Rail Accident Investigation Branch

Rail Accident Report

Freight train derailment at Lewisham, south-east London 24 January 2017

Report 04/2018
February 2018

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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Preface

The purpose of a Rail Accident Investigation Branch (RAIB) investigation is to improve railway safety by preventing future railway accidents or by mitigating their consequences. It is not the purpose of such an investigation to establish blame or liability. Accordingly, it is inappropriate that RAIB reports should be used to assign fault or blame, or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

The RAIB's findings are based on its own evaluation of the evidence that was available at the time of the investigation and are intended to explain what happened, and why, in a fair and unbiased manner.

Where the RAIB has described a factor as being linked to cause and the term is unqualified, this means that the RAIB has satisfied itself that the evidence supports both the presence of the factor and its direct relevance to the causation of the accident. However, where the RAIB is less confident about the existence of a factor, or its role in the causation of the accident, the RAIB will qualify its findings by use of the words 'probable' or 'possible', as appropriate. Where there is more than one potential explanation the RAIB may describe one factor as being 'more' or 'less' likely than the other.

In some cases factors are described as 'underlying'. Such factors are also relevant to the causation of the accident but are associated with the underlying management arrangements or organisational issues (such as working culture). Where necessary, the words 'probable' or 'possible' can also be used to qualify 'underlying factor'.

Use of the word 'probable' means that, although it is considered highly likely that the factor applied, some small element of uncertainty remains. Use of the word 'possible' means that, although there is some evidence that supports this factor, there remains a more significant degree of uncertainty.

An 'observation' is a safety issue discovered as part of the investigation that is not considered to be causal or underlying to the event being investigated, but does deserve scrutiny because of a perceived potential for safety learning.

The above terms are intended to assist readers' interpretation of the report, and to provide suitable explanations where uncertainty remains. The report should therefore be interpreted as the view of the RAIB, expressed with the sole purpose of improving railway safety.

The RAIB's investigation (including its scope, methods, conclusions and recommendations) is independent of any inquest or fatal accident inquiry, and all other investigations, including those carried out by the safety authority, police or railway industry.

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Freight train derailment at Lewisham, south-east London 24 January 2017

Contents

Summary

At about 05:30 hrs on 24 January 2017 two wagons within an aggregate train derailed on newly-laid track at Courthill Loop South Junction in Lewisham, south-east London. The first of the wagons ran derailed, damaging the track, then overturned spilling its payload of sand. There was major disruption to rail services while the wagons were recovered and the infrastructure reinstated. No-one was injured.

The new track had been installed during renewal work on the weekend of 14 and 15 January 2017. It was made up of separate panels of switch and crossing track, comprising the rails, point and crossing components and the supporting concrete bearers. Most of these track panels had been brought to site pre-assembled. A mechanical connector, known as a 'bearer tie', was used to join the concrete bearers that were designed to support rails on more than one panel. Network Rail originally developed the concept for this type of track in the mid-2000s; it is referred to as 'modular S&C'.

Planned follow-up engineering work was undertaken on the subsequent weekend. The derailment happened on the day after hand-back checks on completion of this work had confirmed that the track geometry was suitable for the passage of trains. It occurred because the first of the two derailed wagons, which was probably carrying an uneven payload, encountered a significant track twist, resulting in there being insufficient wheel load at the leading left-hand wheel to prevent its flange climbing over the rail head.

The track twist had developed rapidly following the hand-back because:

- the support offered by the track bed to the concrete bearers was poor; and
- the inherent flexibility of the bearer ties located between the two running rails made one side of the track more susceptible to the poor track bed support than the other.

Network Rail's engineering processes for specifying and developing modular S&C layouts were an underlying factor, in that they were inadequate for controlling the risks associated with flange climb derailment.

The RAIB has made five recommendations:

- Four are directed to Network Rail, concerned with:
  - the processes it uses to identify and manage risks associated with vertical track geometry features following track renewal and heavy maintenance; and
  - the design and validation of its modular S&C layouts.
- One is directed to RSSB concerned with understanding and managing the derailment risks associated with uneven loading of bulk hopper wagons.

The RAIB has additionally identified learning points concerning the management and planning of track installation work, and procedures for the routine maintenance of railway vehicles.

Introduction

Key definitions

1 Metric units are used in this report, except when it is normal railway practice to give speeds and locations in imperial units. Where appropriate the equivalent metric value is also given.

2 All mileages in this report are measured from a datum at Charing Cross station, London. The directions left and right are relative to the direction of travel of the train.

3 The report contains abbreviations and technical terms (shown in *italics* the first time they appear in the report). These are explained in appendices A and B.

The accident

Summary of the accident

4 At about 05:30 hrs on 24 January 2017 two wagons within freight train 6M90[1] derailed on newly-laid track at Courthill Loop South Junction in Lewisham, south-east London (figure 1). Train 6M90 was the scheduled 03:56 hrs service from the Grain aggregate terminal, on the Thames estuary, to a ready-mix concrete plant in Neasden, north London. The train was carrying sand.

5 Train 6M90 had been routed from the Up Slow to the Up Courthill Loop line (figure 2), and it was travelling at around 20 mph (32 km/h). The 16th wagon on the train derailed to the left as it traversed the track between the points on the Up Slow (871 points) and the *diamond crossing* on the Down Slow. It was then pulled back towards the loop lines before overturning, separating from the wagon in front, and coming to rest. The 17th wagon derailed as a consequence, but remained upright. The brakes automatically applied and brought the forward part of the train to a stand after running a further 190 metres along the Up Courthill Loop line. All the wheels of the 18th wagon, the last in the train, remained on the track. Figure 3 shows the location of the last three wagons after the derailment.

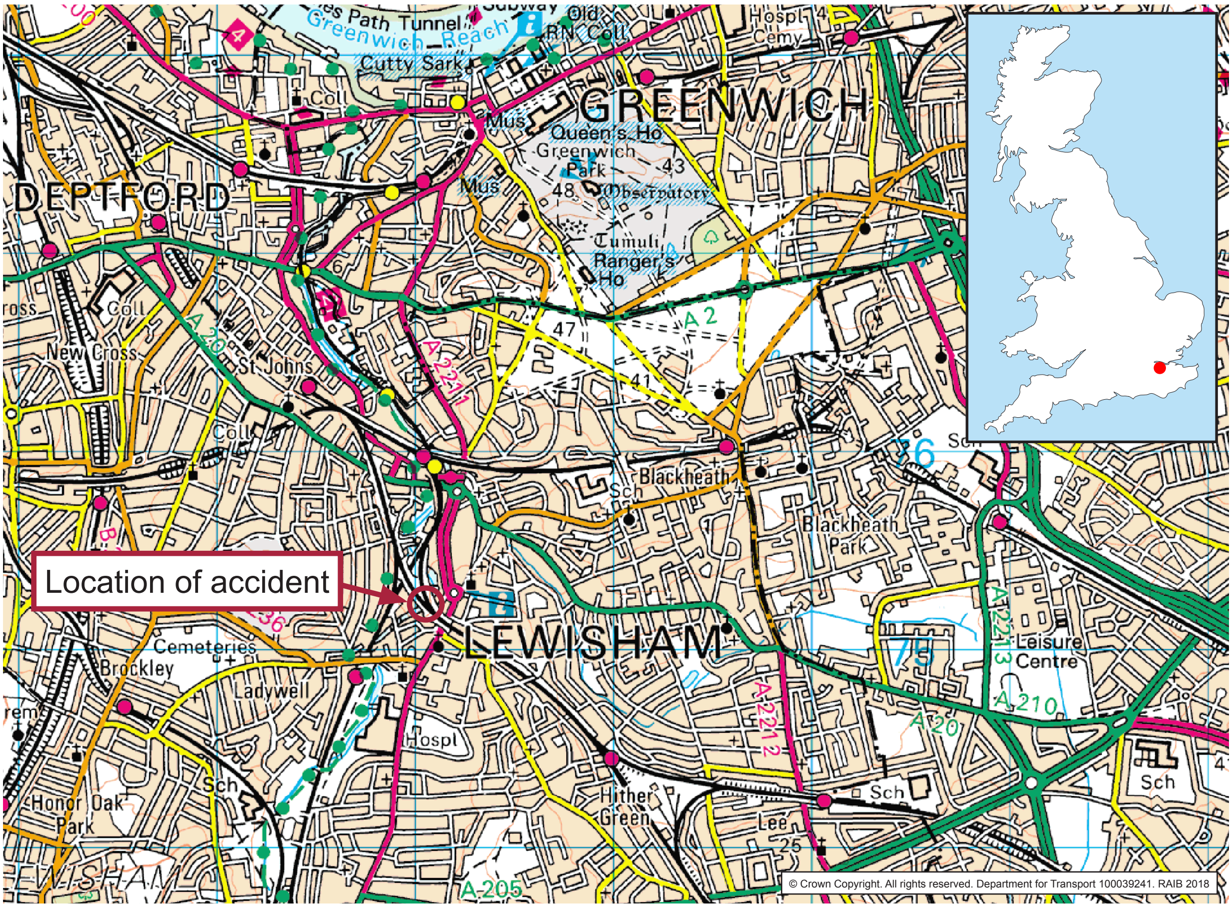

Figure 1: Extract from Ordnance Survey map showing location of the derailment

[1] An alphanumeric code, known as the 'train reporting number', is allocated to every train operating on Network Rail infrastructure.

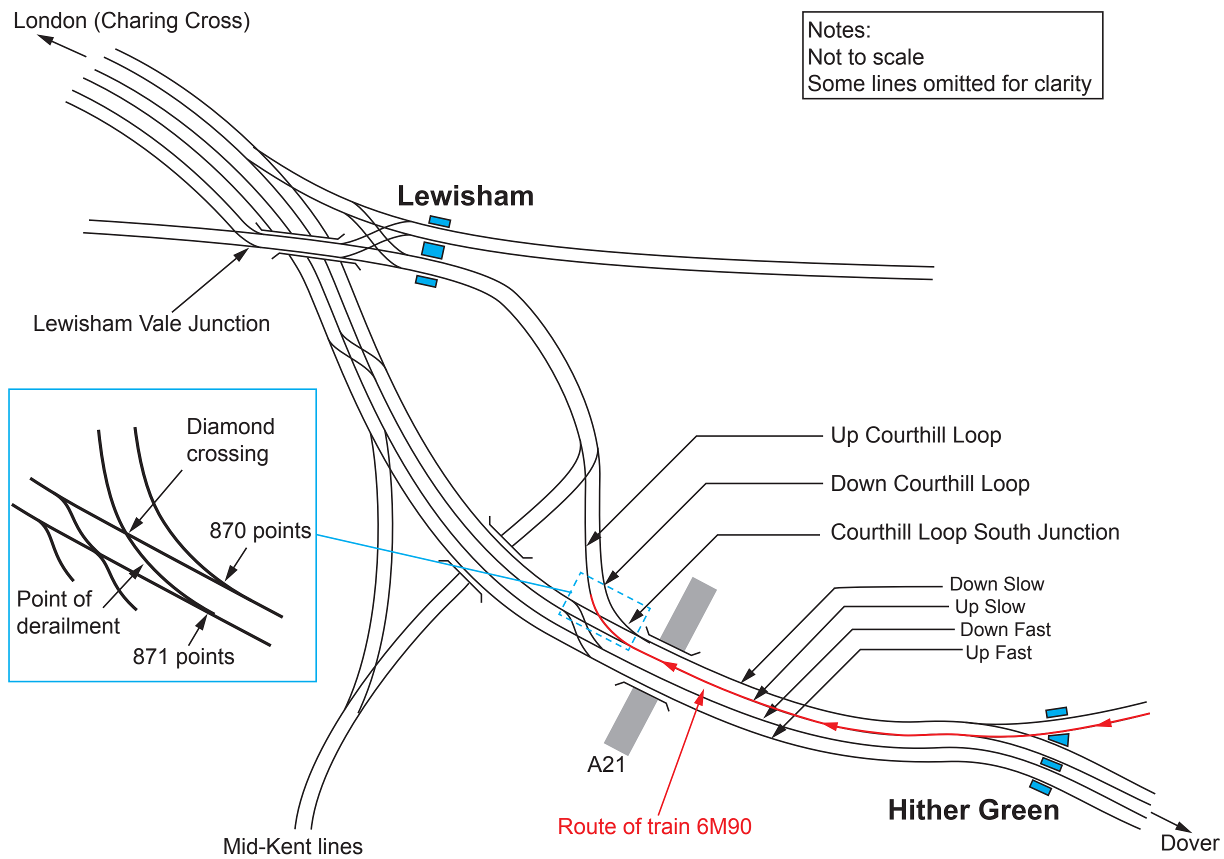

Figure 2: Track layout at Courthill Loop South Junction showing the route of train 6M90

Figure 3: Location of the last three wagons of train 6M90 after the derailment

6 There was major damage to the track and the derailed wagons. No-one was injured. However, a derailment of this nature has the potential to foul adjacent lines open to traffic and came close to doing so in this case.

Context

Location

7 Courthill Loop South Junction is located in central Lewisham at 6 miles 21 chains on the main line between London (Charing Cross) and Dover. Here the railway runs elevated on an embankment and comprises four lines: the Up Fast and Down Fast, and the Up Slow and Down Slow. The two Courthill loop lines (the Up Courthill Loop and the Down Courthill Loop) branch off the two slow lines at a double junction, enabling trains to be routed onto the Mid-Kent lines, which pass through Lewisham station and towards Lewisham Vale Junction.

8 After passing through Hither Green station, London-bound trains approach Courthill Loop South Junction on a right-hand curve and rising gradient before reaching Underbridge 125, which crosses the A21 (Lewisham High Street). On crossing the bridge the main line continues to curve right but starts to run downhill; at the junction, the Courthill loop lines curve further right and run more steeply downhill in order to meet the Mid-Kent lines at a lower level. Crossovers are also provided at the junction to enable trains to be routed between the fast and slow lines.

9 The following permanent speed restrictions apply at the junction:

- Fast and slow lines, 45 mph (72 km/h).
- Courthill loop lines, 20 mph (32 km/h).
- Crossovers, 40 mph (64 km/h).

10 The signalling in the area is controlled from London Bridge signal box. The tracks are electrified on the *third rail DC traction power system*. Neither the signalling nor the traction power system played a part in the derailment.

Organisations involved

11 Network Rail owns and manages the railway infrastructure where the derailment occurred; it is part of its South East Route. Network Rail also developed the concept of the ‘modular S&C’ (see paragraphs 54 to 57) involved and approved designs and products relating to it.

12 The S&C South Alliance oversaw the design of the new double junction at Courthill Loop South Junction and installed the new track. This is a renewal organisation, comprising a partnership of Network Rail, AECOM (an engineering consultant) and Colas Rail (a civil engineering contractor). Network Rail established the organisation in 2014 for the dedicated purpose of renewing S&C on the southern part of the national network. In summary, although there is some role overlap and interchangeability, AECOM takes the lead for design, Colas Rail for installation, and Network Rail for project management and design approval. The S&C South Alliance undertook the track renewal work for Network Rail, the client.

13 Vossloh Cogifer UK (VCUK) produced the detail design layout of the *switch and crossing* elements of the double junction. It also manufactured and preassembled the associated S&C panels. VCUK is one of three manufacturers that Network Rail has an arrangement with for the supply of this type of track.

14 The sand on train 6M90 was being carried for Aggregate Industries UK (Aggregate Industries). It operates the aggregate terminal at Grain, where its staff loaded the train.

15 GB Railfreight (GBRf) operated train 6M90 and completed pre-departure checks at the Grain terminal. GBRf leased the wagons that derailed from NACCO UK (NACCO), and subcontracted Wabtec Rail to maintain them. GBRf was the *entity in charge of maintenance*.

16 Network Rail, AECOM, Colas Rail, VCUK, Aggregate Industries, GBRf, NACCO and Wabtec Rail freely co-operated with the investigation.

Train involved

17 Train 6M90 comprised a class 66 diesel electric locomotive and a mixture of 18 JGA and HYA type bogie hopper wagons. All were loaded with a mixture of dredged sea sand and sand from crushed quarried granite. Table 1 is a summary of the last three wagons on the train, the first to derail and the two following. They are all of the JGA type, and are referred to in the report according to their position in the train.

	Wagon number	Gross wagon mass[2]	
Wagon 16	ERG 17320	87.12 tonnes	Derailed first and overturned
Wagon 17	ERG 17302	85.68 tonnes	Derailed and remained upright
Wagon 18	ERG 17316	88.58 tonnes	Remained on the track

Table 1: Last three wagons of train 6M90

18 JGA wagons have a welded steel hopper body, with three internal partitions and four sets of pneumatically-operated bottom discharge doors, mounted on a steel underframe. The underframe is supported on a pair of bogies, with a wheelbase of 1.8 metres and bogie centres 11.5 metres apart (figure 4). They are permitted to be loaded to a maximum gross wagon weight of 90 tonnes.

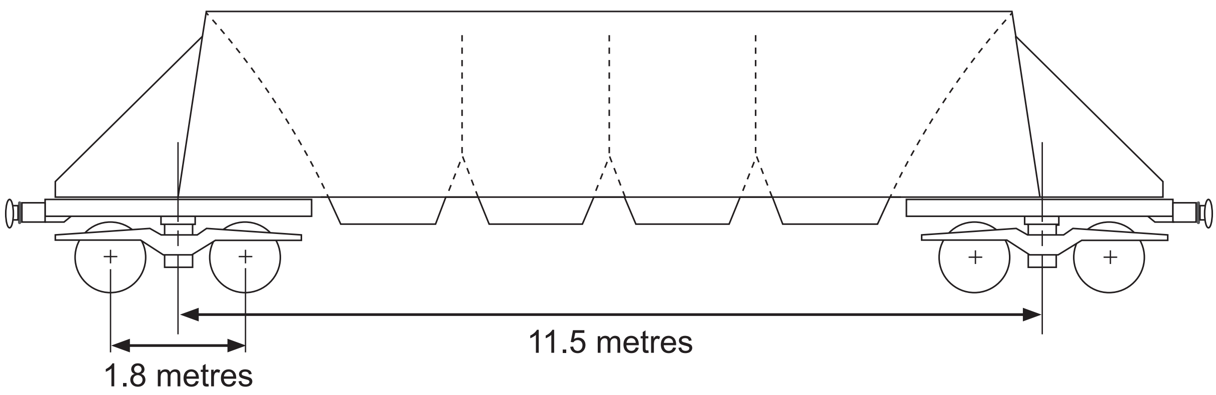

Figure 4: Simplified diagram of a JGA bogie hopper wagon

[2] Weighbridge measurement at Grain terminal.

19 The bogies are of the GPS 22.5 type manufactured by the Gloucester Railway Carriage and Wagon Company. They comprise a fabricated steel bogie frame supported on four pedestal primary suspension units, each with dual coil springs and a wedge-operated damper arrangement designed to provide a friction force that increases with carried load (figure 5). The wagon body is supported on a conventional UIC-type secondary suspension: a hemispherical *centre pivot*, with a composite friction liner, and a pair of *side-bearers*, each comprising a coil sprung top plate with a friction pad on the top and a metal *downstop* underneath (figure 5 inset).

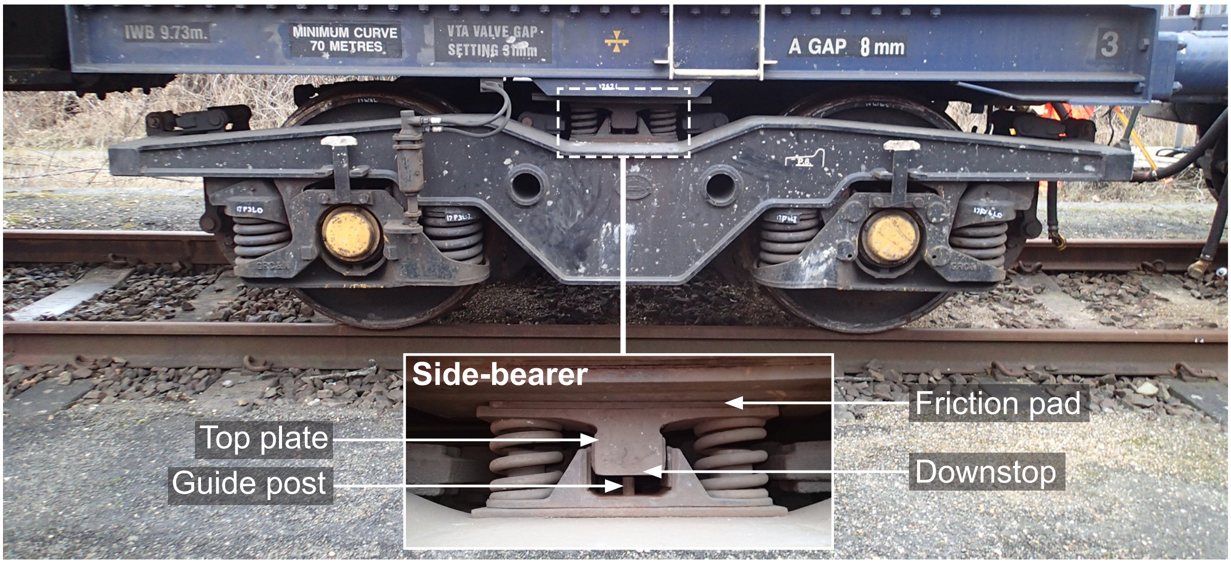

Figure 5: GPS 22.5 bogie

20 GBRf requires that the JGA wagon fleet it operates is maintained in accordance with a time-based programme: a weekly visual inspection, a four-monthly planned preventative maintenance task (PPM) and an annual vehicle inspection and brake test (VIBT). The wagons are scheduled for general repair, a maintenance process that involves dismantling, refurbishment and rebuilding, every nine-and-a-half years. Wagon 16 last underwent general repair in June 2015 at which its bogies were overhauled. The work required included renewal of the centre pivot friction liners and repair of the side-bearers. The last major maintenance task was the PPM on 25 November 2016 where additional work to one of the side-bearers was identified. At the time of the derailment wagon 16 was displaying a green card, which had been applied to highlight the need to repair a brake system air leak that had been found on 14 January 2017; this had no bearing on the accident (paragraph 68).

21 The wagons were modified in 2004 by wagon manufacturer W H Davis. The RAIB found limited information regarding their earlier manufacture, and no records of testing, calculation or approval work relating to derailment resistance performance.

Track involved

22 The newly-laid track at the double junction comprises *CEN56* rail supported on concrete *bearers* and sleepers, and stone ballast. In the vicinity of the derailment the rails are seated on rubber pads and are secured to the bearers with rail fastenings.

23 The strategic management of track assets on Network Rail routes is the responsibility of the Route Asset Manager for track. The Route Asset Manager responsible for the track at Courthill Loop South Junction had identified the need to renew the layout at the double junction because of serviceability issues with the old S&C layout: degrading timber bearers, component wear, *choked ballast*, *wet beds* and poor track geometry, which had resulted in the need for speed restrictions on the Down Slow line. In order to match the existing track geometry in the area, a like-for-like renewal was specified. At the time of the derailment the newly-laid track had yet to be handed back from the renewals project team to the Network Rail Track Maintenance Engineer who is responsible for the routine inspection and maintenance of track assets at Courthill Loop South Junction (paragraph 63).

24 Figure 6 is a diagram of the new track layout showing the limits of the renewal, the way it was subdivided into (modular) S&C panels and the main elements that VCUK supplied. It includes a cross-section through the layout close to where the derailment occurred showing the common concrete bearer that supported the rails on the Up Courthill Loop, the Down Slow and the Down Courthill Loop lines and the concrete bearer that supported the rails on the Up Slow line.

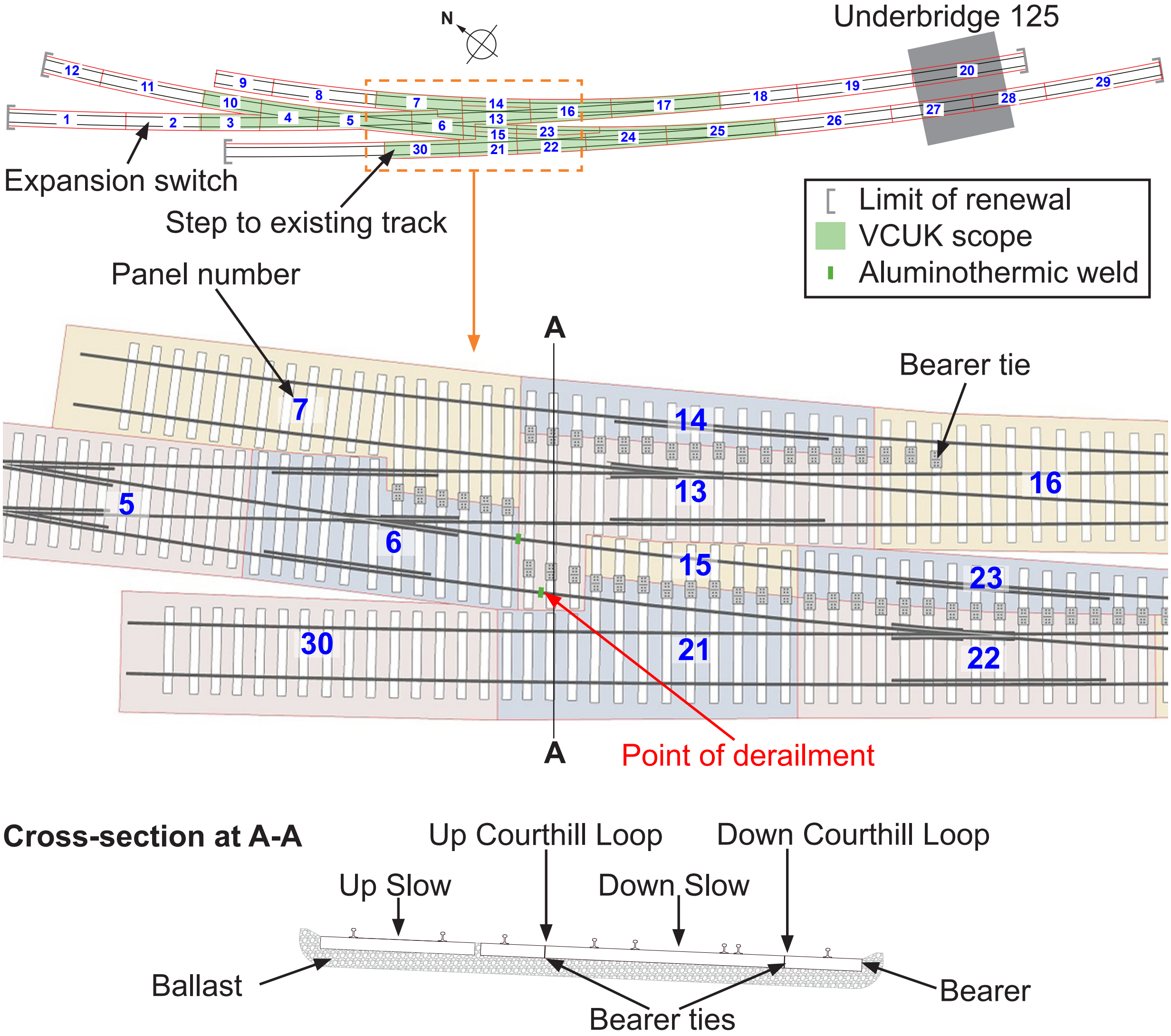

Figure 6: The new track layout at Courthill Loop South Junction

External circumstances

25 It was dark at the time of the derailment. An *accredited agent* appointed by the RAIB reported that the weather at the site was cold and cloudy, with little wind. The rails were 'bright' and without contamination, and while ground conditions were described as damp, there was no rain. A local weather station in Lewisham recorded an air temperature of 1 °C.

The sequence of events

Events preceding the accident

The track

26 The S&C South Alliance arranged to renew the double junction at Courthill Loop South Junction during a weekend *engineering possession* that started early on Saturday 14 January 2017. The work, referred to as the Core Works, was planned to be undertaken in pre-defined stages over seven work shifts. Each shift had a nominated lead engineer who was responsible for overseeing work affecting the installed track geometry, undertaking survey measurements to check compliance with design requirements and confirming that, when it needed to be handed back into traffic, it was safe for the passage of trains. The lead engineer on each shift was supported by an assistant.

27 After the engineering possession was granted, the Core Works proceeded by first cutting out and removing the track on the Down Slow line, the Down Courthill Loop line and the Up Courthill Loop line, east of the diamond crossing. After digging out the old ballast, levelling the *formation*, putting in the specified track bed treatment (a standard *geotextile* and *geogrid*), and then laying, levelling and consolidating the new ballast stone, the site was ready for the installation of the first S&C panels. Making reference to figure 6, by 18:30 hrs on the Saturday afternoon shift the panels on the northern section of the Down Slow line were reported as having been installed up to, and including, the diamond crossing (panels 1 to 5); and by 20:15 hrs work had started to cut out the track, and excavate and prepare the track bed for the remaining part of the renewal: the Up Slow line and the Up Courthill Loop line west of the diamond crossing.

28 Installation of the panels continued until around 01:00hrs on Sunday 15 January when the rail crane on site (the Kirow crane) broke down. *Road rail vehicles* were used to move some of the smaller panels in the meantime, but it was only possible to complete the panel installation work after the Kirow crane had been repaired. All the panels were reported as being in place and clamped[3] at 11:45 hrs, with the *top stone* laying complete around two hours later.

29 Two S&C *tamping machines* had been booked so that the lead engineer could adjust and correct the track geometry, and ensure the supporting ballast was consolidated. One was used to tamp the Up Slow and the Up Courthill Loop lines. The other was used to tamp the Down Slow (including the area around the diamond crossing) and the Down Courthill Loop lines. They completed one tamping pass on each line. Both machines finished their work and departed before the start of the next and final shift on Sunday evening.

30 The lead engineer for the final shift of the Core Works arrived at around 22:30 hrs on Sunday 15 January. One of his main tasks was to certify compliance of the track geometry so that the site could be handed back for service trains to run after the weekend engineering possession had been given up.

[3] The rail joints between the track panels were temporarily clamped in preparation for welding on the following weekend.

31 Together with the lead engineer from the earlier shift, he surveyed the installed track (the ‘as-built’ survey) and established that the vertical level of the Up Slow line was considerably lower than that specified. He also identified a visible transition step where the newly-laid track needed to rise to match the level of the existing track on the Up Slow line (figure 6). Because no tamping machines were left on site, he arranged for manual *lifting and packing* of the ballast to smooth the transition step. Additional measurements were made with a *track measurement trolley*. The only other significant defect found was a *track twist* that needed lifting and packing on the *expansion switch* north of the diamond crossing, on the Down Slow line (figure 6). ‘Form A: Track Geometry Certificate’ (Form A certificate), from Network Rail’s track engineering form TEF 3203, was used to certify compliance[4]. With the exception of the transition step on the Up Slow line, which was required ‘to be watched under traffic’, the track was generally described as being visually suitable for train operation. While some out-of-tolerance values were recorded elsewhere (mainly concerning alignment and track gauge), these were 5 mm or less, or on track that had not been renewed.

32 The engineering possession was given up at 07:26 hrs on Monday 16 January, four-and-a-half hours later than had been planned. The weather reported on site at the time included periods of sun and rain, with an air temperature of 3 to 4 °C. Staff sent to inspect the transition step on the Up Slow line reported that ‘trains were riding OK over it’.

33 The S&C South Alliance planned to carry out further work during an engineering possession on Sunday and early Monday morning of the following weekend. It referred to this as the follow-up work. In addition to welding the clamped rail joints (paragraph 28), one of the main tasks was to check and correct the track geometry. Nominated lead engineers were on site throughout to oversee the related work and certify compliance.

34 The engineering possession for the follow-up work was granted at 02:26 hrs on Sunday 22 January; a lead engineer completed an as-built survey of the track and found that it had settled by around 20 mm over the intervening week. Witness evidence indicated that he considered this to be reasonable. By 04:00 hrs the two tamping machines that had been booked were on site. After being set up with the geometry corrections required, one machine completed a tamping pass over the Up Slow line while the other tamped the Down Slow line. Witness evidence indicated that afterwards the lead engineer was concerned that the lift achieved on the Up Slow line was not enough and that a step remained at the transition. He was about to be relieved by the lead engineer for the next shift and asked for the machine on the Up Slow line to tamp the line again; in the meantime the tamping machine on the Down Slow line moved to complete a tamping pass over the Down Courthill Loop line. The two machines completed this work and left site by around 10:30 hrs. No tamping had been undertaken on the Up Courthill Loop line. However, manual lifting and packing work was later undertaken with the intention of consolidating the supporting ballast.

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[4] The Form A certificate is one of a series of certificates that Network Rail uses to certify infrastructure conformance prior to hand back into traffic. The Form B to F certificates relate to track components, rail stressing, signalling, traction power supply, site condition and speed restriction signage. The Form G certificate is used to certify overall infrastructure compliance (paragraph 37).

35 The lead engineer who had been first on site returned later on Sunday[5]. One of his main tasks was to certify compliance of the track geometry before the site could be handed back for trains to run. When making measurements of the Up Courthill Loop line with a track measurement trolley, he found a twist fault greater than the hand-back requirement of 1 in 300[6] and gaps under the short bearers on panel 15, one of the *spine panels* on the right-hand side of the Up Courthill Loop line, which was on the approach to the point of derailment.

36 He used a track measurement gauge to locate the twist fault and requested additional lifting and packing to correct it. He also arranged for additional packing under the three short bearer sections on panel 13 that were on the left-hand side of the track, around the point of the derailment. He used the track measurement gauge and re-measured a twist of 1 in 333. He recorded this on the Form A certificate, ticked the box to confirm that the maximum twist was within tolerance (less than 1 in 300) and, at 00:35 hrs on 23 January, signed to certify that he was satisfied that the track on the Up Courthhill Loop line was safe for trains to run at the maximum permitted speed of 20 mph (32 km/h) (paragraph 9); see Appendix C.

37 The person authorised to certify conformance of the overall infrastructure (the authorised person) was on site and discussed the track condition with the lead engineer. He held the railway competency allowing him to hand back track at speeds up to 90 mph (145 km/h). He confirmed receipt of the Form A certificate and, at 01:00 hrs, signed the overall Form G certificate deeming the track safe. The renewal site was handed back into traffic at 01:49 hrs.

The train

38 The train that was to form 6M90 arrived at the terminal at Grain at 23:41 hrs on 23 January with 19 empty wagons. It was shunted over the weighbridge at the terminal to establish the wagon tare weights. Aggregate Industries staff loaded each wagon in the same manner: from a stockpile of sand on the left of the train using a mechanical *front-end loader*. Load sensors on the front-end loader were used to control the amount of sand tipped, and the train was progressively drawn forward over the weighbridge to confirm that the maximum gross wagon weight was not exceeded (paragraph 18). GBRf's *train preparer* had identified that one of the wagons had faulty discharge doors when the train arrived. The wagon was loaded in error and needed to be withdrawn, reducing the number of wagons on the train to 18. Aggregate Industries staff reported no other loading issues.

39 After completing a satisfactory brake test, the train preparer collected and signed the *train document,* and handed it to the driver. Train 6M90 departed from Grain terminal on time at 03:56 hrs on 24 January. It was routed via Hoo Junction and Dartford Junction, and joined the Up Slow line at Hither Green station (paragraph 8). It remained on time and the driver reported no issues with the train or its operation prior to the derailment.

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[5] He was a qualified civil engineer with over 17 years track experience. He held a range of technical railway competences including surveying, excavation, tamper control and track hand-back. He was also assessed as competent to undertake the role of *contractor's responsible engineer (construction)*, and was appointed as result.

[6] When handing a renewal site back, Network Rail requires that track twist is measured over a three metre base. The same base is used to monitor track twist during routine maintenance.

Events during the accident

40 The driver of train 6M90 reported the controlling signal aspect for Courthill Loop South Junction changing from a yellow to two yellow aspect as he approached. It then cleared to display a green aspect and the route indicator showed that the train was being routed onto the Up Courthill Loop line. The driver applied the throttle for a short period, and then allowed the train to coast. It was 05:28:30 hrs. He then observed the *brake pipe* pressure falling. He attempted to recharge the brake pipe, but the pressure continued to decrease and the brake automatically applied, bringing the train to a stand.

41 The driver contacted the signaller using the GSM-R radio; it was 05:30 hrs. They agreed that the driver would walk back along the train to investigate. He was surprised to find that the last three wagons had separated from the train; he had not heard or felt anything to suggest this. Concerned that a derailment might have occurred, the signaller took immediate action to stop a train that was approaching on the Down Courthill Loop line. The *electrical control operator* became aware of traction power supply circuits tripping (automatically switching off) around the same time and took separate action to isolate the traction power in the area. This tripping of the traction power supply was almost certainly the result of damage from train 6M90.

42 On walking further back, the driver saw that wagons had derailed and that one had overturned. He notified both the signaller and the electrical control operator accordingly. He then called the GBRf control office.

Events following the accident

43 Network Rail took action to stop all trains in the area and to divert and terminate services.

44 At 12:38 hrs it was able to re-open the fast lines, but kept the slow and loop lines closed for recovery of the rolling stock and repair of the railway infrastructure. The railway was not fully re-opened until 12:25 hrs on 30 January 2017, six days after the derailment.

Key facts and analysis

Background information

Post-derailment examination of the track

45 The RAIB inspected the track and found four sets of marks on the left-hand rail of the Up Courthill Loop line that were consistent with the flanges of the left-hand wheels of the four *wheelsets* of wagon 16 climbing on to the rail head, running along the top and then dropping into the *six-foot* between the Up Slow and Down Slow lines. The first mark started close to an *aluminothermic* weld located within the three short bearer sections on the left-hand rail of panel 13 (paragraph 36). The RAIB found complementary marks on the right-hand rail showing that opposite wheels of the wheelsets had dropped into the *four-foot* of the Down Slow line after the *crossing nose*, the flanges of two of the wheels having first run on top of the *wing rails.* Distortion of the track further along the Down Slow line, and other damage, indicated that the leading end of the first wagon to derail was then pulled to the right by the wagon ahead, which was correctly running on the Up Courthill Loop line. The forces involved would explain the separation of the train, between wagon 15 and 16, and wagon 16 overturning.

46 The *gauge face* and the rail head close to the area of the aluminothermic weld were relatively rough due to grinding work that had been undertaken to dress the weld (figure 7). Similar grinding work had been done to dress an aluminothermic weld around 800 mm further along the Up Courthill Loop line on the right-hand rail.

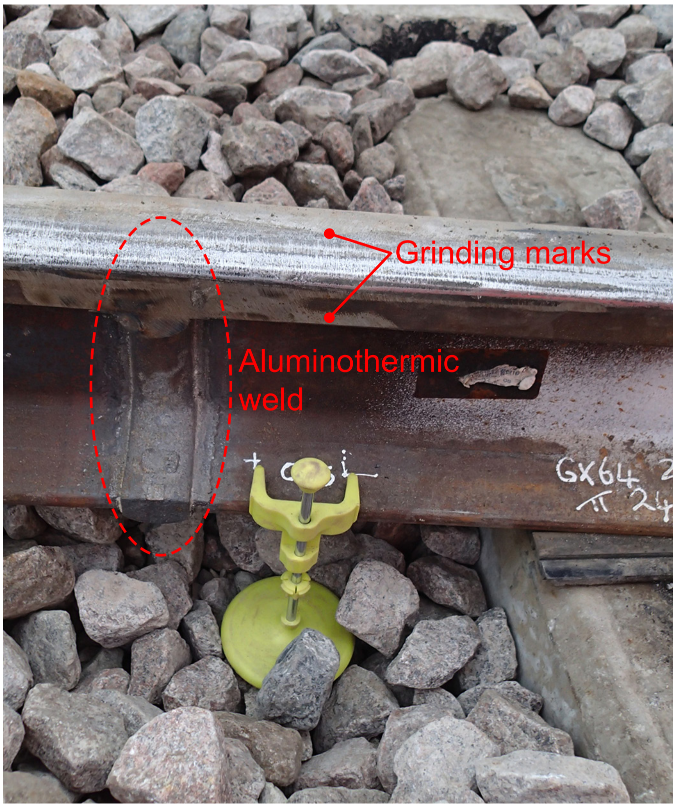

Figure 7: Aluminothermic weld on the left-hand rail of panel 13 (photograph shows a void meter used to measure track deflection)

47 The RAIB used *void meters* to measure the amount by which the track on the Up Courthill Loop line deflected under the weight of a loaded wagon. It also witnessed Network Rail's survey of the track on the Up Courthhill Loop line in its undeflected state. This included measurement of the track *cant* and gauge (using a track measurement trolley), vertical and lateral position of both rails (using *total station survey* equipment) and rail profiles. The track measurement trolley data showed that the static cant (the cant of the track without the effect of wheel loading from passing trains) varied on the approach to where the wheelsets started to derail (the point of derailment), resulting in a maximum static twist of 1 in 130 over three metres. The effect of the measured track deflection caused additional cant variation, resulting in a maximum dynamic twist (the twist of the track including deflection due to wheel loading from passing trains) of 1 in 97 over three metres. This is close to the immediate action limit of 1 in 90 that is defined in Network Rail standard NR/N2/TRK/001, 'Inspection and maintenance of permanent way', which requires trains to be immediately stopped (in the event of detection during routine maintenance).

48 Figure 8 is a simplified diagram of the key features of the track in the area of the derailment. It shows the identified path of the first derailed wheelset, the nominated point of derailment and where void measurements were made. Figure 9 is a plot of the static and dynamic cant that was measured.

Vehicle derailment risk on twisted track

49 The witness marks from the wheels of wagon 16 showed that the mechanism of derailment was flange climbing of a left-hand wheel of wagon 16 (paragraph 45). There is a risk of derailment by flange climb when the ratio of the lateral force of the wheel flange on the rail (Y) to the vertical wheel load (Q), known as the Y/Q derailment quotient, exceeds a critical limit value. Because of this, the lower the wheel load (or the higher the lateral force), the greater the risk of derailment.

50 Track twist presents a general derailment hazard for railway vehicles because it results in cant differences between wheelsets that can induce significant torques within the suspension system and wagon structure. The torques are reacted at each wheelset by the wheel load increasing at one wheel and reducing correspondingly (unloading) at the other.

51 Two types of track twist affect bogie vehicles:

- Short base twist - a cant difference over the bogie wheelbase that induces a torque within the bogie frame and primary suspension of an individual bogie.
- Long base twist - a cant difference over the bogie centres that induces a torque within the complete vehicle, the primary and secondary suspensions of both bogies and the wagon body.

The effects of short and long base twists on reducing the wheel load at an individual wheel are additive if the twists are of the same sense. This is recognised in current railway vehicle derailment resistance assessments such as that defined in Appendix A of Railway Group Standard GM/RT 2141, 'Resistance of railway vehicles to derailment and roll-over'. This describes a vehicle acceptance test based on measuring wheel load changes due the combination of a long base twist (of 1 in 300) and a short base twist (of 1 in 150).

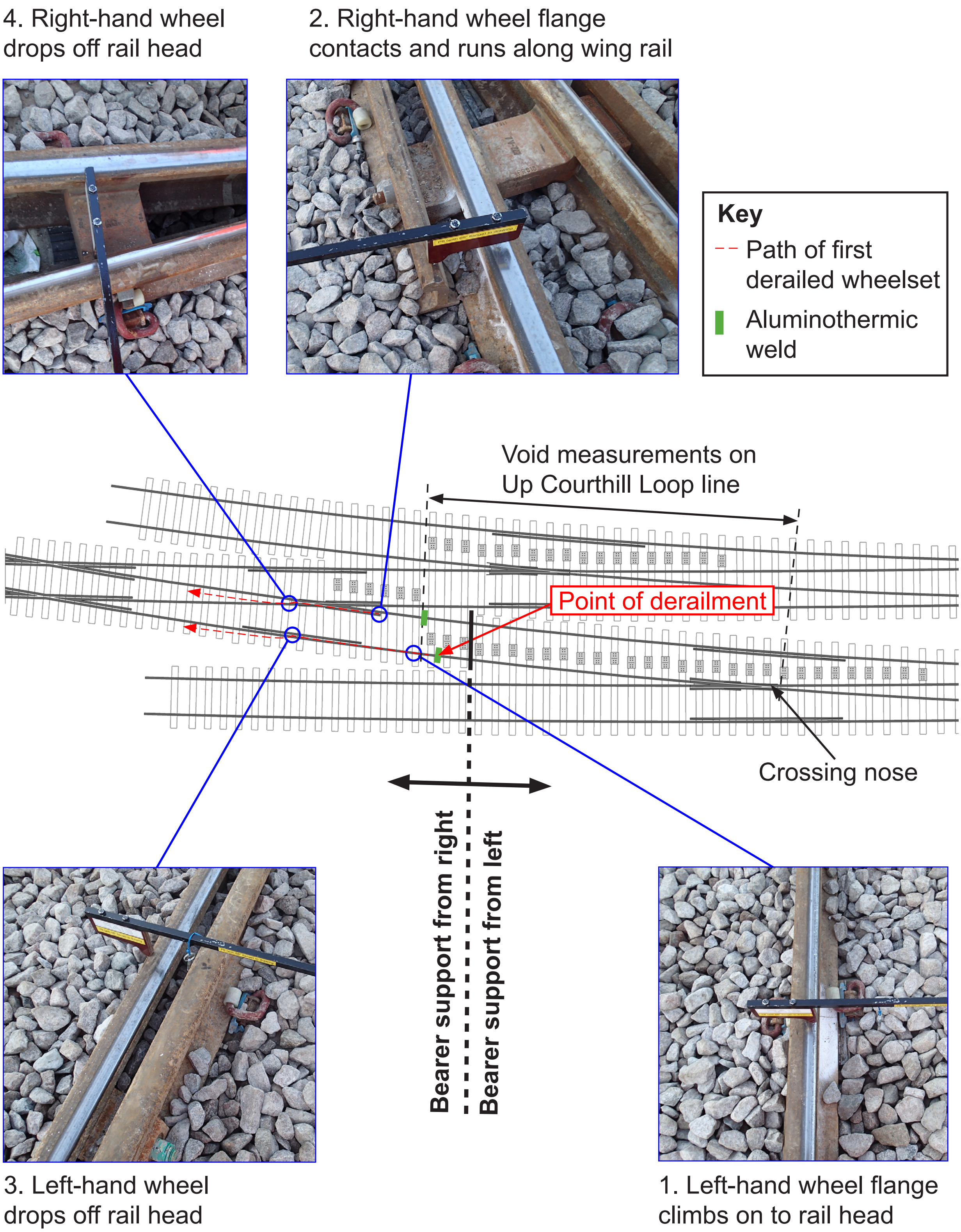

Figure 8: Key features of the track in the vicinity of the point of derailment (photographs show wheelset template used to identify and match derailment marks)

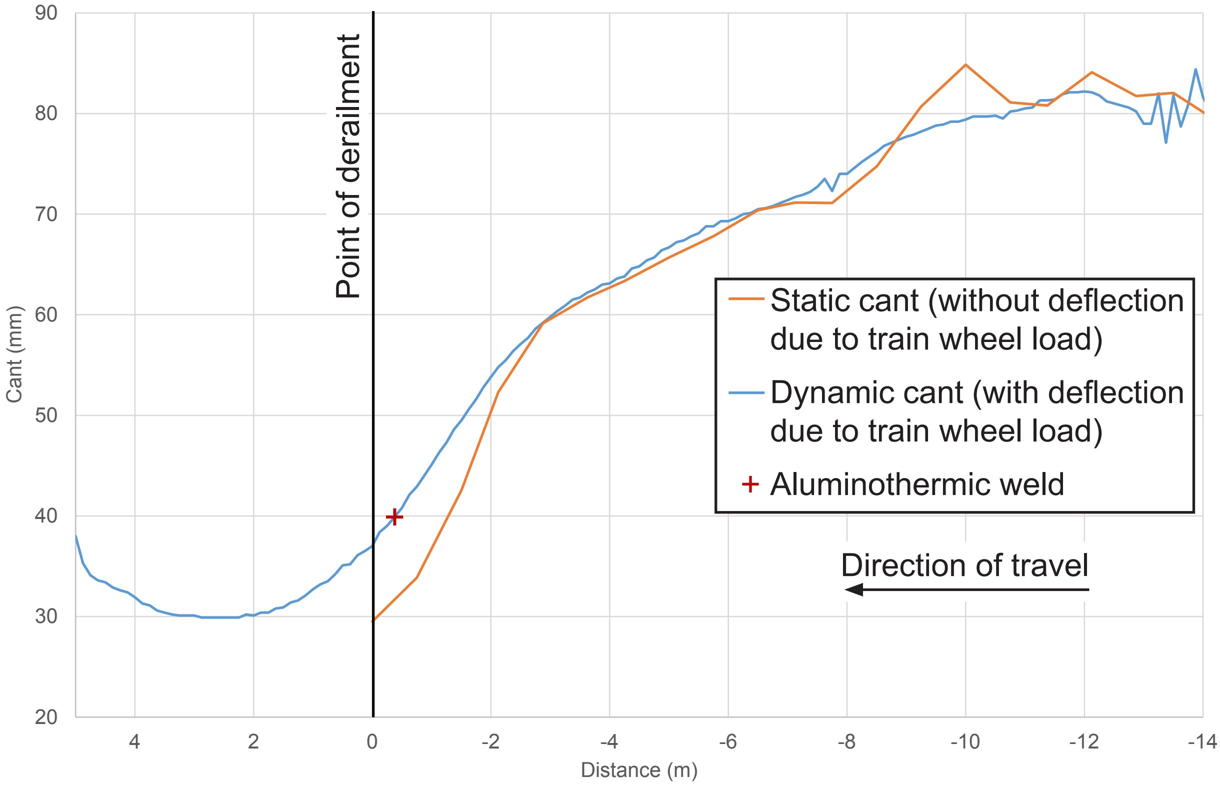

Figure 9: Static and dynamic cant measured on the Up Courthill Loop line after the derailment

52 The RAIB observed that both the static and dynamic cant on the approach to the point of derailment (figure 9) resulted in short and long base twists that were of the same sense and that would cause wheel unloading at the leading left-hand wheel.

53 Network Rail carries out routine maintenance of its track in accordance with company standard NR/L2/TRK/001. This requires that track twist is measured over a three metre base. For bogie vehicles, it is apparent that this focusses on the derailment risk associated with short base twists. Network Rail's Form A certificate (paragraph 31) requires assessment against the same track twist measurement base prior to handing back a track renewal site into traffic. Long base twists are generally associated with cant differences occurring over a longer distance, which are sometimes referred to as cant gradients. Cant gradients are often an intended design feature, used to allow track to transition between different specified levels of cant.

Modular S&C

54 Network Rail started to develop the concept of modular S&C in the mid-2000s with the objective of reducing the time to renew a single element of S&C (a *point end*) to eight hours. It also wanted to be able to install equipment that had been pre-assembled and tested in a controlled factory-type environment to minimise on-site quality issues. It adopted a method that involved transporting pre-assembled S&C panels, which could be laid in place and joined together on site. The project included the acquisition of *tilting wagons* and Kirow rail cranes (paragraph 28), to transport the panels and lift them on site, and the development of point operating equipment and other track-mounted electrical equipment that could be installed without the need for extensive on-site wiring work.

55 Conventional S&C uses relatively long continuous bearers to support the rails, particularly in areas where lines diverge, cross and come together. With modular S&C, the bearers need to be split into shorter lengths (bearer sections) so that the track panels can be made small enough to enable them to be transported to site. A significant task was to develop a means of joining the bearer sections together on site. Network Rail decided to seek an engineering solution from industry suppliers and issued a competitive tender. It selected a mechanical connector comprising an inverted U-shaped steel channel, designed to fit over the abutting bearer ends (separated by a resilient pad) and then screwed into place (figure 10). In responding to Network Rail's tender, the successful tenderer described the mechanical connector as being 'rigid'; suggesting that the connected bearer sections would behave like a single continuous long bearer.

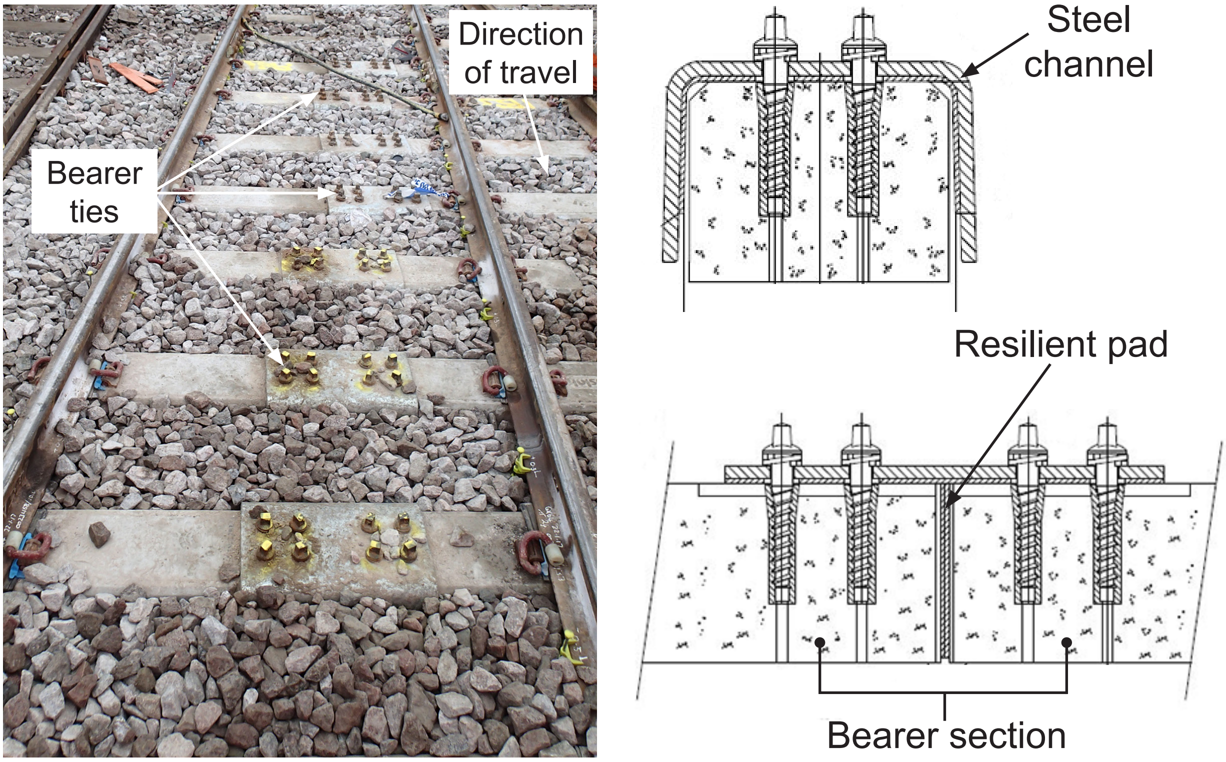

Figure 10: Bearer ties on the Up Courthill Loop line (drawings courtesy of Network Rail)

56 Network Rail refers to the connector as a 'bearer tie' and it now owns the design. Network Rail recognises the bearer tie as a track engineering standard design and has published an associated series of standard permanent way drawings (RE/PW drawings). Network Rail has issued a Certificate of Acceptance approving the bearer tie's use and sources the components from several manufacturers. Network Rail has also produced standard design arrangements of modular S&C layouts that define where bearer ties are to be positioned on a number of common junction and crossover types. These are also published as RE/PW drawings. Network Rail often refers to these as RE/PW general arrangement drawings.

57 Bearer ties of this type are now widely used in new S&C layouts.

Renewal of the track at Courthill Loop South Junction

58 Network Rail planned and managed the renewal of the double junction by following its eight-stage process for the Governance for Railway Investment Projects (GRIP).

59 In support of work up to GRIP stage 3 (option selection), Network Rail arranged survey work to establish the geometry of the existing infrastructure and an investigation of the local ground conditions (track bed investigation)[7]. The track bed investigation used a variety of techniques, including a desk top study, trial pits, ballast sampling and ground-penetrating radar. The report described the geology at the site as 'made ground comprising ash, rubbish, fill and slag', which was underlain by gravel and sand. It concluded that drainage in the track bed was good and would continue to rely on the soak away properties of the ground. It also specified the required track bed treatment (paragraph 27).

60 The requirement specification for the renewal was signed off on behalf of the Route Asset Manager for track on 1 June 2016. It prescribed that the track at the double junction was to be renewed on a like-for-like basis (paragraph 23). Consistent with the track bed investigation report, track bed treatment was required but no drainage. No other renewal option was to be considered.

61 The S&C South Alliance developed and detailed the design of the S&C layout during GRIP stages 4 (single option development) and 5 (detail design). Although the requirement specification did not explicitly define the type of S&C to be used, the design team explained that it would only be possible to complete the renewal, in the time during which the railway was closed, if it was designed using modular S&C technology. By 10 August 2016, Network Rail's *designated project engineer*, working within the S&C South Alliance, and the Route Asset Manager for track had signed off the outline design of the S&C layout (the Form A layout drawing). The Form A layout drawing was then shared with VCUK, the strategic permanent way supplier specified by Network Rail's central supply chain organisation.

62 VCUK used the Form A layout drawing to develop the manufacturing drawing of the elements it was to produce and supply (paragraph 24), essentially the *turnouts* for 870 and 871 points and the diamond crossing. This work included subdividing the layout into S&C panels and finalising the position of the bearer ties. The detail of the layout was defined on a drawing known as the '1 in 50' layout. Network Rail's designated project engineer reviewed and approved the '1 in 50' layout drawing and, on 20 December 2016, signed VCUK's factory layout inspection report to accept delivery. In the meantime, the S&C South Alliance progressively updated and added detail to its layout drawing of the double junction, culminating in the issue of the 'approved for construction' version (the AFC layout drawing).

63 The renewal advanced to GRIP stage 6 (construction, test and commissioning). The installation team identified a mismatch between their initial site survey and that used for the design. The designers remedied the anomaly, and the installation team visited the site on 8 January 2017 to confirm that they were satisfied that the work planned for the next two weekends could go ahead. The work commenced (paragraphs 26 to 37) and the renewal project team continued to be responsible for the track, handing it back between engineering possessions so that trains could run in the meantime. The derailment occurred during GRIP stage 6.

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[7] Staff from the S&C South Alliance supported Network Rail with this work.

Examination of the train

64 The RAIB examined wagon 16 after it had been re-railed and recovered from site and arranged for it to be partially dismantled to allow the bogie and suspension components to be inspected.

65 The RAIB found that one of the primary springs on the left-hand side of the leading bogie had fractured and that, given the degree of corrosion on the fracture face, the spring had been in this condition at the time of the derailment (figure 11).

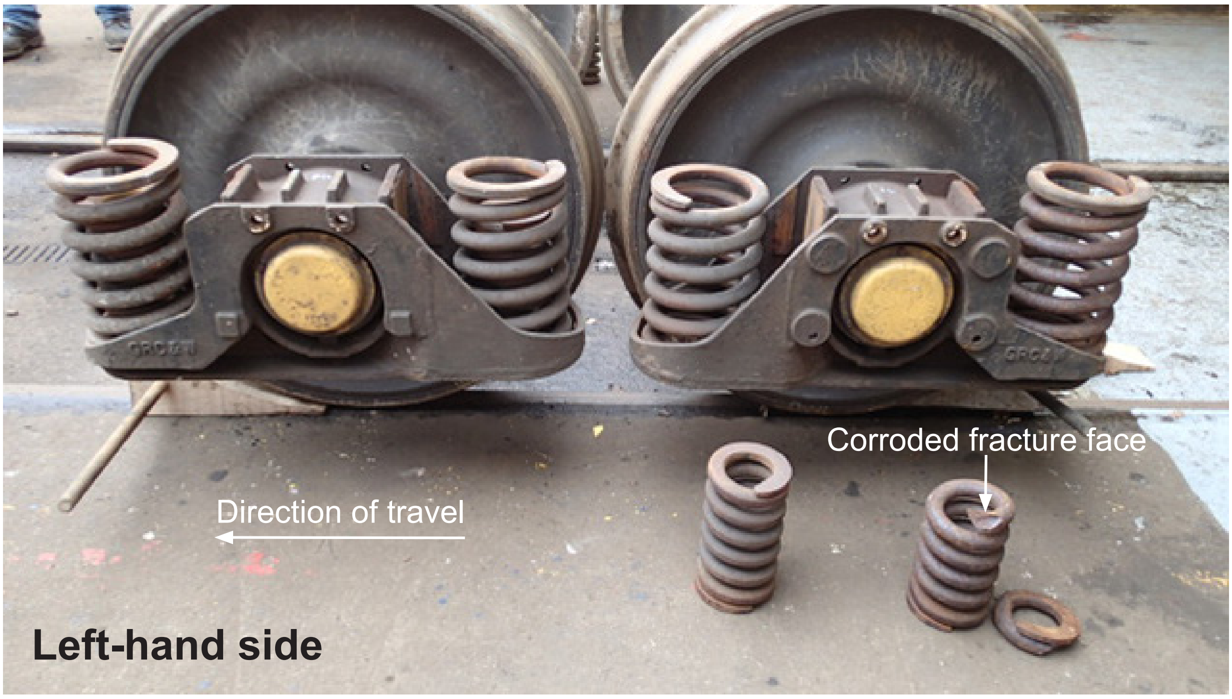

Figure 11: Fractured primary spring found on leading bogie of wagon 16

66 All the side-bearer units on the wagon had become dislodged, and a number of secondary springs had fractured, including one on the left-hand side of the leading bogie (figure 12). The dislodgement was almost certainly as result of the wagon running derailed or overturning. Although the fracture faces were bright and there was little corrosion, detailed examination revealed marks that indicated that the fracture had been growing progressively (figure 12 inset) and it is possible that the spring failed beforehand. The RAIB found a spring that had failed in a similar manner on wagon 18, one of the wagons that did not derail. A more detailed examination of side-bearer components revealed evidence that some guide posts had failed and shortened, and that some had been contacting the underside of the top plate (figure 13). While this suggested reduced side-bearer gaps that may, in certain circumstances present an increased derailment risk, more detailed examination discounted this as a factor in this derailment (paragraph 75).

67 With the wagon body lifted, the RAIB found some evidence of out-of-plane distortion of the bogie frames and the wagon underframe. However, as this would have tended to increase the wheel load at the leading left-hand wheel it did not increase the risk of this derailment, and so it has been discounted as a potential factor.

68 The RAIB additionally arranged for a brake test to investigate the significance of the reported air leak defect (paragraph 20). It was found that the leak was unlikely to have resulted in a permanent brake application (dragging brake), and it has also been discounted as a potential factor.

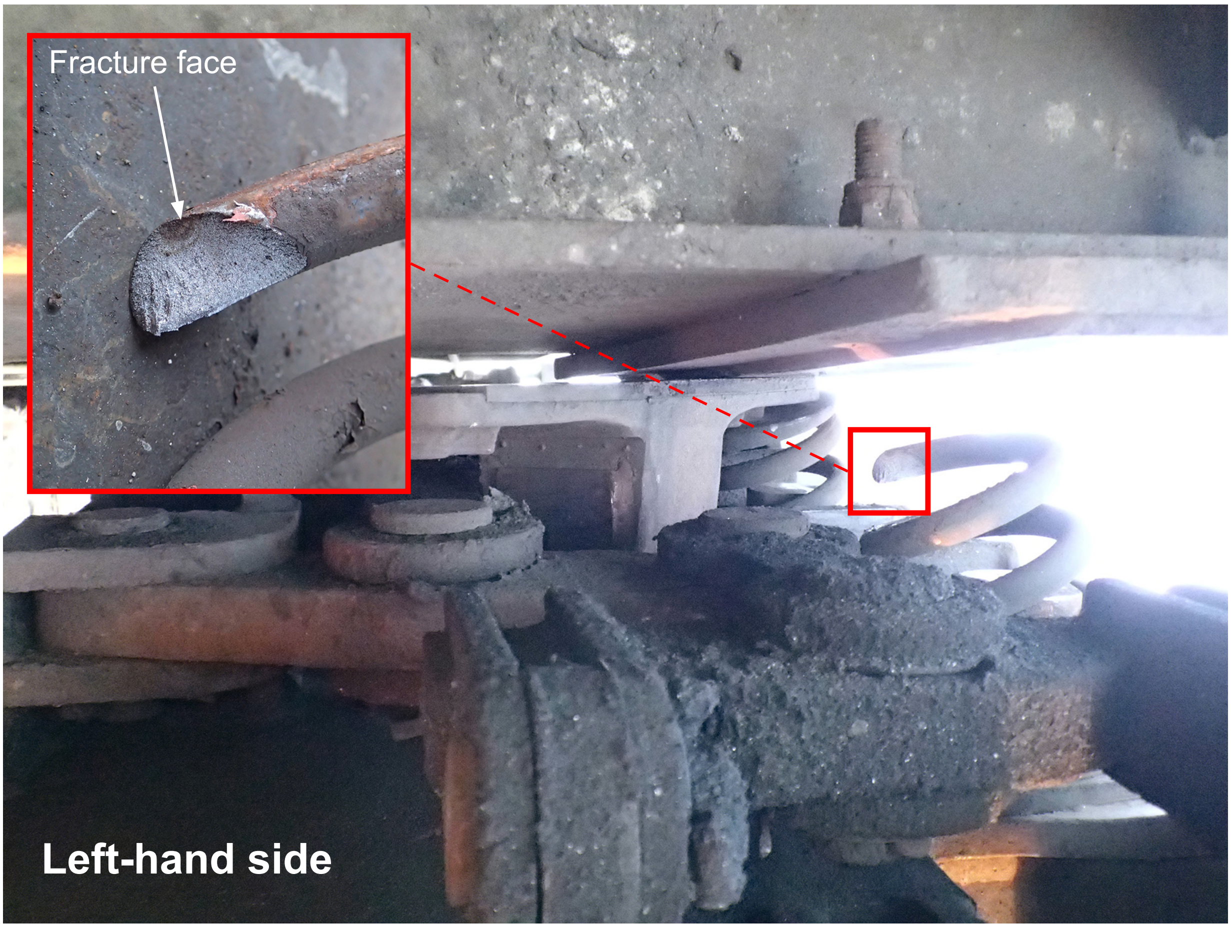

Figure 12: Dislodged side-bearer and fractured secondary spring found on the leading bogie of wagon 16

69 The RAIB retained wagon 18 for reference purposes. It observed that the sand was loaded to the right-hand side and that this had resulted in the side-bearer gaps closing on that side of the wagon (figure 14). It subsequently arranged for the wheel unloading behaviour of the wagon to be measured on the track twist conditions defined in Appendix A of GM/RT2141 (paragraph 51) and a simulation of that measured on the approach to the point of derailment (paragraph 47). These measurements were used to check the behaviour of the computer simulation model used to study the derailment mechanism (paragraph 72).

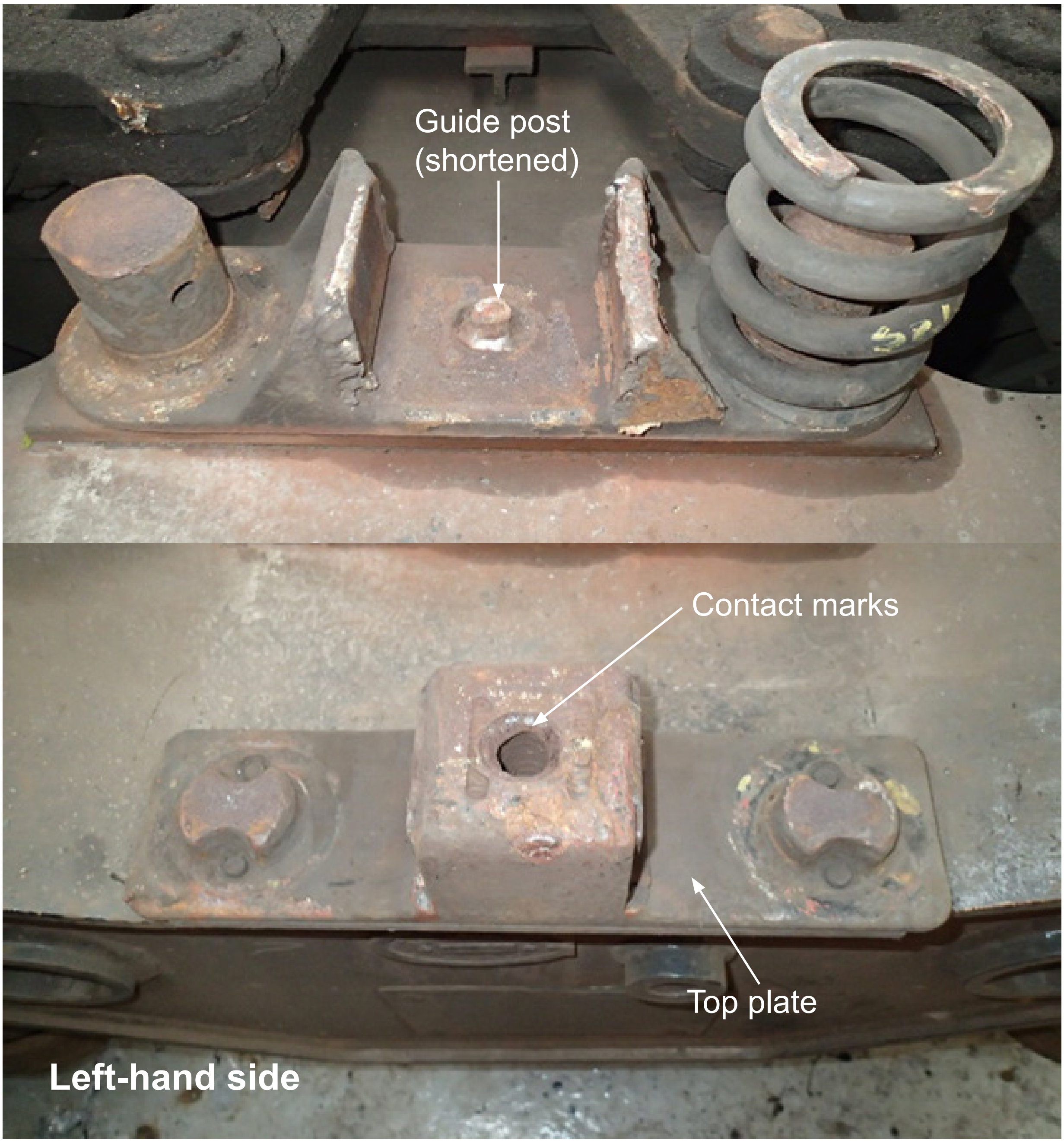

Figure 13: Side-bearer components from the left-hand side of the trailing bogie on wagon 18, showing guide post damage and contact marks

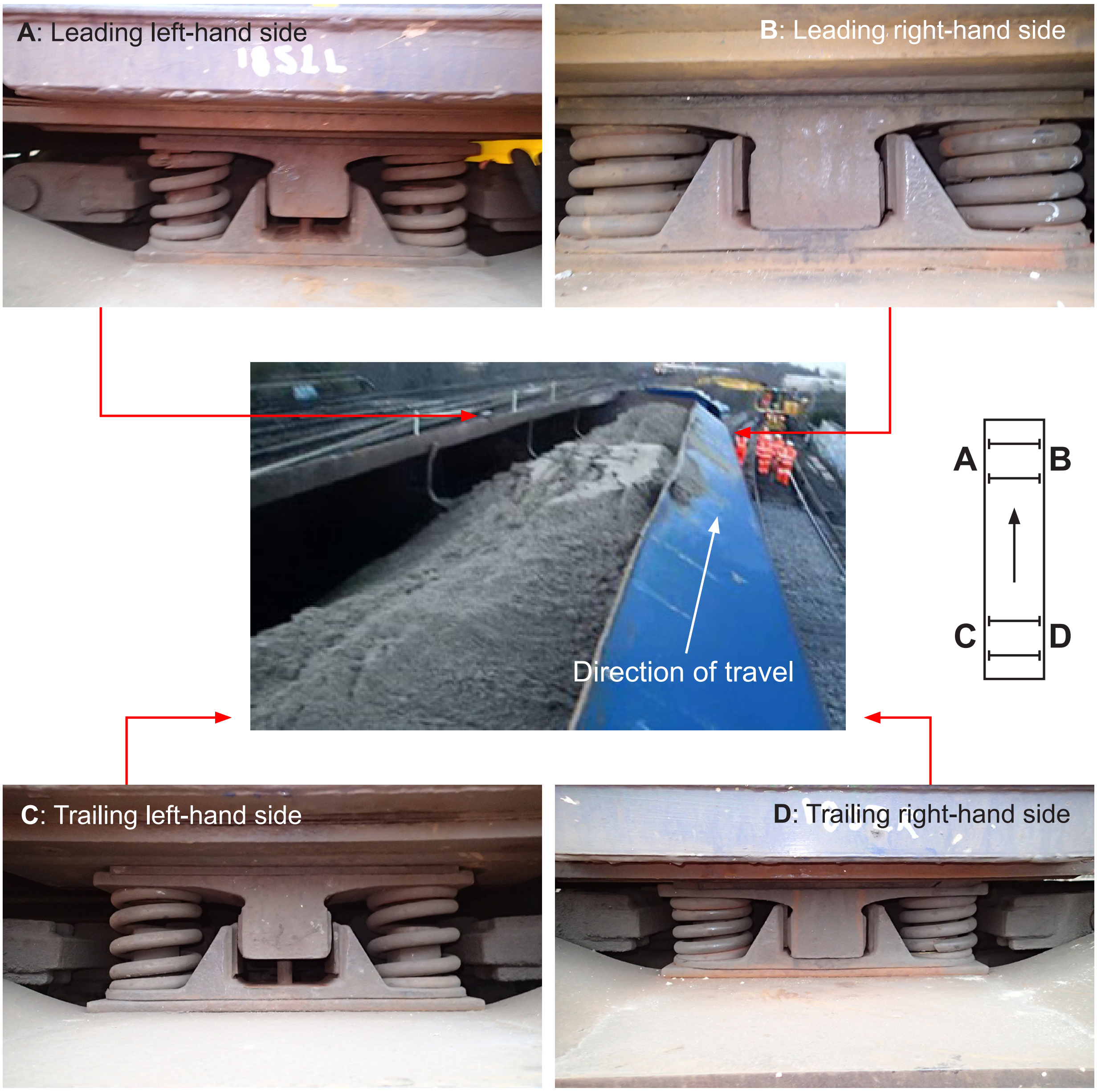

Figure 14: Sand payload in wagon 18 and the condition of the side-bearers

Payload offset on JGA wagons

70 Network Rail has a number *wheel impact load detectors* located around the national network that also record the individual wheel loads of passing trains. While train 6M90 did not pass over a wheel impact load detector site on its way to Courthill Loop South Junction, the RAIB identified several earlier occasions when similar trains had. The RAIB analysed the data from these occasions and calculated a range of lateral (and longitudinal) offsets of the wagon body centres of gravity. While the majority of the measured lateral offsets were less than 40 mm, offsets in excess of 100 mm were not unusual, the highest, from the limited data, being just above 140 mm.

71 After the derailment, the RAIB requested that wagon 18 be routed over Network Rail's wheel impact load detector site at Swanley. Analysis of the recorded wheel loads suggested that the wagon body centre of gravity was laterally offset by around 110 mm to the right; the longitudinal offset was negligible.

Vehicle dynamics study

72 A number of factors can affect the Y and Q forces acting at the wheel-rail contact point. The RAIB commissioned a vehicle dynamics study, using computer simulation, to investigate their significance in the derailment. The computer model of wagon 16 was configured from a model of a JGA wagon developed for GBRf's own investigation into the derailment. This had been assembled and developed from a combination of sources: historical design information, wagon examination and measurement, and suspension component tests. The results from the wheel unloading tests on wagon 18 (paragraph 69) were used to check the characteristics of its behaviour on twisted track. Weighbridge (paragraph 38) and wagon examination (paragraph 64) information was used to make the parameter adjustments needed to represent wagon 16. The computer model of the track focused on the conditions on the approach to the point of derailment. It was created from track survey measurements made at the derailment site, and included the deflection measured by the void meters (paragraph 47).

73 The study focused on the derailment indicators (primarily the amount of wheel climb and the Y/Q derailment quotient) at the leading left-hand wheel, the wheel that was almost certainly the first to climb over the rail head[8]. The study investigated the sensitivity of these to a variety of potential factors, including:

- train speed;
- the level of friction at the wheel-rail contact;
- the suspension condition: secondary and primary[9] spring failure (paragraphs 65 and 66), centre pivot friction and side-bearer friction and clearance;
- the height and offset of the wagon body centre of gravity;
- track gauge and rail head rotation; and
- track twist.

74 The simulations showed that the leading left-hand wheel climbed in a large number of cases considered. However, unless the lateral offset of the wagon body centre of gravity was much greater than the typical values identified by the wheel impact load detector data analysis (paragraph 70), it was not sufficient for the flange to climb onto, and over, the rail head. Despite this, with lateral offsets around 100 mm, the leading left-hand wheel climbed to a position at which the contact angle between the wheel flange and the rail started to reach a maximum. In this condition the wheel is in an unsafe state, and the RAIB has used this as the criterion for derailment[10]. The wheel impact load detector data indicated that lateral offsets of around 100 mm were credible. Furthermore, wheel climb much less than that associated with the above adopted derailment criterion was predicted for centres of gravity close to the wagon longitudinal centre line.

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[8] The derailment occurred on a right-hand curve, with a local horizontal design radius of 281.5 metres. Experience of the running behaviour of conventional bogie rail vehicles on curved track is that the outer (in this case the left) wheel on the leading wheelset is most prone to derailment by flange climbing.

[9] The vehicle dynamics study showed that the fractured secondary (side-bearer) and primary suspension springs that were found on the leading bogie had negligible influence on derailment risk. In fact the failed primary spring was actually found to slightly reduce the risk of derailment.

[10] Classic derailment theory states that as the contact angle between the wheel flange and the rail becomes smaller so does the level of Y/Q (paragraph 49) needed to initiate wheel climb. Therefore, as the contact angle reaches its maximum and then starts to diminish, it becomes theoretically easier for the flange to climb the additional amount needed to clear the rail head.

75 The only other factor of any significance[11] was if the gaps on both side-bearers on the leading bogie had closed or had bridged out. The gaps on the right-hand side-bearers are likely to have been closed due to the lateral offset of the wagon centre of gravity (paragraph 69). Therefore, of concern were marks suggesting that the guide post on the left-hand side-bearer had disengaged from the top plate and come into contact on the underside of the downstop, thereby bridging the gap on the left-hand side. However, detailed component inspection showed that this was probably not the case, and that the marks were the result of the downstop contacting a weld feature at the foot of the guide post. Therefore, the marks had formed when the guide post was engaged. As a result, this factor was discounted.

76 A number of other credible factors were predicted to increase wheel climb but their effects were only found to be small. They included:

- high friction due to the increased surface roughness in the vicinity of the two aluminothermic welds (paragraph 46); and
- rail head rotation due to the bearer sections hinging about the bearer ties where the measured voids were greatest (paragraph 117).

Identification of the immediate cause

77 There was insufficient wheel load at the left-hand wheels of the leading bogie of wagon 16 to prevent the wheel flanges climbing over the rail as the wagon negotiated the newly-laid curved track.

78 The following evidence supports this:

- The witness marks on the running rails and the wing rails, the general distortion of the track and the final position of wagon 16, which are consistent with the left-hand wheel flanges of wagon 16 climbing over the rail on the Up Courthill Loop line and then running in the six-foot between the Up Slow and Down Slow lines (paragraph 45).
- The magnitude and sense of the long and short base twists measured on the approach to the point of derailment (paragraphs 47 and 52), and that it was probable that the payload on wagon 16 was offset to the right (given the condition of the sand payload in wagon 18 (paragraph 69) and the similar way in which it was loaded at Grain terminal (paragraph 38)); both favoured significant wheel unloading at the leading left-hand wheel.
- The computer simulations from the vehicle dynamics study, which predicted that, with a credible lateral offset of the wagon body centre of gravity, the flange of the leading left-hand wheel of wagon 16 climbed to a position at which it was very susceptible to derailment on the track geometry measured on the approach to the point of derailment (paragraph 74).

[11] Ignoring factors such as train speed, track twist, and primary spring condition, where there was a good degree of certainty regarding their value or state; see paragraphs 40,48 and 55.

Identification of causal factors

79 Insufficient wheel load at the leading left-hand wheel of wagon 16 was as result of:

a. The significant track twist that formed on the Up Courthill Loop line between the renewal site being handed back into traffic on 23 January and the passage of train 6M90 on 24 January. This was because:

- the track bed poorly supported the bearers on the Up Courthill Loop line when the renewal site was handed back (paragraph 80); and
- the configuration of the bearers made one side of the track more susceptible to the poor track bed support than the other (paragraph 100).

b. The probable lateral offset of the sand payload in wagon 16 (paragraph 118).

Track twist – track bed support

80 **A track bed that poorly supported the bearers on the Up Courthill Loop line remained in place without measures to protect the safe running of trains.**

81 Ballasted track, like that newly laid at Courthill Loop South Junction, is reliant on the condition of the track bed to maintain the vertical level of the rails and avoid unintended cant differences leading to the formation of significant track twists. The rapid deterioration of the track twist on the Up Courthill Loop line from the compliant level of 1 in 333, when the track was handed back into service on 23 January (paragraph 36), to 1 in 97, which wagon 16 encountered around 28 hours later, is evidence that the track bed was in a very poor condition.

82 The RAIB has concluded that this was almost entirely due to support deficiencies in the ballast layer (poor ballast consolidation) and not in the formation underneath. While choking and wet bed formation was identified as an issue with the old ballast (paragraph 23) the RAIB found evidence that indicates these issues were no longer a factor following the renewal work. In particular:

- the track bed investigation report found the drainage to be good throughout the site and that the ballast was laid on made ground with soak-away properties (paragraph 59);
- excavation of the track bed in the vicinity of the point of derailment revealed no obvious wetness in the formation when the old ballast was removed (figure 15);
- the old (contaminated) ballast was removed and replaced with new clean stone (paragraph 27); and
- a purpose-designed geotextile barrier was specified and installed to separate the new ballast stone from the formation underneath (paragraph 27).

83 It is therefore concluded that this causal factor arose due to a combination of the following:

a. the lack of any mechanised work specifically intended to correct geometry faults and consolidate the ballast on the Up Courthill Loop line (paragraph 84);

b. that the manual track geometry repair work, which was carried out instead, was not fully effective (paragraph 90); and

c. there were no measures in place to mitigate against the risk of the ballast being poorly consolidated (paragraph 95).

Figure 15: Excavation of the track bed close to the point of derailment on 14 January 2017 (photograph courtesy of Network Rail)

Ballast consolidation – tamping work

84 **There was no mechanised work to correct residual geometry faults and consolidate the ballast on the Up Courthill Loop line after the adjacent and connected slow lines were tamped.**

85 The S&C South Alliance planned to tamp the new double junction during the weekend after the track panels were installed (paragraph 33). Two tamping machines were booked to work on 22 January: machine DR 75410 and machine DR 75502. Records show that both were booked on 22 December 2016. They were scheduled to leave site at 10:00 hrs and 10:10 hrs respectively.

86 To achieve the best track geometry on the lines normally most heavily trafficked, general practice is to tamp the main route of a double junction first, applying vertical (lift), lateral (line) and cant geometry corrections. However, given their connection and proximity, lifting the track on the slow lines (the main route at Courthill Loop South Junction) inevitably meant disturbing the track on the loop lines. Mechanised tamping work on the Up Courthill Loop line offered the best opportunity for correcting residual geometry faults and, importantly, consolidating the supporting ballast.

87 Machine DR 75502 started tamping the Up Slow line at 06:05 hrs. It was known that the track on the Up Slow line had been installed too low[12] (paragraph 31) and it had settled further over the intervening week. Unfortunately, it was not possible to achieve the amount of lift needed with one tamper pass (paragraph 34). The need for the second tamper pass meant that machine DR 75502 remained occupied until 09:30 hrs leaving no time for it to then tamp the Up Courthill Loop line before it was due to depart. Figure 16 shows the level of the track at the start of the tamping work, and that achieved after each tamping pass. It also illustrates the step at the transition to the existing track that witness evidence suggests was of concern to the lead engineer during the Core Works (paragraph 31).

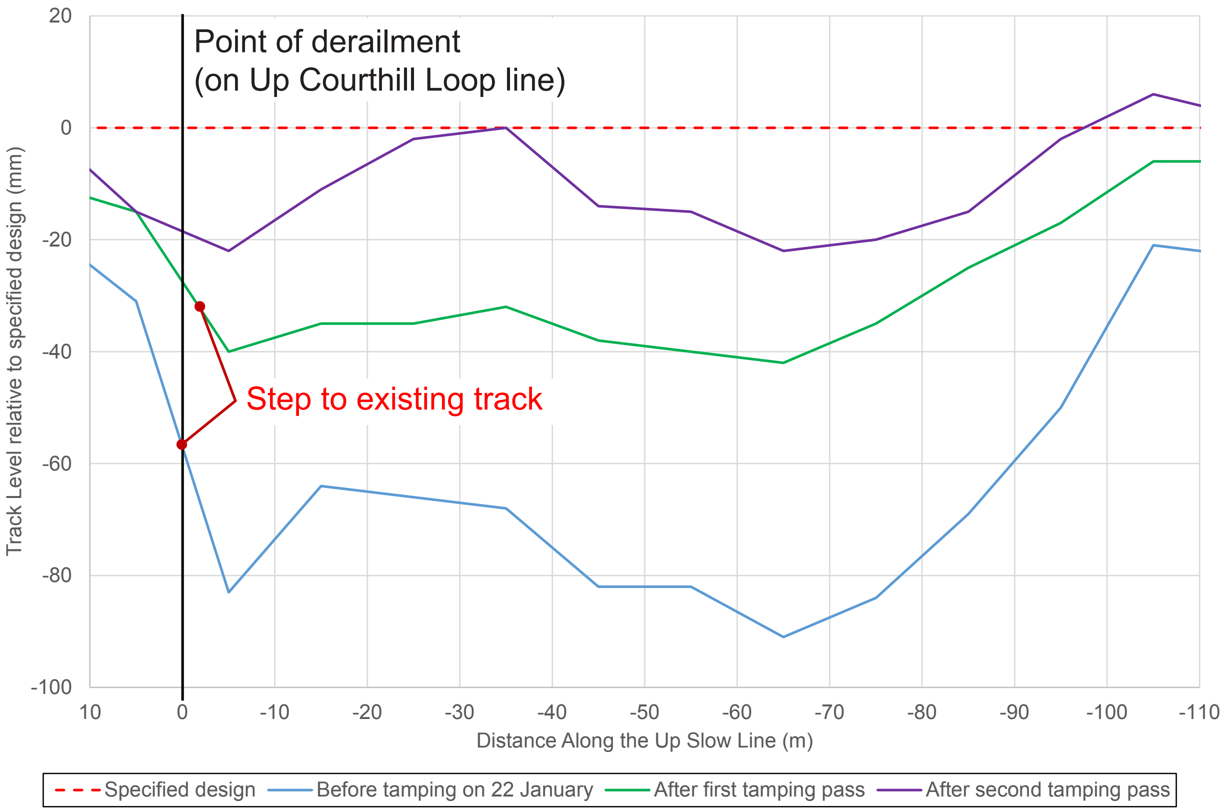


Figure 16: Level of the Up Slow line prior to the tamping work on 22 January 2017, and after each tamping pass

88 Machine DR 75410 did not complete its tamping work until around the same time as machine DR 75502.

89 Witness evidence indicated that even if they had been able to tamp the Up Courthill Loop line on 22 January, the installation team would not have attempted to apply lift or line geometry correction between 871 points and the diamond crossing (the section of the line where wagon 16 derailed). This is because the connecting bearers would have risked introducing geometry faults into the already-tamped slow lines. However, they would have used the tamper to consolidate the ballast. This is often referred to as 'squeezing up'.

[12] The RAIB investigation has not investigated the reasons for the Up Slow line being installed too low. It has focussed on the arrangements in place for managing the condition of the track when the renewal site was last handed back into traffic before the derailment. Deviations from design are not unusual, especially when renewal work is incomplete (paragraph 23), and these arrangements are intended to ensure that only track that is safe for traffic is allowed back into service.

Ballast consolidation – manual work

90 Manual work to correct residual track geometry faults on the Up Courthill Loop line did not sufficiently consolidate the ballast under the bearers.

91 Figure 17 shows the areas on the Up Courthill Loop line where the ballast is unlikely to have been fully consolidated by the tamping undertaken on 22 January.

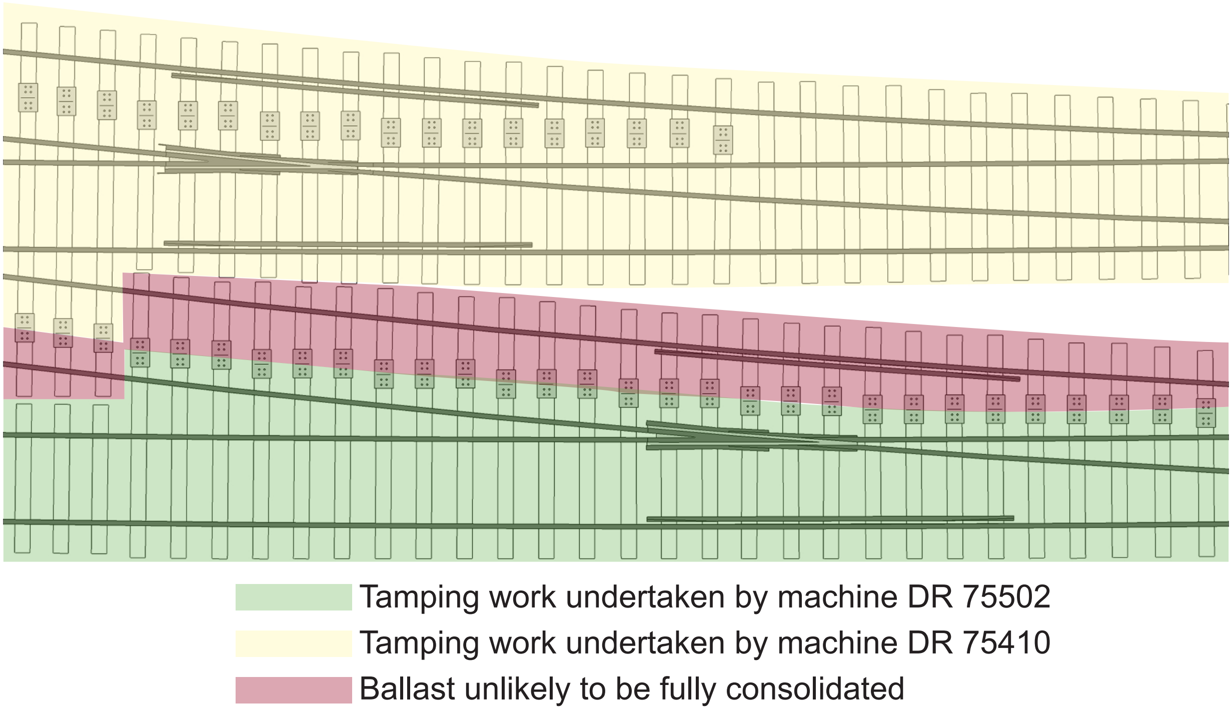


Figure 17: Areas of the double junction affected by tamping work on 22 January 2017

92 There is evidence that the installation team were aware of this and that they arranged for manual lifting and packing work on the Up Courthill Loop line to address it (paragraph 34). Furthermore, additional lifting and packing work was arranged by the lead engineer who was later tasked with the final certification of the track geometry (paragraph 36).

93 Network Rail recognises manual lifting and packing as a suitable method for consolidating ballast (and repairing twist faults) and uses it widely on the national network. However, in this case, it resulted in ballast that was insufficiently consolidated to prevent a compliant track twist rapidly deteriorating to one that was a safety hazard. The RAIB observes that, while lifting and packing may be a relatively quick method for correcting vertical track geometry, Network Rail recognises that it is not the most durable solution. The RAIB also observes that lifting and packing may not reliably consolidate ballast following large scale track bed disturbance.

94 Figure 18 shows the cant levels that were measured on the Up Courthill Loop line to verify the manual repair undertaken during the follow-up work, and how this then deteriorated over 28 hours to form the track twist feature on which wagon 16 derailed. It also summarises the associated maximum twist levels on the immediate approach to the point of derailment: over three metres, and over the wheelbase (1.8 metres, short base twist) and bogie centres (11.5 metres, long base twist) of a JGA wagon.

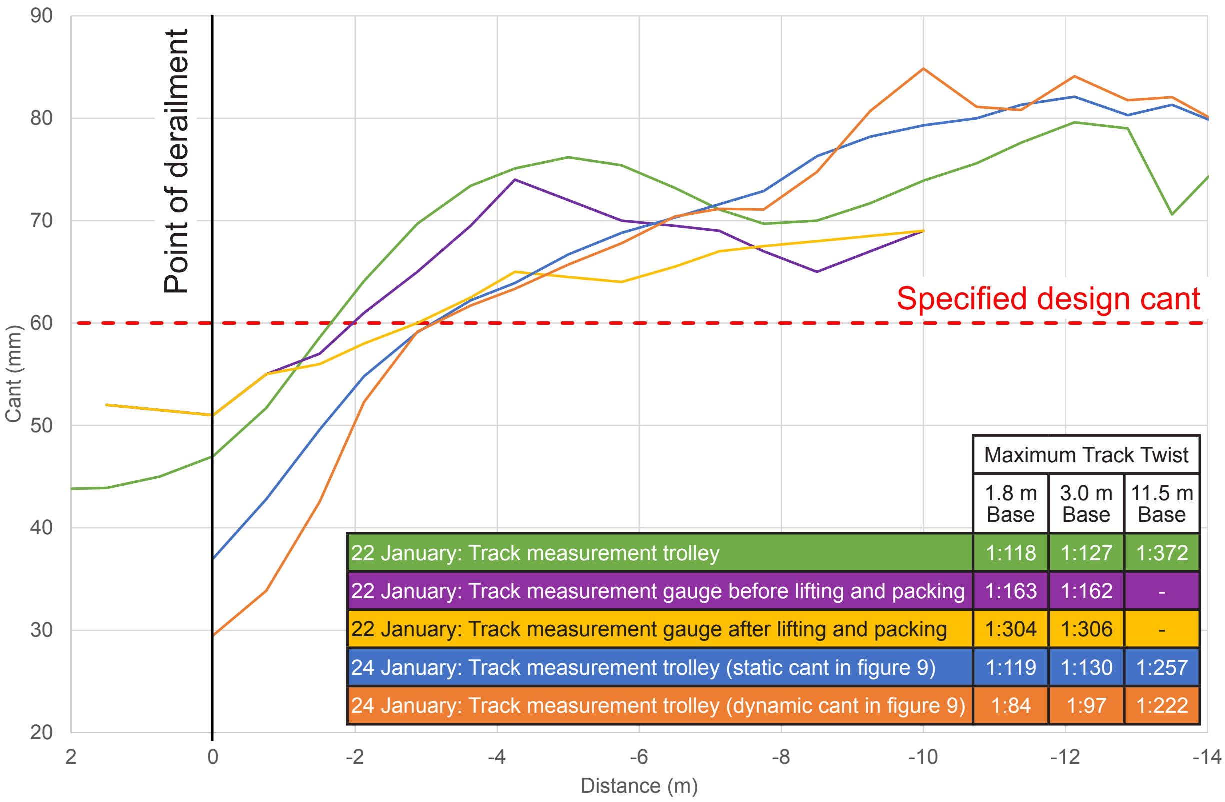


Figure 18: Track cant on the Up Courthill Loop line

Ballast consolidation – detection and mitigation

95 **No measures were taken to mitigate the risk that the ballast on the Up Courthill Loop line may have been poorly consolidated.**

96 One of the compliance statements on the Form A certificate reads ‘Assessment/measurement of voiding undertaken’, and adds ‘follow up inspection may be required – add comment below’. On the Form A certificate completed for the Up Courthill Loop line on 23 January (paragraph 36), an ‘X’ was entered in the adjacent box, meaning that no assessment or measurement was made; and no comment was made regarding a related mitigation action, such as the need to monitor the track during the passage of trains or introduce a speed restriction[13] (see Appendix C).

97 Some of the track deflection measured by the RAIB after the derailment (paragraph 47) would be due to ballast settlement from rail traffic passing during the 28 hours after the renewal site was handed back. However, it is probable that a significant amount of the deflection would have been detectable if void measurements had been made as part of the track geometry compliance checks (paragraphs 35 and 36).

98 The identification of voiding on the Up Courthill Loop line would have been an indication of poor ballast consolidation and support, and the risk that the vertical geometry, and hence cant variation and track twist, would deteriorate rapidly.

[13] Although reduced speed would have mitigated the consequences of the accident, the vehicle dynamics study (paragraph 73) predicted the risk of derailment remained. In fact, at 5 mph (8 km/h), the lowest speed considered, the risk increased significantly. The RAIB has observed increased derailment risk at lower speed on a number of other derailments that it has investigated.

99 Network Rail standard NR/L2/TRK/2102, 'Design and construction of track', specifies the lack of vertical movement of the track during the passage of trains as a criterion to be achieved before a renewal site can be handed back to the Track Maintenance Engineer for routine maintenance. However, although the Form A certificate requires the person checking the track geometry to record if a voiding 'assessment/measurement' was made (paragraph 96), the RAIB found no requirement for assessing track movement during the passage of trains when a renewal site is being temporarily handed back into traffic. Witness evidence indicated that the lead engineer, who had completed the Form A certificate for the Up Courthill Loop line, spoke with the authorised person and considered that the condition of the track and track bed was satisfactory. There had been recent manual work to consolidate the ballast (paragraphs 34 and 36) and visual checks had not suggested that it was unsuited for train operation. Furthermore, the work needed to correct the twist fault that had been found required the track to be lifted by an amount that was considered to be neither excessive (it was less than 15 mm), nor requiring observation under the passage of a train. Computer simulations from the vehicle dynamic study showed that removing the effects of the measured voids on the Up Courthill Loop would, on its own, have prevented the left-hand wheel of wagon 16 being at risk of derailment.

Track twist – bearer configuration

100 **The configuration of the bearers made one side of the track on the Up Courthill Loop line more susceptible to poor track bed support than the other.**

101 On the approach to the point of derailment, the bearers that support the track on the Up Courthill Loop line also support the track on the Up Slow line, to the left. Then, close to the aluminothermic welds (paragraphs 45 and 46), the arrangement changes, and the bearers jointly support the Up Courthill Loop line, and the Down Slow and Down Courthill Loop lines, to the right (figure 8).

102 There are bearer ties throughout the four-foot, from ten bearers before the crossing nose to the aluminothermic welds. There is evidence that these bearer ties were flexible and allowed the poor track bed support to affect the cant on the Up Courthill Loop line more than if the shared bearers had been continuous. Furthermore, the change (from the left to the right) of better support, offered by the bearer sections that carried more than one rail, meant that the cant along the line initially increased and then reduced. The effect of this is to amplify a twist that favoured wheel unloading at the leading left-hand wheel of wagon 16 as it approached the point of derailment.

103 This causal factor arose due to a combination of the following:

a. the mechanical flexibility of the bearer tie allowed differential rotation of the short bearer sections on either side (paragraph 104); and

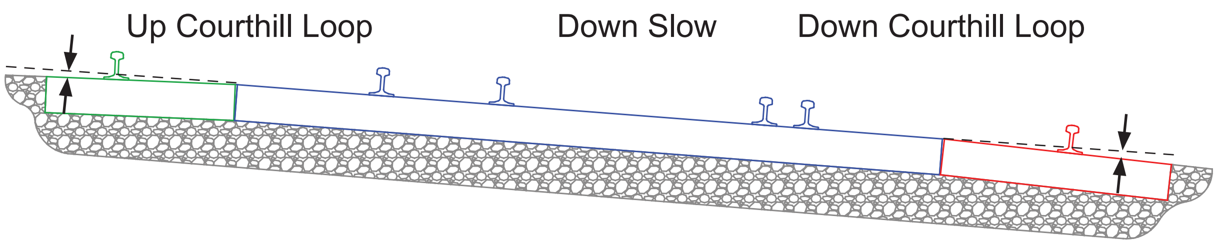
b. the approved engineering drawings for the S&C layout specified bearer ties that were located in the four-foot of the Up Courthill Loop line (paragraph 108).

Bearer ties – mechanical flexibility

104 **The mechanical flexibility of the bearer tie allowed differential rotation of the short bearer sections on either side.**

105 If the concrete bearers had been continuous (paragraph 55), and not split into short sections, their inherent rigidity would have helped ensure that the cant on the Up Courthill Loop line was the same as (or similar to) that on the other lines supported by the same bearer. Furthermore, and importantly, since a continuous (more rigid) bearer would more readily be able to distribute vertical force, this would be largely independent of the local track bed condition. Conversely, a split bearer with flexible bearer ties will be less able to distribute vertical force and may promote further track bed deterioration under bearer sections that are more heavily loaded.

106 The bearer closest to the point of derailment supports three lines. It has a bearer tie in the four-foot of the Up Courthill Loop line as well as in the four-foot of the Down Courthill Loop line. The bearer section supporting the Down Slow line is continuous in between (figure 6). The RAIB analysed the track measurement trolley recordings made during the follow-up work (paragraph 35) and the void measurements and track measurement trolley recordings made after the derailment (paragraph 47). With reference to figure 19, it found that, at the time of the follow-up work, the cant on the individual lines on the bearer varied: the static cant on the Up Courthill Loop line was less than that on the Down Slow line (in the middle of the bearer), and the static cant on the Down Courthill Loop line was more. The different amount of cant on each line is explained by the fact that the bearer ties were acting as hinges, which allowed the bearer sections to rotate relative to one another. By the time of the derailment, the static cant on the Up Courthill Loop line had reduced considerably further. The dynamic cant was even less, evidencing how vulnerable the short bearer section under the left-hand rail was to inadequate track bed support.



Cant (mm)	Up Courthill Loop	Down Slow	Down Courthill Loop
At follow-up weekend	45	49	59
Post-derailment (static)	37		
Post-derailment (dynamic)	29.5		

Figure 19: Track cant on the bearer closest to the point of derailment

107 The RAIB found the following evidence that Network Rail's standard bearer tie is inherently flexible:

- VCUK reported that it does not lift S&C panels that are connected together because of the amount of rotation that occurs at the bearer tie connections;
- track installation teams have reported that, when tamping S&C layouts, the lack of rigidity on shared bearers with bearer ties prevents machine operators being able to use *extendable tamper arms* to reach out and apply corresponding lift corrections on connected adjacent lines; and
- structural analysis work undertaken for Network Rail that reviewed early laboratory testing of the bearer tie and concluded that it acted as a 'pin-joint', in other words, a hinge.

Bearer ties – location

108 **The approved engineering drawings for the S&C layout specified bearer ties that were located in the four-foot of the Up Courthill Loop line.**

109 The S&C South Alliance provided VCUK with the Form A layout drawing. VCUK used the underlying design information to develop the 1 in 50 layout drawing that defined how the new track for the double junction was to be subdivided and transported to site (paragraphs 61 and 62).

110 VCUK determined the location of the bearer ties on the Up Courthill Loop line when it decided how it was going to manufacture the new track layout. Witness evidence indicated that, while the Form A layout drawing diagrammatically showed the position of some bearers, and that bearer ties were shown on a large number of these, S&C South Alliance designers had only intended this to be indicative. In fact, it was explained that the number of bearers shown on the drawing was unusual and that it would be normal to only show where the last long bearer needed to be located. The Form A layout drawing included no other information relating to, or implying, how the track was to be subdivided into panels.

111 Clause 11.6.3 of Network Rail standard NR/L2/TRK/2102 includes requirements for bearer ties[14] (Appendix D). These state that bearer ties should be located in accordance with RE/PW general arrangement drawings (paragraph 56). They define a set of principles to be followed when a general arrangement drawing is not available.

112 VCUK stated it had adopted the practice of working in accordance with Network Rail's standard RE/PW drawings where possible. In so doing, it considered its role as one of configuring, as distinct from designing, customised S&C layouts for manufacture from standard parts using spatial (and other) information gathered from general arrangement drawings. This included helping to decide where to locate bearer ties. The RAIB found evidence that the S&C South Alliance had a different view, in that it believed bearer tie location decisions were fully delegated to the manufacturer.

[14] Network Rail classed this clause as an 'amber' requirement, meaning that compliance is required unless a variation has been approved.

113 Network Rail does not publish an RE/PW general arrangement drawing that is directly applicable to the like-for-like complex geometry that was required for the double junction at Courthill Loop South Junction. Particular deviations from published general arrangement drawings were that the junction was curved and that the six-foot (between the Up Slow and Down Slow lines) was wider than normal. While the RAIB found a general consensus about the need to refer to a higher design authority (within Network Rail) in the event of deviation to RE/PW general arrangement drawings, it was unable to find any Network Rail specification of the degree of deviation that required this. The S&C South Alliance stated that a large proportion of its renewals are for layouts where no RE/PW general arrangement drawing is available. Therefore, strict application could result in a burdensome requirement to regularly refer outside the organisation on design matters.

114 The RAIB found no evidence that VCUK, or the S&C South Alliance, referred the decision for locating the bearer ties to a higher design authority. Rather, it was evident that such decisions were driven by practical considerations (such as how the resulting panels were to be transported and lifted, and ease of manufacture) while endeavouring to follow RE/PW general arrangement drawings to aid standardisation (for instance, later component replacement).

115 The RAIB observed that a number of RE/PW general arrangement drawings include bearer ties located in the four-foot, and that a significant number of these are associated with spine panels, like panels 15 and 23 on the Up Courthill Loop line. While the additional principles defined in Clause 11.6.3 of NR/L2/TRK/2102 (for when RE/PW general arrangement drawings are not available) state that bearer ties should be located in the six-foot rather than the four-foot, elsewhere they state that, if bearer ties need to be in the four-foot, they should be on the turnout (or crossover) line. This was generally the case with the new track layout for Courthill Loop South Junction[15].

116 Although Network Rail's designated project engineer's formal review of the VCUK 1 in 50 layout drawing (paragraph 62) did not comment on the bearer ties on the Up Courthill Loop line, it did refer to the possibility of removing panel 14, a spine panel on the Down Courthill Loop line, and combining it with panel 13. This would have removed bearer ties from the four-foot of the Down Courthill Loop line. Ultimately, this work was not done and these bearer ties remained.

117 As well as affecting cant, the flexibility of bearer ties located in the four-foot will probably cause rail head rotation on a poorly supporting track bed. This can introduce an additional flange climb derailment risk (paragraph 76).

Wagon payload

118 The probable lateral offset of the payload on wagon 16 significantly reduced the wheel load at the front left-hand wheel.

119 Wagon 16 overturned and the sand it was carrying spilt onto the track. The RAIB sought to use wheel load records to understand how the sand had been distributed. However, it found that the weighbridge at the Grain terminal (paragraph 38) did not record information on individual wheels and that train 6M90 was not routed over one of Network Rail's wheel impact load detector sites on its journey to Courthill Loop South Junction (paragraph 70).

[15] A group of five bearer ties are located in the four-foot of the Down Slow line. These connect bearer sections that each support at least two rails and, in the majority, three.

120 Visual examination of wagon 18, and post-derailment wheel impact load detector records, showed that its sand payload was offset to the right, thereby reducing the wheel load at the left-hand wheels. The vehicle dynamics study showed that the degree of offset was enough for the wagon to be at risk of derailment on the track leading up to the point of derailment (paragraphs 71 and 74). The following evidence suggests that it is probable that the sand payload of wagon 16 was offset to a similar extent:

- closed circuit television (CCTV) images of train 6M90 passing Bexley station, which show the profile of the sand in wagons 16 and 18 was similar (figure 20); and
- that wagons 16 and 18 were loaded using the same process (paragraph 38).

Figure 20: CCTV images of train 6M90 passing through Bexley station on 24 January 2017 (images courtesy of London and South East Railway Limited)

121 The RAIB found that, while importance was given to ensuring that the maximum wagon weight was not exceeded, Aggregate Industries, who loaded train 6M90, did not have processes for controlling the evenness of the payload. GBRf, who prepared train 6M90 prior to allowing it to depart from Grain terminal, reported that, while it requires its staff to visually check that wagons are sitting correctly on their suspension, it does not ask them to inspect the condition of the payload.

Identification of underlying factors

122 **The engineering processes that Network Rail and its suppliers were using to develop S&C layouts incorporating its standard bearer tie were inadequate for controlling the risks associated with flange climb derailment.**

123 The RAIB has concluded that the approach Network Rail promoted for developing modular S&C layouts did not fully recognise the criticality of the mechanical behaviour of its standard bearer tie on undesired rail displacement, in particular:

- vertical track geometry changes, leading to cant variation and the development of unintended short and long base twist; and
- unwanted rail roll.

Both of these effects may affect the safe running of trains, because they have the potential to increase the risk of flange climb derailment (paragraphs 49, 50 and 76).

124 From its investigation the RAIB found evidence:

- of a variety of engineering opinion within Network Rail and the S&C South Alliance regarding the rigidity of Network Rail's standard bearer tie; although it is difficult to determine the general accepted view prior to the derailment, some reported that they had considered it provided a rigid connection (as was stated when it was first proposed (paragraph 55)) whereas others had concluded it acted like a hinge;
- that Network Rail generally adopts a process for locating bearer ties that does not prohibit the specification of short bearer sections that support only one rail; this process is based on matching standard general arrangement drawings, with some general principles to be followed when these drawings are not available (paragraphs 111 and 115);
- of a difference of understanding of the engineering responsibilities associated with specifying the location of bearer ties (paragraph 112); and
- of a lack of criteria on when to refer decisions to a higher design authority when developing S&C layouts for non-standard arrangements (paragraph 113).

Observations

Track twist – unintended cant gradient

125 **An unintended cant gradient that was at the extreme of design limits was present on the Up Courthill Loop line when the track was handed back into traffic.**

126 Cant measurements were made using a track measurement trolley prior to the track being handed back after the follow-up works (paragraph 35). This revealed that there was a general static cant gradient on the Up Courthill Loop line that was at the extreme of the design limit of 1 in 400 (as specified in Railway Group Standard GM/RT 5021, 'Track System Requirements'). The effect of this was to expose wagon 16 to a long base twist of 1 in 372[16] on the immediate approach to the point of derailment (paragraph 94 and figure 18). The S&C South Alliance specified a non-varying cant of 60 mm on this section of the Up Courthill Loop line on its AFC layout drawing. Therefore, the cant gradient was unintended.

127 Measurements made after the derailment showed that, including the deflection of the track due to wheel load, the long base twist affecting wagon 16 had deteriorated to 1 in 222 (figure 18). Computer simulations undertaken as part of the vehicle dynamics study, showed that reducing the cant gradient to achieve a long base twist compatible with the extreme design limit (1 in 400) reduced the derailment risk. While the predicted derailment risk reduction was not as great as that due to the effect of removing the voids under the track (paragraph 99), which mainly influenced the short base twist, the RAIB also observes that, in other circumstances, the effect of a long base twist may be more significant.

[16] The lead engineer made further cant measurements using a track measurement gauge after this. However, these did not extend to 11.5 metres from the point of derailment and so cannot be used to quantify the long base twist.

128 The RAIB did not seek to establish the precise reason for the formation of the cant gradient. However, at least two explanations are possible, either individually or in combination:

- Because the Up Slow line had been installed low during the Core Works (paragraph 31), the track was on a different canted plane to that on the Down Slow line. On crossing between them, the Up Courthill Loop line had to distort to match the two different planes. The cant gradient measured towards the end of the follow-up work may have been what remained of the track distortion.
- The large amount of lift that was applied to the Up Slow line during the follow-up work could have disturbed the vertical geometry of the track on the connected Up Courthill Loop line. The omission of the tamping on the Up Courthill Loop line meant that any cant variation arising from this disturbance was not corrected (paragraph 87).

129 It is evident that the magnitude and nature of the work involved in renewing ballasted track (especially the excavation and preparation of the new track bed, and the work then needed to correct the new track geometry) presents a major risk that long base track twists will form. The RAIB additionally observes that, while Network Rail requires lead engineers to check for the presence of short base track twists before handing back a renewal site into traffic (paragraph 53), it does not require checks to confirm that the cant gradient is compliant over longer distances.

Track twist faults - routine maintenance

130 **The track twist that had formed on the Up Courthill Loop line was a significant hazard to wagon 16, yet was not of a magnitude that would have required trains to be immediately stopped if it had been identified as part of a routine maintenance activity.**

131 The dynamic track twist that wagon 16 encountered on the Up Courthill Loop line measured 1 in 97 over the standard three metre base that Network Rail uses to monitor track twist faults during routine maintenance (paragraph 53). Therefore, it was just compliant with the 1 in 90 criterion that requires trains to be immediately stopped (paragraph 47). However, the RAIB observes that the short base twist affecting wagon 16 acted over 1.8 metres (the bogie wheelbase (paragraph 18)) and was 1 in 84 (figure 18). The RAIB acknowledges that track twists of these magnitudes were not detected prior to the derailment.

Wagon side-bearers

132 **Witness marks suggested occasions when the side-bearer gaps had reduced and become bridged out, increasing the risk of wagon 16 derailing when that condition was present.**

133 The RAIB was able to discount the possibility that a witness mark on the leading left-hand side-bearer was evidence of a factor in the derailment because it was not the result of guide post disengagement and contact (paragraph 75). However, witness marks on the left-hand side-bearer on the trailing bogie, which had a guide post that had fractured and become shortened, did suggest guide post contact and that there were occasions when the side-bearer gap had reduced and become bridged out (paragraph 66 and figure 13).

134 Therefore, in other circumstances, it is possible that the condition of the left-hand side-bearer on the trailing bogie resulted in reduced side-bearer gaps that, given the findings of the vehicle dynamics study (paragraph 75), increased the risk of derailment.

Previous occurrences of a similar character

135 The RAIB has investigated a number of freight train derailments that have resulted from flange climb on twisted track. Those having similar characteristics include:

- Cricklewood Curve, 31 January 2006 (RAIB report 02/2007[17]). The eighth and ninth wagon of an aggregate train, comprising 18 bogie hopper wagons, derailed and overturned on an excessive track twist on an embankment. The track twist had formed at the site of repair work that was being carried out on the embankment for Network Rail.
- Duddeston Junction, 10 August 2007 (RAIB report 16/2008). The seventh and eighth wagons of a container train, comprising 24 bogie container flat wagons, derailed on a combination of track twists on an S&C layout; a container toppled off the train and another became dislodged. The first wagon to derail was unevenly loaded.
- Santon, 10 January 2008 (RAIB report 10/2009). The tenth wagon of a coal train, comprising 18 bogie hopper wagons, derailed on a track twist on a plain line curve that had excessive cant. The track twist had formed due to issues with the track bed support. The wagon was unevenly loaded.
- Reading West Junction, 28 January 2012 (RAIB report 02/2013). The 24th wagon of a container train, comprising 25 bogie container flat wagons, derailed on a track twist on an S&C layout. The wagon was unevenly loaded. There had been recent mechanised track maintenance work; the track had been handed back into traffic around a month before.
- Camden Road West Junction, 15 October 2013 (RAIB report 21/2014). The fifth wagon on a container train, comprising 22 bogie container flat wagons, derailed on a combination of short and long base track twists on a plain line curve; a container toppled off the wagon. The wagon was unevenly loaded.
- Angerstein Junction, 2 April 2014 (RAIB report 11/2015). The eighth and ninth wagons on an aggregate train, comprising 20 bogie hopper wagons, derailed on a combination of short and long base track twists. The train was departing from an aggregate terminal, where it had recently been unloaded. The first wagon to derail was unevenly loaded due to residual material that had accumulated on the sides of the hopper.

[17] RAIB reports are available at www.raib.gov.uk.

Summary of conclusions

Immediate cause

136 There was insufficient wheel load at the left-hand wheels of the leading bogie of wagon 16 to prevent the wheel flanges climbing over the rail as the wagon negotiated the newly-laid track on the Up Courthill Loop line at Courthill Loop South Junction (paragraph 77).

Causal factors

137 The derailment occurred due to the combination of a significant track twist and a probable lateral offset of the wagon payload.

138 The track twist formed rapidly on the Up Courthill Loop line after the renewal site was handed back into traffic on 23 January 2017 because of two causal factors:

a. A track bed that poorly supported the bearers remained in place without measures to protect the safe running of trains (paragraph 80). This causal factor arose due to:

i. The lack of mechanised work to correct residual geometry faults and consolidate the ballast after the adjacent and connected slow lines were tamped (paragraph 84, **Learning point 1**).

ii. The manual work undertaken to correct the residual track geometry faults that did not sufficiently consolidate the ballast under the bearers (paragraph 90, **Recommendation 1**).

iii. The lack of measures to mitigate the risk that the ballast may have been poorly consolidated (paragraph 95, **Recommendation 2**).

b. The configuration of the bearers made one side of the track on the Up Courthill Loop line more susceptible to poor track bed support than the other (paragraph 100). This causal factor arose due to:

i. The mechanical flexibility of the bearer tie, in that it allowed differential rotation of the short bearer sections on either side (paragraph 104, **Recommendation 4**).

ii. The approved engineering drawings for the S&C layout, in that they specified bearer ties that were located in the four-foot of the Up Courthill Loop line (paragraph 108, **Recommendation 4**).

139 The probable offset payload on wagon 16 significantly reduced the wheel load at the front left-hand wheel (paragraphs 118, 162 and 163, **Recommendation 5**).

Underlying factor

140 The engineering processes that Network Rail and its suppliers were using to develop S&C layouts incorporating its standard bearer tie were inadequate for controlling the risks associated with flange climb derailment (paragraph 122, **Recommendation 4**).

Additional observations

141 Although not linked to the accident on 24 January 2017, the RAIB observes that:

a. An unintended static cant gradient that was at the extreme of design limits was present on the Up Courthill Loop line when the track was handed back into traffic (paragraph 125, **Recommendation 3**).

b. The track twist that had formed on the Up Courthill Loop line was a significant hazard to wagon 16, yet was not of a magnitude that would have required trains to be immediately stopped if it had been identified as part of a routine maintenance activity (paragraph 130, no recommendation (paragraphs 154 and 161)).

c. Witness marks suggested occasions when the side-bearer gaps had reduced and become bridged out, increasing the risk of wagon 16 derailing when that condition was present (paragraph 132, **Learning point 2**).

Previous RAIB recommendations relevant to this investigation

Derailment at Santon, near Foreign Ore Branch Junction, Scunthorpe on 25 January 2008, RAIB report 10/2009, Recommendation 9

142 **While recognising that it was not addressed to the company that operated train 6M90, the RAIB considers that a wider consideration of recommendation 9 in RAIB report 10/2009, and more effective implementation, could have resulted in industry-wide action that would have improved the control of the derailment risk associated with uneven payload on bulk hopper wagons.**

143 This recommendation read as follows:

Recommendation 9

Freightliner should assess the permissible level of offset load before the derailment risk criteria in the Railway Group Standard GM/RT2141, Resistance of Railway Vehicles to Derailment and Roll-Over, is exceeded, and should put processes in place to ensure that any bogie hopper wagon, such as the HHA wagon, with an offset exceeding the permissible level does not enter into traffic.

144 In its response to the RAIB[18] on 29 April 2010, the Office of Rail and Road (ORR) reported that Freightliner (the freight operating company responsible) reasoned that the recommendation should not be implemented. ORR reported on further discussion with Freightliner. It advised that Freightliner had proposed that, via RSSB[19], the rail industry undertake research to understand the nature of offset train loads in the UK. This was with a view to quantifying the economic benefit of a control measure of the type proposed and enabling revised guidance regarding the application of GM/RT2141 at the vehicle design stage. This was considered by various RSSB industry committees which concluded that the limits defined by GM/RT2141 included 'a margin for such factors as lateral load offset' and that, based on the risk associated, there was no business case for further investigation.

145 The RAIB has expressed its concern to the ORR that the risk has yet to be addressed. However, it is aware that the ORR wrote to industry parties on 5 December 2014 concerning recent freight train derailments, the interaction between track, vehicle and uneven payload, and potential areas for improvement. While the ORR's initial concern regarding payload unevenness was focused on freight containers, the cross-industry freight derailment working group, which has since been established, has now identified unevenness of payloads in bulk hopper wagons as a topic for further investigation (paragraph 153).

146 The cross-industry freight derailment working group includes representatives from Network Rail, freight operating companies, RSSB and rail consultancy organisations. It is chaired and facilitated by RSSB.

[18] The status of RAIB recommendations can be found at www.raib.gov.uk.

[19] A not-for-profit company owned and funded by major stakeholders in the railway industry, and which provides support and facilitation for a wide range of cross-industry initiatives. The company is registered as 'Rail Safety and Standards Board' but trades as 'RSSB'.

Derailment at Camden Road West Junction on 15 October 2013, RAIB report 21/2014, Recommendation 2

147 **The RAIB considers that early effective implementation of recommendation 2 in RAIB report 21/2014, and in particular full consideration of item a) iii, should result in Network Rail having a better understanding of the actions needed to improve its criteria for assessing the hazards arising from track twist following track renewal work.**

148 This recommendation read as follows:

Recommendation 2

Freightliner and Network Rail should jointly request that RSSB:

a) researches the factors that may increase the probability of derailment when container wagons are asymmetrically loaded, and in particular:

i. sensitivity to combinations of longitudinal and lateral offsets in loads that can reasonably be encountered in service;

ii. the predicted performance of wagons with high torsional stiffness along their length (using the FEA type as an example); and

iii. the effect of multiple twist faults, track twist over distances other than 3 metres (as commonly specified and measured by Network Rail) and lateral track irregularities.

b) updates and amends as necessary the risk assessment contained within the RSSB and Transport Research Laboratory joint report ('Potential risks to road and rail transport associated with asymmetric loading of containers'); this should take into account the results from the research referred to in a) and additional evidence presented in this investigation report; and

c) works with industry stakeholders to use the outputs of a) and b) to identify, evaluate and promote adoption of any additional reasonably practicable mitigations capable of reducing the risk from asymmetric loading of wagons.

149 Item c) of the recommendation referenced a list of potential mitigation measures to be considered. These included:

- changes to track inspection and maintenance criteria, to consider track twist measurement distances relevant to the bogie spacing of modern freight vehicles; in effect, taking into account the effect of long base twist; and
- limiting freight wagon lateral payload offset.

150 In its response to the RAIB on 13 October 2015, the ORR reported that it considered that RSSB had been requested to undertake the work required. However, while the RAIB is aware that the cross-industry freight derailment working group has established a programme of work that is examining some of the issues identified, it has expressed its concern that the findings have yet to be fully concluded and considered.

Previous RAIB recommendations that had the potential to address factors identified in this report

Accident at Angerstein Junction on 2 April 2014, RAIB report 11/2015, Recommendation 6

151 **The RAIB considers that completion of recommendation 6 in RAIB report 11/2015 should lead to actions that will result in the improved management of the risks associated with the offset payloads of hopper wagons.**

152 This recommendation read as follows:

Recommendation 6

RSSB, in consultation with industry, should review the risks associated with the uneven loading of wagons, with particular reference to partial loads, and propose any necessary mitigation, so that the extent of permitted load imbalance is effectively controlled.

153 In its response to the RAIB on 6 July 2016, the ORR reported that it was aware of RSSB's plans to implement this recommendation as part of the cross-industry freight derailment working group work programme and that it was seeking further information on how the planned work (which was initially focused on uneven freight container loads (paragraph 145)) would be extended.

Recommendations that are currently being implemented

Accident at Angerstein Junction on 2 April 2014, RAIB report 11/2015, Recommendation 4

154 The above recommendation (in RAIB report 11/2015) addressed an observation identified in this investigation (paragraph 141b). So as to avoid duplication, it is not remade in this report. However, shown below is a recap of its wording and an account of its current status.

Recommendation 4

Network Rail should liaise with RSSB to review whether the existing 3 metre measurement base used for identification of track twist is sufficient for managing the derailment risk applicable to rolling stock currently operating on Network Rail infrastructure. If found to be inadequate or insufficient, Network Rail should:

- *update its process for assessing track twist by the inclusion of additional and/or alternative measurement bases; and*
- *implement a time-bound plan to apply the new process to all of its infrastructure.*

155 The intent of this recommendation was to establish whether the historical three metre base that Network Rail uses to monitor track twist (paragraph 53) remains a sufficient control in view of the type of rolling stock now operating on its infrastructure, and in particular, their wheelbase and bogie centre dimensions and the short and long base twists to which they may be susceptible. Although focused on the effects of long base twist, one of the potential risk mitigation measures to be considered in response to recommendation 2 in RAIB report 21/2014 (paragraph 149) is similar in its objective.

156 In its response to the RAIB on 6 July 2016, the ORR reported that it was satisfied with the progress Network Rail had made, although it had some concerns regarding wider input from other rail industry parties.

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

157 The S&C South Alliance repaired and re-instated the track on the double junction at Courthill Loop South Junction and made arrangements to remotely monitor the vertical geometry under the passage of trains. It has since removed a number of the concrete bearers that had bearer ties and replaced them with continuous bearers.

158 Network Rail has advised that it has sought to establish where similar bearer configurations have been used on other S&C layouts on the national network. It identified three; it has inspected them and considers that they pose no additional risk.

159 Network Rail has also reported that it has commissioned a review of its standard bearer tie design and its suitability for the applications in which it is currently being used. It is additionally considering changes to related company procedures and their use. So far, it has reported that it has:

- agreed that, where no RE/PW general arrangement drawing is available, new S&C layout designs need to be endorsed by Network Rail's Professional Head of S&C; and
- published a new work instruction for the installation of modular S&C: Network Rail standard NR/L3/TRK/3406, 'Installation of modular S&C'.

160 As well as monitoring track geometry on similar S&C layouts at other renewal sites, Colas Rail has reported that it has made improvements to how it installs new track. These have included mandating track geometry measurements by track measurement trolley (or its equivalent) after tamping and lifting and packing work, the implementation of survey methods to record the levels associated with the preparation and construction of the track bed and the use of deflectometer measurements to determine the consistency of ballast consolidation. It has also advised that it has introduced new training and competence arrangements for its site teams, and is developing processes and criteria for the wider remote monitoring of track geometry after renewal work.

161 RSSB has advised the RAIB on the progress of the cross-industry freight derailment working group. It has reported that:

- Two studies are seeking to consider the suitability of the existing three metre base that Network Rail uses to monitor track twist during routine maintenance. The RAIB understands that the overall conclusions from these will be used to inform implementation of recommendation 4 in RAIB report 11/2015. This has removed the need for the RAIB to make a recommendation to address an observation in this investigation (paragraph 141b)[20].

[20] Neither of these studies are seeking to consider the major effect that track renewal and heavy maintenance work may have on introducing new and significant track geometry features. As a result, the RAIB has concluded that it needs to make Recommendation 3.

- Work considering the effect of payload offset has so far concentrated on container freight wagons. However, RSSB has advised that it is currently retaining a degree of oversight on follow-on projects being delivered by industry parties; these include identification of control measures for bulk loads (this is being led by Aggregate Industries (paragraph 163)) and improvements in wheel impact load detector reporting. It is also considering introducing a criterion for payload offset in Railway Group Standard GM/RT 2141 (paragraph 51).

162 GBRf has reported that it, along with other industry parties, including representatives of the cross-industry freight derailment working group, is engaged with a practical trial to improve the loading of aggregate products in both bulk hopper and box wagons. It is envisaged that this will involve understanding how the wheel load distribution and the profile of the loaded product compare, and using this to establish criteria for visually confirming payload evenness. GBRf has also reported that it has taken action to address issues relating to the maintenance of suspension components that are critical to derailment risk.

163 Aggregate Industries has confirmed that it is working together with GBRf and other industry parties on the new trial (paragraph 162). It has also advised that it plans to install CCTV at its Grain terminal to monitor payload evenness, and that it is working with its front-end loader operatives to develop improved loading techniques.

Recommendations and learning points

Recommendations

164 The following recommendations are made[21]:

1 *The intent of this recommendation is to limit the use of manual lifting and packing of track to such cases where it is sufficient to give adequate support to the track. Consideration of its use following renewal and heavy maintenance, where there has been significant disturbance to the track and ballast, is of particular relevance*.

Network Rail should assess the suitability and limitations of manual lifting and packing following track renewal and other work likely to result in significant change to track geometry or the supporting ballast. It should update its process and guidance, as necessary, and brief its track teams (both in-house and those working for its suppliers and contractors) on changes made (paragraph 138a.ii).

2 *The intent of this recommendation is to ensure suitable confirmation that the track is adequately supported, or where this is not possible, that suitable mitigation measures are put in place, in particular following renewal and heavy maintenance, where there has been significant disturbance to the track and ballast.*

With respect to hand back into service following track renewal, and other work likely to result in significant change to track geometry or the supporting ballast, Network Rail should:

- assess and define the ciriterion (for instance degree of track bed disturbance) for which it is expected that the vertical track geometry should be confirmed under load, and
- define the specific mitigation measures that need to be applied when this is not possible.

It should then update its process and guidance to include objective limits and mitigation measures, as necessary, and brief its track teams (both in-house and those working for its suppliers and contractors) on changes made (paragraph 138a.iii).

[21] Those 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 the Office of Rail and Road to enable it to carry out its 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 200 to 203) can be found on RAIB's website www.gov.uk/raib.

3 *The intent of this recommendation is to ensure that excessive cant gradients are not inadvertently introduced into the track following renewal and heavy maintenance work.*

Network Rail should determine the circumstances when cant gradient should be measured before handing back track into service following renewal, and other work likely to result in significant change to track geometry or the supporting ballast, and the limits that apply. It should update its process and guidance to include the requirement and associated limits, and brief its track teams (both in-house and those working for its suppliers and contractors) on changes made (paragraph 141a).

4 *The intent of this recommendation is to minimise the likelihood of vertical track geometry features that are hazardous to the safe passage of trains, from forming in modular S&C layouts.*

Network Rail should review the design and validation of the standard bearer tie that it uses on modular S&C layouts, taking into account the applications in which it is being used and how its mechanical behaviour promotes the formation of track twist faults and unintended cant gradients. It should use its findings to determine the validity of requirements and guidance defined in its technical standards and on its standard design drawings, and amend and brief designers, suppliers, installers and others as appropriate (paragraphs 138b.i, 138b.ii and 140).

5 *The intent of this recommendation is to hasten the establishment of a practical means of preventing bulk hopper wagons travelling on the national network with a significant laterally-offset payload.*

In its role of managing the development programme of the Cross-industry Freight Derailment Working Group, the RSSB should expedite work to define an acceptable limit for the lateral offset of the payload carried by bulk hopper wagons permitted to operate on the national network. The working group should additionally research and propose how compliance with this limit can be managed (paragraph 139).

Learning points

165 The RAIB has identified the following key learning points[22]:

1 It is important that, in managing the installation of new track, Infrastructure Managers systematically and robustly identify any emerging work, additional to that originally planned, that is necessary to achieve compliance with track geometry requirements. They should plan the necessary resources, equipment and facilities to deliver the work (paragraph 138a.i).

2 It is important that Entities in Charge of Maintenance ensure that their routine maintenance procedures include examination of all vehicle suspension components that are critical to derailment risk and that necessary rectification is undertaken in a timely manner (paragraph 141c).

[22] 'Learning points' are intended to disseminate safety learning that is not covered by a recommendation. They are included in a report when the RAIB wishes to reinforce the importance of compliance with existing safety arrangements (where the RAIB has not identified management issues that justify a recommendation) and the consequences of failing to do so. They also record good practice and actions already taken by industry bodies that may have a wider application.

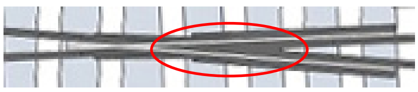
Appendices

Appendix A - Glossary of abbreviations and acronyms

CCTV	Closed circuit television
GBRf	GB Railfreight
GRIP	Governance for railway investment projects
GSM-R	Global system for mobile communications - railways
ORR	Office of Rail and Road
S&C	Switches and crossings
VCUK	Vossloh Cogifer UK

Appendix B - Glossary of terms

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

Accredited agent	A member of railway staff trained and appointed by the RAIB to identify and record perishable evidence pending the arrival of RAIB inspectors.*
Aluminothermic	A welding process using the chemical reaction between aluminium and iron oxide to produce both iron and the heat needed to melt the iron to form a joint between two lengths of rail.
Bearer	A term used to describe a wooden or concrete beam used to support the track in a switch and crossing layout.*
Brake pipe	A pipe running the length of a train (such as train 6M90) that controls and supplies the train's air brakes. A reduction in brake pipe air pressure, as happens when the pipe is separated or ruptured, applies the brakes.
Cant	The amount by which one rail is raised higher than the other rail on the same track.*
CEN56	A type of flat-bottomed rail having a weight of 56 kilograms per metre.
Centre pivot	The mechanical assembly on the underframe of a rail vehicle body about which a bogie rotates.
Choked ballast	Ballast in which the voids between individual pieces are filled with a finer medium such as sand or mud affecting drainage.
Common crossing	An assembly of track components used to support and guide the wheels where two running rails cross at an acute angle. 
Contractor's responsible engineer (construction)	A person within a construction organisation contracted to Network Rail with accountability for day-to-day management and co-ordination of the technical and engineering activities within a specific engineering discipline for a specific contract.
Crossing nose	The apex of the v-shaped track component that is located where the two rails cross at a *common crossing*. 
Designated project engineer	A professional engineer appointed to a project by Network Rail to lead the acceptance of engineering designs for, and on behalf of, Network Rail.

Diamond crossing	An assembly of track components that allows two railway tracks to intersect at an angle, without the facility to enable trains to change from one track to another.
Downstop	A device fitted to the suspension of a railway vehicle to limit downward movement.
Electrical control operator	The person having control over supply to, switching of and isolation of the traction power system in a geographical area.*
Engineering possession	The closure of a specific section of line to railway traffic to allow engineering work to take place on the infrastructure.*
Entity in charge of maintenance	A person or organisation responsible for the maintenance of rail vehicles that has to ensure that, through a system of maintenance, a vehicle for which is it responsible is safe to run on the mainline railway.
Expansion switch	A sliding joint in the rails to allow thermal expansion and contraction to take place.
Extendable tamper arm	A horizontal metal beam that extends laterally from the body of a tamping machine and supports the vertical tines used to compact track ballast.
Formation	The prepared surface of the ground on which the ballast and track is laid.*
Four-foot	The area of the track between the two running rails.*
Front-end loader	A heavy plant vehicle used to move loose materials using a front-mounted bucket or scoop.
Gauge face	The side of the rail head facing towards the opposite running rail.*
Geogrid	(Tradename) A synthetic mesh used as a strengthening material for soils (and other granular materials).*
Geotextile	A woven membrane used to separate the ballast from the formation, thereby preventing the ballast becoming contaminated.
Lifting and packing	The action of raising the track and adding ballast underneath the sleepers (and bearers). The term is usually associated with a manual operation involving ratchet jacks, shovels and hand-held electric hammers.*
Loading gauge	The set of dimensions that a load on a rail vehicle must be within in order to run in normal traffic.*
Point end	Term used to describe the pair of fixed (stock) and movable (switch) rails at a turnout.

Road rail vehicles	A road vehicle that has been adapted to make it capable of running on railway track as well as on the road.
Side-bearer	A component located on the side frame of a bogie (one per side) which provides vertical support to the wagon body underframe whilst allowing the bogie to rotate.*
Six-foot	A term used for the space between two adjacent tracks.*
Spine panel	A term used to describe a modular S&C track panel comprising a single length of rail and a series bearer sections that are only directly attached to that rail.
Switches and crossings	A generic term used to describe parts of the track where a train can move from one line to another or can cross over another line.
Tamping machine	A rail vehicle which lifts and aligns track and simultaneously compacts the ballast underneath.
Third rail DC traction power system	A general term used to describe the type of electrification that involves the supply of DC current to trains by means of a conductor rail laid along one side of the track (the ‘third rail’).
Tilting wagons	Special flatbed wagons designed to carry modular S&C track panels inclined in order to maximise the space available within the *loading gauge.*
Top stone	The layer of ballast above the underside of the sleepers and bearers.*
Total station survey	A method of surveying geographical features using an optical and electronic device that accurately measures their position.
Track measurement trolley	A small, usually unpowered, trolley fitted with devices that measure track attributes such as gauge, cant and twist.
Track twist	The change in cant, along the track, measured over a specific distance.
Train document	A series of sheets giving information relevant to the operation of the train including a departure time; origin; destination points; maximum load; brake force and type; tonnage; length limit and maximum speed.*
Train preparer	A person appointed and passed competent to carry out train preparation duties before departure. Duties include checking the train for compliance with the train document and physically checking all vehicles to ensure that they are properly coupled.*
Turnout	A piece of track which is designed to allow trains to be diverted to another track. Also referred to as a set of points.

Void meter	A device that measures the vertical deflection of the track under passing trains and hence the size of the voids under the sleepers or bearers.*
Wet bed	An area of ballast, usually between sleepers, contaminated with mud.
Wheel impact load detector	A rail-mounted system used to monitor the wheel-rail forces from passing trains in order to detect excessive wheel loads and wheel flats.
Wheelset	Two rail wheels mounted on their joining axle.*
Wing rails	The short lengths of rail fastened to the v-shaped track component at a common crossing to guide the passage of rail vehicle wheels. 

Appendix C - Form A certificate for the Up Courthill Loop, dated 23 January 2017

FORM A: TRACK GEOMETRY CERTIFICATE	TEF 3203 issue 5
	June 2015
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Location: COURTHILL JTN   ELR: XTD/NCS   Line: Up loop

Project/UID No: 16SCKSCOURS   *Affected* Miles/ Yds From: 6M 17CH   *Affected* Miles / Yds To: 6M 41CH

Guidance notes for completion of this certificate can be found in Appendix 2

TRACK GEOMETRY COMPLIANCE STATEMENTS

If a cross **X** (a "no" answer) is entered in response to any of the compliance statements listed below, the Engineering Supervisor and Authorised Person must be consulted to agree a safe opening speed and any action that is needed to allow the safe passage of trains. The outcomes of any such consultations, particularly, any assessments visual or otherwise that have been made to determine the suitability of the track geometry and the need for an ESR and/or Watchman must be recorded below.

	Item	Statement	Enter a **tick** (yes), **X** (no) or **N/A** (not applicable)	Worst Values
1	Vertical Alignment (Top)	The top is within tolerance required for the **Planned Opening Speed**:	✓	28
		Assessment/measurement of voiding undertaken *(follow up inspection may be required – add comment below)*	✓	
2	Horizontal Alignment (Line)	The line is within tolerance required for the **Planned Opening Speed**:	✓	21
3	Cross Level (Cant)	The cant is within tolerance required for the **Planned Opening Speed**:	✓	5
4a	Twist	The maximum twist is within tolerance required for the **Planned Opening Speed**:	✓	1:335
4b	DAR Inspector / Amber trolley has been used to monitor twist: ✓	Recording parameters were set correctly : YG		
5a	Gauge	The 4' gauge is within tolerance required for the **Planned Opening Speed**	✓	1432 wide
5b	Gauge variation	Gauge variation is within tolerance for the **Planned Opening Speed**	✓	6

Intervention limits and rectification timescales for track gauge variation (measured over 3 metres)		
Speed	**Variation**	**Action**
Up to 60mph	8mm	Re-gauge within 52 weeks
65 – 95mph	7mm	Re-gauge within 26 weeks
100 – 125mph	6mm	Re-gauge within 13 weeks

5c DAR Inspector / Amber recorder has been used to monitor gauge: ✓   Recording parameters were set correctly : YG

If more than one tolerance is exceeded, assess the combined effect they have on the safe passage of trains and action accordingly.

Non-Compliances/ Comments:	**Mitigating Action(s):**
Twist found on Amber trolley 26mm, 1:115 and Kango pack check with cross level 9mm twist.	Amber trolley used recorded @ 26-50mph

TOLERANCES

SPEED	Difference between consecutive design variances measured at 10m intervals		MEASURED VALUES [1 in 300 twist equates to 10mm variation in cross level over 3m]				
	TOP	ALIGNMENT	CANT	TWIST	GAUGE		
					WIDE	TIGHT	
Up to 20 mph	± 30mm	± 30mm	± 20mm	1 in 300	1455mm	1426mm	Values provided in this table are 'Maintenance Tolerances', which can be used to assess whether the track is fit for operational use at the planned opening speed. In order to proceed with final handback into maintenance, the site must conform to 'Installation Tolerances'.
25 to 40 mph	± 25mm	± 25mm	± 20mm	1 in 300	1450mm	1429mm	
45 to 60 mph	± 20mm	± 20mm	± 20mm	1 in 300	1450mm	1429mm	
65 to 95 mph	± 16mm	± 16mm	± 15mm	1 in 300	1450mm	1430mm	
100 to 125 mph	± 13mm	± 13mm	± 15mm	1 in 300	1450mm	1430mm	

FORM A: TRACK GEOMETRY CERTIFICATE	TEF 3203 issue 5
	June 2015
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Location: COURTHILL JTN ELR: XTD/NCS Line: Up loop

Project/UID No: 16SCKSCOURS *Affected* Miles/ Yds From: 6M 17CH *Affected* Miles / Yds To: 6M 41CH

STRUCTURAL AND PASSING CLEARANCES
(refer to Appendix 2 item 6 for guidance)

CATEGORY	TOLERANCE (Variance from design)
Design 'Special Reduced' Clearances - Points where the clearance is greater than 0mm but less than 50mm	No closer to the structure than the designed position plus design tolerances
Design 'Reduced' Clearances - Points where the clearance is 50mm or more but less than 100mm	Can be up to 15mm closer than the designed position plus design tolerances
Design 'Normal' Clearances - Points where clearances are 100mm or more	

LOWER SECTOR CLEARANCE STRUCTURES <1100mm Above Rail Level
(refer to Appendix 2 item 6 for guidance)

CATEGORY	TOLERANCE (Variance from design)
All Clearances	No closer to the structure than the designed position plus the design tolerances

			Enter a **tick** (yes), **X** (no) or **N/A** (not applicable)	Worst Values
6a	Structural clearances	Clearances are within tolerance required for the **Planned Opening Speed**	✓	
6b	Passing clearances	Clearances are within tolerance required for the **Planned Opening Speed**	✓	

If more than one tolerance is exceeded, assess the combined effect they have on the safe passage of trains and action accordingly.

Non-Compliances/ Comments:	**Mitigating Action(s):**

If Absolute Track Geometry is being reinstated on a WCRM route, the more onerous requirements specified in NR/L3/TRK/0030 [Reinstatement of Absolute Track Geometry (WCML Routes)] apply and additional certification is required.

Planned Opening Speed: 20 mph **Maximum Recommended Opening Speed (Based on track geometry and clearances):** 20 mph

Arrangements shall be made for the imposition of an Emergency Speed Restriction (ESR) when opening the line at a lower speed than the published 'Planned Opening Speed'.

CERTIFICATION BY THE CHECKER
Having visually examined the track and paid particular attention to any portion that is outside tolerance, I am satisfied, subject to any restrictions arising from other checks/assessments, that it is safe for trains to run at the **Recommended Opening Speed** shown:

Print Name: [redacted] **Signature:** [redacted] **Date:** 23/01/17 **Time:** 00.35

CONFIRMATION OF RECEIPT BY THE AUTHORISED PERSON

Print Name: [redacted] **Signature:** [redacted] **Date:** 23/1/17 **Time:** 0100

Appendix D - Extract from Network Rail standard NR/L2/TRK/2102

11.6.3 Bearer ties in S&C

Bearer ties shall not be positioned in the four foot of switch panels.

AWS magnets, TPWS equipment and axle counters shall not be installed in beds with bearer ties.

Where bearers are split into three 'parts' the centre section shall contain at least one pair of rails across track gauge.

No more than two ties shall be used on a bearer.

S&C containing bearer ties shall have the cant and longitudinal levels designed so that tracks connected by tied bearers have no difference in the plane of the rails or a change in gradient within 18 m of a tied bearer.

Bearer ties shall be positioned as shown on RE/PW general arrangement drawings.

For geometries where general arrangement drawings with bearer ties are not available ties shall be positioned in line with the principles shown below:

a) the number of ties shall be kept to a minimum, short ended bearers shall be used to reduce the number of ties;
b) bearers shall be shortened on the turnout or crossover route before being shortened on the through route;
c) ties shall be positioned in the 6 ' rather than the 4 ';
d) where ties have to be positioned in the 4 ' they shall be installed on the turnout or crossover line in preference to the through route;
e) the number of part bearers supporting only one rail shall be kept to a minimum;
f) the lengths of part bearers shall where practicable be in increments of 75 mm; and
g) in crossovers spanning parallel tracks (with matching geometry on sides) the position of bearer ties and bearer lengths shall be mirrored either side of the mid-point of the crossover.
h) Bearer ties are not permitted on single leads where two levelling is required. If two levelling of a single lead is required then only continuous through bearers shall be used.

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