing was such that road traffic forces in both directions were attempting to move the panels towards the centre of the road carriageway. Although there was no legged base plate present in the B row of panels in the up line, any longitudinal forces in panels in one carriageway were likely resisted by opposing forces from the other. Therefore longitudinal movement of the whole of the B row panels on the up line has been discounted.

353 However, the shortening of panel lengths would have resulted in the longitudinal movement of joints between adjacent panels in each road carriageway.

354 The cumulative loss in panel lengths, from their nominal 1800 mm, from the joint between panels B7 and B8 through to the unsupported end of panel B4 was 76 mm. Although there is evidence of gapping between panels at Croxton (paragraphs 265 and 266) it is not to this degree. Neither was gapping known to be a persistent problem at Croxton.

355 Therefore, any movement of a panel towards the road centre is likely to have led to a pulling movement of its adjacent panel; the result was that no significant gaps occurred. Evidence of the splits in the base plate location region of the panels indicates that there are high forces present in these areas (paragraphs 277 and 282).

356 Panel gaps are known to be an issue as they can be a risk to cyclists; the specification RT/CE/S/40 limits these gaps to a maximum of 10 mm.

357 Although, Network Rail, Holdfast and Rosehill Polymers were aware that gaps could form between panels they were not aware of the effect of panels shortening during service. This lack of awareness is a contributory factor.

358 It is likely that the permanent compression was caused by the combination of road traffic volume, speed and the angle of the crossing. The degree of contribution by these factors to the amount of permanent set within a panel is not known.

359 The evidence from the limited RAIB level crossing surveys suggests that, although comparative loading was not assessed, a decrease in the crossing intersection angle affects the degree to which the panels reduce in length.

360 The loading conditions on the panels due to the layout and usage at Croxton are therefore causal factors.

Causal and contributory factors associated with the lack of response to previous reports

Causal factors

361 Between April 2006 and the derailment on 12 September 2006 various reports were made on the state of Croxton level crossing on at least eleven occasions, with seven of these logged with Network Rail IFC (paragraphs 53 to 71).

362 Between April 2006 and the derailment on 12 September 2006, five written or verbal reports relating to the condition of the panels were made to the level crossing supervisor.

363 He despatched staff to the site, and on 23 August they carried out a temporary repair. Five reports of the state of the crossing were made between then and the derailment 20 days later.

364 On Monday 11 September 2006, less than 24 hours before the accident, the level crossing supervisor decided to take action, and planned a road closure for the following week.

365 Network Rail not taking earlier action to the many reports about the state of Croxton level crossing was a causal factor to the derailment.

Contributory Factors

366 The level crossing supervisor did not appreciate that there was a risk of a panel coming out.

367 This is partly due to the fact that neither Network Rail collectively, HoldFast nor Rosehill Polymers, had experience of a panel having ever come out.

368 The panels were heavy and to remove them from track required great effort. Also the crossing was performing better with the HoldFast panels as the problem of broken four foot Bowmac panels ceased to be an issue. Both of these facts led to the lack of appreciation of any risks of a panel becoming dislodged.

369 Neither HoldFast nor Network Rail had given any direction on examination of degradation of HoldFast crossings. The previous performance of HoldFast crossings gave no cause to anticipate that such guidance was necessary for the particular risk that led to the derailment.

370 The lack of perception of the possible risk of a panel becoming dislodged, within Network Rail, HoldFast and Rosehill Polymers collectively is a contributory factor.

Identification of underlying causes

Underlying cause relating to incorrect sleeper spacing

371 The lack of understanding of the requirement to have the sleepers correctly spaced was an underlying cause of the accident (paragraph 343).

372 Many of the staff involved in the installation and subsequent maintenance of the crossing were not aware of the requirements of RT/CE/S/040, nor of the HoldFast requirements, for sleeper spacing.

373 Although this requirement was contained within the HoldFast installation manual, this was not made available to all involved with level crossing installation and maintenance.

374 Railtrack and subsequently Network Rail had not provided any instruction, briefings or training on HoldFast level crossing panel installation and maintenance.

375 Although the requirement for correct sleeper spacing was contained within specification RT/CE/S/040, the front-line staff involved with level crossings were not aware of it and it was not in a format suitable for this purpose.

376 The lack of provision of suitable information detailing the requirement to have correct sleeper spacings to all personnel involved with level crossing installation and maintenance is an underlying cause.

Underlying cause relating to incorrect panel lengths

377 Prior to the accident all parties were unaware of the extent to which that the panels could become shorter in service.

378 Although the limits of the actual duty that a panel can be subjected to without a critical loss in length has not been ascertained, it is likely as a result of longitudinal loads from road traffic and hence related to the skew of the crossing and the volume of road traffic.

379 At the time of supplying Croxton, the panels were a new development for Rosehill Polymers. The change in the base plate design to overcome the splits found in the panels is further evidence that development was still in progress. Although it is not known whether the OMNI panels exhibited a change in length due to loading, the material's composition and hence properties would have been different.

380 Some testing was done by Rosehill Polymers at the time of the development (paragraph 128), which indicated that the material could exhibit permanent compression under a sustained load, albeit this was at an elevated temperature. However, the significance of the findings to the application to level crossing surfaces was not recognised.

381 Although HoldFast and Rosehill Polymers now recognise that the crossing angle is likely to have a large influence of the behaviour of the panels in service, the actual limit of crossing angle and loading that leads to an unacceptable loss in panel lengths remains unknown.

382 The speed, vertical profile and crossing angle directly affected the way in which the loads from road vehicles were transferred from the road carriageway onto, and over, the crossing's surface. The volume of traffic affected the rate of loading and hence the likely rate of length changes.

383 These parameters were contained within specification RT/CE/S/040, against which the HoldFast panels were given acceptance for use on the rail network. The specification defines levels of these parameters as 'normal operating conditions' for a panel level crossing (paragraph 119).

384 Croxton crossing was outside of these 'normal operating conditions' in respect of its crossing angle. The specification does not state what should happen if the 'normal operating conditions' did not apply.

385 The parameter of gradient of the road approach stated within the specification is an average and does not take into account local variations in road carriageway levels. Local variations were found at Croxton where the road meets the level crossing surface which affected the loads applied as vehicles travelled onto and over the crossing (paragraph 261).

386 The definition of road traffic volume in RT/CE/S/040 is that this should be less than 2 500 commercial vehicles per day over each carriageway of the road. As a commercial vehicle has not been defined, it is not possible to define the actual loading that a level crossing surface should withstand.

387 Section 6 of the specification defines a load derived from a British Standard for bridges.

388 At the time of consideration for product acceptance, tests were undertaken which involved the application of this load to a HoldFast panel (paragraph 134 to 136); Railtrack's concern was to ensure that the panel would not deflect to a degree that would expose the rail head to contact with road vehicle wheels. This was the only load test performed on the panels.

389 The Rubber and Plastics Research Association (RAPRA) has reviewed specification RT/CE/S/040 for the RAIB. Their report concluded that the specification may not be suitably address the service performance of level crossing surfaces under dynamic conditions.

390 Section 6 of the specification defines only the static load that the panels must withstand. RAPRA and RAIB are of the opinion that with this limited requirement, and in consideration of the solely static testing undertaken at the time of product acceptance, the specification gives insufficient consideration to performance under dynamic conditions which can give rise to degradation in level crossing panel materials.

391 This is supported by the evidence of the need to replace broken Bowmac panels prior to the fitting of the HoldFast panels.

392 The lack of specification and assurance by testing of the duty to which level crossing panels were to be exposed is an underlying cause.

Application of the HoldFast panels at Croxton

393 The Railtrack Certificate of Acceptance issued to HoldFast states the scope of application of the panels is that defined within RT/CE/S/040.

394 The application of the panels to Croxton was outside of the defined ‘normal operating conditions’ contained within the specification in respect of the crossing angle.

395 Neither the specification nor the certificate gave any guidance to the course of action if a crossing is outside of the normal conditions.

396 HoldFast had identified that the skew was considerable (paragraph 198), but incorrectly judged the angle as around 45 degrees (which is still above the limit of the normal operating conditions), rather than 27 degrees. HoldFast did not recognise that the crossing was non-compliant to the specification’s requirement. Local Railtrack personnel were unaware of this requirement.

397 The certificate also stated that the scope was ‘a replacement for entire level crossing surface systems on an existing public vehicular level crossing’. The intent of this requirement was to avoid changes in skid resistance over the surface of the crossing.

398 This was not complied with as the crossing retained Bowmac panels outside of the four foot and, although of no relevance to the accident, indicates that the correct application of the HoldFast system was not understood.

399 The change of the base plates from the ‘grip-tight nut’ type to the turreted type was undertaken without informing Railtrack of this change (paragraph 181).

400 Railtrack gave product acceptance for the design based on the ‘grip-tight’ nuts. Although the performance of this retention system was not assessed with Rosehill manufactured panels, HoldFast did not consider it necessary to submit the change to the ‘turreted’ design to Railtrack for further approval, despite the clear requirement to do so as stated in the general conditions of their certificate of acceptance.

401 HoldFast has informed the RAIB that they saw no need to inform Railtrack of the change to the base plate design as the changes were deemed by HoldFast to be an improvement to the product. This change was to overcome deficiencies found with the earlier design leading to splits in the side walls of panels. The RAIB has found no evidence that Railtrack were informed of this deficiency or that a risk assessment had been undertaken of this change.

402 These issues demonstrate that the design and the application of the HoldFast level crossing system was not correctly controlled. This is an underlying cause.

403 The HoldFast level crossing panels were widely adopted across the network following their acceptance for use.

404 In consideration of the novelty associated with the panels and the limited testing conducted at the time of acceptance, a risk assessment and possible monitored trials should have been undertaken.

405 Product acceptance within Railtrack, and now Network Rail, is based on the application of the principles within their Engineering Safety Management System, known as the 'Yellow Book', which mandates such an approach. However, Railtrack accepted the HoldFast design by checking it against the requirements of RT/CE/S/040, which have been found to be limited, rather than by looking at the potential hazards that could arise from its use, and how they were mitigated.

406 Although in-service experience had been gained from the previous OMNI panels, the recent HoldFast panels were of a different material, had different methods of vertical retention and were used in applications outside of those specified as 'normal operating conditions'.

407 The lack of a thorough risk assessment and monitoring of the behaviour of the product in service are underlying causes.

Underlying cause relating to lack of response to previous reports

408 The lack of perception of the possible risk of a panel becoming dislodged, within Network Rail, HoldFast and Rosehill Polymers was contributory to the accident.

409 None of the parties had given any direction on examination of degradation, or the potential for degradation of HoldFast crossings which may have provided an opportunity to review performance and assess any risks. The previous performance of HoldFast crossings gave no cause to anticipate that such guidance was necessary for the particular risk that led to the derailment.

410 However, similar to the underlying cause of the panel becoming shorter in service, the lack of a thorough risk assessment in identifying such risks is an underlying cause.

Other factors for consideration

411 The RAIB has not studied the performance of HoldFast panels when they are installed in accordance with the requirements of RT/CE/S/040 and HoldFast's own instructions, and has not assessed whether the panels are, or are not, fit for purpose in those circumstances.

412 The original installation of Bowmac panels in Croxton level crossing would have been outside of the 'normal operating conditions' defined in RT/CE/S/040, as the angle of the crossing was non-compliant, irrespective of the design of panel used. Although these panels were installed before RT/CE/S/040 had been written, if a review of Railtrack's existing infrastructure had been undertaken, then the fundamental issue of whether Croxton crossing could have a panel surface at all might have been addressed before the HoldFast panels were installed.

413 After the accident the level crossing barriers did not raise, because of damage to the control gear caused by the derailed train. At 06:04:13 hrs, ie 37 seconds after the derailment, a van zig-zagged the barriers and crossed the railway, even though the lights were still flashing red.

Conclusions

Immediate cause

414 The immediate cause of the derailment was the train striking a HoldFast level crossing panel which had been dislodged by a tanker trailer lorry less than ten minutes earlier (paragraph 325).

Causal factors

415 Causal factors were:

a. the lack of support under the Thetford end of crossing panel B4 due to incorrect sleeper spacings (paragraph 336, **Recommendation 1**);

b. the lack of support under the Thetford end of crossing panel B4 due to the panels being less than their manufactured lengths (paragraph 336, **Recommendation 1**);

c. the panels had shortened in length whilst in service (paragraph 351, **Recommendation 3**);

d. the loadings at Croxton caused the panels to shorten (paragraph 360, **Recommendation 3**); and

e. Network Rail not taking earlier action in response to the many reports of problems on the crossing in the five months prior to the derailment (paragraph 365).

Contributory factors

416 The following factors were considered to be contributory:

a. the sleepers were not maintained in their correct positions when the panels were last refitted (paragraph 343);

b. there was a lack of understanding of the requirement to have the sleepers at the correct positions (paragraph 344, **Recommendation 2**);

c. the effect of panels shortening in service was not appreciated (paragraph 357, **Recommendation 4**); and

d. there was no perception of risk that panel could come out (paragraph 370, **Recommendation 4**).

Underlying causes

417 The underlying causes were:

a. no provision of information to personnel involved with the crossing of the need to ensure correct sleeper spacings (paragraph 376, **Recommendation 2**);

b. lack of specification and assurance of the duty to which level crossing panels are exposed (paragraph 393, **Recommendation 5**);

c. lack of adequate control of the design and application of the HoldFast level crossing system (paragraph 403, **Recommendations 6 and 7**); and

d. lack of a thorough risk assessment and monitoring of the behaviour of the product in service (paragraph 410, **Recommendation 8).**

Additional observations

418 The installation of Bowmac panels at Croxton, both before the installation of the HoldFast panels, and since their removal after the accident, does not comply with the normal operating conditions specified in RT/CE/S/040, and in its current replacement, NR/SP/TRK/040 (paragraph 415, **Recommendation 9**).

419 The HoldFast panels in the A row on the up line at Croxton were referenced to a legged 'turreted' base plate that was not placed at the centre of the roadway, as recommended by HoldFast and there were no such plates in the B row (paragraph 285, **Recommendation 1**).

420 The lack of clear, visible and unique identification marks for each type of HoldFast crossing panel in a visible position means that it is impossible to identify the type of panel without removing it from the crossing (paragraph 161, **Recommendation 10**).

421 HoldFast and Rosehill Polymers supply level crossing panels to other UK and world wide rail authorities. Any lessons learnt during the addressing of the recommendations of this report should be transferred appropriately to these other users (paragraph 144, **Recommendation 11**).

Actions reported as already taken or in progress relevant to this report

422 Network Rail issued a Track Engineering Letter of Instruction (LOI) on 15 December 2006, requiring the lifting of all HoldFast panels installed on level crossings, track access points and road rail access points. The instruction required the inspection of the panels' undersides and the checking of their correct installation.

423 Defects were found on 126 level crossing sites requiring rectification, with 40 of these having more than one defect. Of the total 174 defects identified, 16 sites had panel ends unsupported by sleepers, 17 sites had wear or splits, 39 sites had missing or broken base plates and 34 sites had variations in panel heights or gaps between panels. At 5 sites the level crossing surface was completely replaced.

424 Network Rail has briefed all the level crossing inspection teams, together with other staff who may have cause to install, lift and replace level crossings for inspection and / or maintenance, on the correct construction of proprietary level crossing surface systems, including HoldFast. The briefing included potential defects to look for and an understanding of risk, associated with defects. Roles and responsibilities for inspection and maintenance of level crossings were briefed to relevant maintenance staff.

425 Network Rail has issued manuals of all proprietary level crossing surface systems, including the HoldFast system, to field staff under a document control process.

426 Network Rail has undertaken a risk assessment of crossings with a mix of HoldFast and other types of panels and a revised certificate of acceptance has been issued for those existing configurations.

427 Network Rail has incorporated a specification for level crossing surface construction in the Track Design Handbook, NR/SP/TRK/049. This is to be issued formally in the June 2008 Network Rail Standards and has been briefed in advance of its formal publication.

428 Network Rail is currently undertaking an audit of level crossing inspection and maintenance which reviews the process and includes a number of sample site checks.

429 HoldFast is arranging with Rosehill Polymers that an identification mark will be added to panels within the moulding process of the product.

430 Rosehill Polymers is currently developing a new level crossing surface system with allowance for the effects of panel compression in service.

431 Following the accident Network Rail has replaced the surface of the level crossing at Croxton with Bowmac panels. Since then several panels have failed and have been further renewed. Network Rail is currently considering another type of level crossing surface system not involving panels for use at Croxton.

Recommendations

432 The following safety recommendations are made[1]:

Recommendations to address causal and contributory factors

1 Network Rail should assess the sleeper spacings and panel length of all HoldFast crossings until the rate of shrinkage is understood, and take such steps as are necessary so that no panel end is left unsupported by a sleeper. At the same time they should ensure that legged base plates are installed as specified by HoldFast Level Crossings Ltd (paragraphs 415a, 415b and 419).

2 Network Rail should review the information that they provide to their level crossing teams, so that the requirements of their standards, the risks of particular crossings using panel surfaces and the installation, inspection and maintenance actions that they expect are clearly communicated to front-line staff in a way that is useful and comprehensible to them (paragraph 416b and 417a).

3 HoldFast Level Crossings Ltd. should define the performance limits of their level crossing panels in consideration of the loads and layouts to which they are exposed (paragraphs 416c and 416d). It is suggested that HoldFast seek assistance from Rosehill Polymers and Network Rail in this task.

4 Network Rail should arrange a complete generic risk assessment of the HoldFast level crossing system by an appropriately technically qualified person, once the service environment of level crossings and the limits of performance of panels have been assessed. This should involve Holdfast Level Crossings Ltd. and Rosehill Polymers Ltd. appropriately in accordance with Network Rail's Engineering Safety Management System definition of 'system supplier'. This assessment should review the risks associated with the design, manufacture, installation and maintenance of the system, and should be supported by a wide review of in-service experience. The principles of Network Rail's Engineering Safety Management System should be adopted for guidance. The generic assessment should then be used to develop a site-specific assessment methodology for all locations where HoldFast crossings are to be used (paragraph 416c and 416d).

continued

[1] Duty holders, identified in the recommendations, have a general and ongoing obligation to comply with health and safety legislation and need to take these recommendations into account in ensuring the safety of their employees and others.

Additionally, for the purposes of regulation 12(1) of the Railways (Accident Investigation and Reporting) Regulations 2005, these recommendations are addressed to ORR(HMRI) to enable them to carry out their duties under regulation 12(2) to:

(a) ensure that recommendations are duly considered and where appropriate acted upon; and

(b) report back to RAIB details of any implementation measures, or the reasons why no implementation measures are being taken.

Copies of both the regulations and the accompanying guidance notes (paragraphs 167 to 171) can be found on RAIB's web site at www.raib.gov.uk.

5 Network Rail should update specification NR/SP/TRK/040 to include any revisions or clarifications of load parameters and assurance measures necessary to better define the performance requirements of level crossing panel systems (paragraph 417b).

6 Network Rail should review how it controls any application and design change associated with level crossing panel systems, including working with suppliers, manufacturers and front-line staff (paragraph 417c). This should take account of the findings in paragraphs 397 to 402 of this report.

7 Network Rail should ensure that HoldFast Level Crossings Ltd. have applied for and received product acceptance of their current base plate design (paragraph 417c).

8 Network Rail should review their processes for approval of level crossing panels and consider adopting the principles of hazard identification and mitigation within their Engineering Safety Management System (paragraph 418).

Recommendations to address observations

9 Network Rail should review all their public highway crossings fitted with panel surfaces to identify any that do not comply with the normal operating conditions defined in NR/SP/TRK/040 or those outside of their limit of application. Any crossings identified as such, should be listed and the risks associated with operating them outside of these conditions assessed and reasonable steps taken to mitigate them (paragraph 418).

10 HoldFast Level Crossings Ltd should amend their panel designs so that the manufacturing configuration of all panels supplied in the future is uniquely and indelibly marked on the panel, so as to be visible when the panel is in-situ in a level crossing (paragraph 420).

11 HoldFast Level Crossings Ltd and Rosehill Polymers Ltd should put in place processes so that any lessons learned during the addressing of the recommendations of this report to other users of their level crossing surface system (paragraph 421).

Appendices

Appendix A - Glossary of abbreviations and acronyms

BR	British Rail
CCTV	Closed Circuit Television
IFC	Infrastructure Fault Control
MOM	Mobile Operations Manager
RAIB	Rail Accident Investigation Branch
RAPRA	Rubber and Plastics Research Association
TAP	Track Access Point
TSM	Track Section Manager

Appendix B - Glossary of terms

All definitions marked with an asterisk, thus (*), have been taken from Ellis' British Railway Engineering Encyclopaedia © Iain Ellis. www.iainellis.com

Automatic half barrier level crossing	An automatic level crossing fitted with half barriers, traffic lights on the highway and a telephone to the relevant signal box.*
Cess	The parts of the track which are on the outsides of the running rails; in this case closest to the edges of the highway.
Continuously welded rail	One or more lengths of rail joined by a weld and not having a mechanical joint.
Diesel multiple unit	A multiple unit train whose source of power is a diesel engine.*
Down (line)	The line from Ely to Norwich.
Ellipse	Network Rail's work planning system (formerly known as MIMS).
Fatigue cracks	Cracks in materials caused by repeated cyclic stresses.
Feet	The lower parts of rail sections.*
Four foot	The area between the two running rails of a standard gauge railway.*
Grandfather rights	The arrangement by which a product's use is allowed to be continued because the product existed prior to subsequent standards (or legislation) being brought into force.
Gauge	The distance between running rails.*
Gauge panel	A level crossing panel situated between the running rails.
Level crossing panel	A constructional unit, which with other units, forms a level crossing surface suitable to carry road traffic over the railway.
Lifeguard	A heavy metal bracket fitted vertically immediately in front of the leading end wheels of a train.*
Line speed	The maximum speed at which trains may run when not subjected to any other restriction.*
Rail clips	A manufactured metal device for fixing flat bottom rails either to a baseplate or a sleeper.*
Six foot	The space between two adjacent tracks.*
Tamped	The operation of lifting the track and simultaneously compacting the ballast beneath the sleepers.*
Track circuits	An electrical train detection system based on the principle of proving the absence of a train.*
Track circuit clips	A pair of clips connected by an electrical conductor used to operate track circuits in cases of emergency.
Up (line)	The line from Norwich to Ely.

Urgent Safety Advice	Guidance issued by the RAIB to the industry and the safety authority which deals with matters of immediate concern. The aim is to prevent another accident being caused by the particular deficiencies that have been found in the early stages of the investigation. There will be reason to suppose that these deficiencies are not a one-off and could happen elsewhere.
Web	The mid section of a rail between the head and the foot.*
Wet beds	An area of ballast contaminated with slurry.*
Wheel flanges	The extended portion of a train's wheel that contacts the rail head and provides the wheelset with directional guidance.*

Appendix C - Key standards current at the time

RT/CE/S/040 – Issue 1 December 1997	Level Crossing Surface Systems
NR/SP/TRK/040 – Issue 1	Level Crossing Surface Systems (formerly RT/CE/S/040 issue 1, 1997)
NR/SP/TRK/001 – Issue 2 October 2005	Inspection and Maintenance of Permanent Way
NR/SP/SIG/19608– Issue 2 February 2006	Level Crossing Infrastructure (Inspection and Maintenance) Handbook
Railtrack Engineering Safety Management - Yellow Book, Issue 2, 1997	Engineering Safety Management System

Appendix D - Urgent Safety Advice issued on 8 November 2006

RAIB SF-3.1.9.1
ISSUE : 2
27 OCTOBER 2005

URGENT SAFETY ADVICE

1. INCIDENT DESCRIPTION			
LEAD / INSPECTOR	[redacted]	CONTACT TEL. NO.	[redacted]
INCIDENT REPORT NO	0139	DATE OF INCIDENT	12th September 2006
INCIDENT NAME	Croxton Level Crossing		
TYPE OF INCIDENT	Derailment of passenger train		
INCIDENT DESCRIPTION	Class 170 unit derailed after striking dislodged panel on public road level crossing		
SUPPORTING REFERENCES			

2. URGENT SAFETY ADVICE	
USA DATE:	19 September 2006
TITLE:	Level Crossing Panels
SYSTEM / EQUIPMENT:	Holdfast level crossing panels – 1800 x 750 x 230mm approx.
SAFETY ISSUE DESCRIPTION:	The train was derailed by striking a displaced four foot Holdfast long level crossing block. The block was found to be unsupported by a sleeper at one end. The length of this free end of the block was approximately 420 mm from the closest supporting sleeper. The bracket at this end of the block, which is believed principally to be for the purpose of longitudinal block engagement, was deformed to a degree that indicates that it had been subject to high and/or repeated loads. (See photograph) The allowable vertical deflection is thought likely to be a precursor to the movement of the block from its fully seated position. When attending the site, the RAIB witnessed the lifting of a second block on the south westerly road carriageway adjacent to the six foot rail. One of the location brackets also exhibited deformation. This block's end was cantilevered by a ballast crib width. This indicates that the loading effects were not solely isolated to the incident block. The position of both blocks and associated deformed brackets were such that they would have been directly under the path of the wheels for the majority of road vehicles. The direction of road vehicle loadings was approaching that of diagonally across the blocks' corners. This is due to the angle present between the road carriageway and the railway.
CIRCUMSTANCES:	Passenger train derailed at 90 mph
CONSEQUENCES	Train ran derailed for 415 metres – no casualties

REASONS FOR ISSUE:	Attention should therefore be given to other crossings with similar characteristics that may present a risk to road and rail vehicles. Some initial guidance is given below. Items for particular attention: 1. Holdfast (or similar) blocks with dimensions 1800 x 750 x 230 mm, although blocks with other dimensions may be of concern. 2. Blocks which are directly under the path of road vehicle wheels, with attention to use by heavy goods vehicles and/or high road traffic frequencies. 3. Situations where the road carriageway crosses the railway at an angle. No exact figures can be given here, but the angle for the Croxton level crossing was in the order of 25 degrees. 4. External visible signs of differential levels in road surface between adjacent blocks and/or rail head level. 5. External visible signs of localised block road surface local wear, indicating high points and possible differential loading. 6. Could equally apply to blocks situated in the 4 foot or 6 foot. 7. Underside of block support conditions whereby the blocks' extreme ends are not supported directly by a sleeper. Associated indications of bracket deformation may be found. 8. In addition to point 7 above, insufficient ballast in the cribs is likely to contribute to bracket deformation and block movement, although it is believed that level ballast alone may not be sufficient to prevent block vertical movements, as ballast levels are subject to degradation over time. 9. Broken or missing running rail foot fastenings, possibly contributing to differential movements between the rail and the sleepers and/or the blocks. 10. Crossings where there have been reports from road traffic users of unevenness.

USA SIGN-OFF*			
INSPECTOR NAME:	[redacted]	CI / DCI NAME:	[redacted]
INSPECTOR SIGNATURE:	Electronic Copy	CI / DCI SIGNATURE:	Electronic Copy
DATE:	19th September 2006	DATE	19th September 2006

Appendix E - Railtrack certificate of acceptance for HoldFast panels

RAILTRACK

Certificate of Acceptance

Certificate No:	PA05/047	Issue: 1	Date: 24th May 1999
Effective date:	24th May 1999		Page 1 of 2

Product: HoldFast Full Depth Rubber Level Crossing.

Manufacturer: HoldFast Level Crossings Ltd.
P.O. Box 170, Bishops Cleeve,
Cheltenham,
Gloucestershire GL52 4US

General Conditions:

The product identified above is accepted for use on Railtrack infrastructure within the scope defined below.

Acceptance of any change to the product is liable to a demonstration that risk arising from the change has been assessed and is negligible. Corresponding change in product configuration shall be notified to Railtrack.

Any deficiency affecting the safety of the product shall be reported in writing to Railtrack.

Scope of Acceptance:

For use, as defined in Railtrack Line specification RT/CE/S/040, as (a) new public vehicular level crossings, (b) a replacement for entire level crossing surface systems on an existing public vehicular level crossing, (c) new/replacement private vehicular, footpath or bridleway crossings.

Specific Conditions:

In accordance with RT/CE/S/040 a user manual shall be supplied with each complete crossing.

See notes overleaf.

Signature:

[redacted]

[redacted] B.Eng (Hons), Ceng, FICE
Professional Head of Track Engineering

Issued by Railtrack Acceptance Services Floor 6 Railtrack House

Railtrack PLC Registered Office Railtrack House Euston Square London NW1 2EE Registered in England and Wales No. 2904587 http://www.railtrack.co.uk

Certificate of Acceptance

Certificate No: PA05/047 Issue: 1 Date: 24th May 1999
Effective date: 24th May 1999 Page 2 of 2

Notes: The following requirements in the current issue of RT/CE/S/040 are no longer applicable:

(1) Clause 10, demonstration that the Skid Resistance Value of the panel shall not reduce below 52 during the 15 year service life of the level crossing surface system.

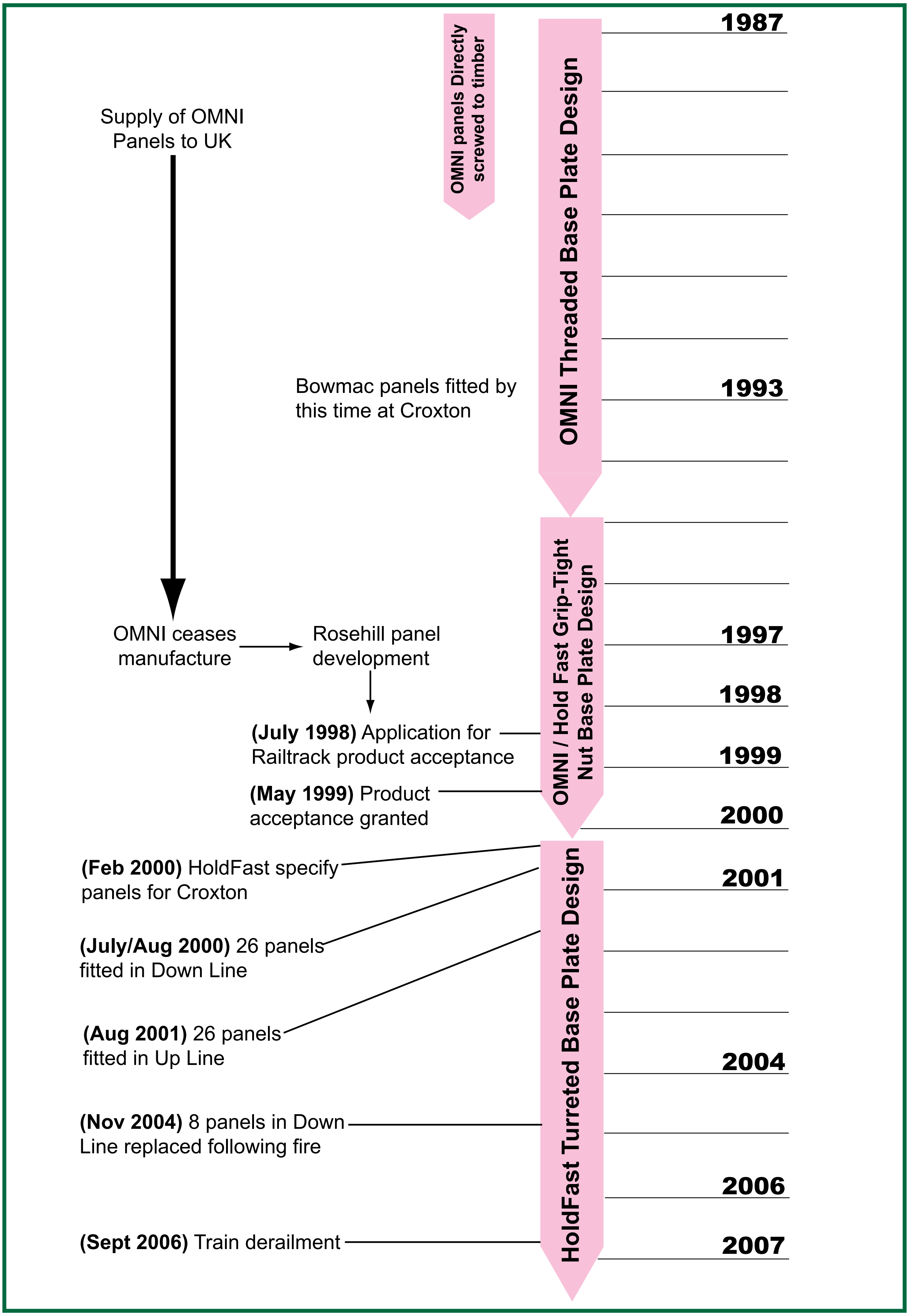
(2) Clause 14, type approval certification from the Health and Safety Executive.

It should be noted that Her Majesty's Railway Inspectorate (HMRI) is empowered to inspect specific level crossing systems and request information from Railtrack in order to be satisfied that such crossings comply with relevant requirements. Such information might relate to the surface system and, if deemed essential, HMRI is empowered to request that changes be made to the system.

DV
[redacted]

Issued by Railtrack Acceptance Services Floor 6 Railtrack House

Appendix F - Timeline of OMNI and HoldFast developments and Croxton level crossing fitment



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