



Rail Accident Investigation Branch

Rail Accident Report



Bridge strike and road vehicle incursion onto the roof of a passing train near Oxshott Station 5 November 2010

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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Summary

At about 15:29 hrs on Friday 5 November 2010, a lorry fell from the Warren Lane (A244) road bridge onto the railway at Oxshott, Surrey, and struck the roof of a passing train. The lorry had collided with the bridge's parapet and partly demolished it. Road users who witnessed the accident responded by contacting the emergency services and assisting the injured lorry driver who was trapped in the lorry's cab.

The rear three carriages of the train were damaged and the rear carriage of the train derailed. One passenger, sitting directly beneath the point of impact, was seriously injured, and five other passengers received minor injuries. No other trains were involved.

The RAIB has made two recommendations to the Department for Transport concerning issuing guidance for local highway authorities, two recommendations to Surrey County Council concerning highway safety inspections and safety measures at the bridge where the accident occurred, and one recommendation to Network Rail to enhance existing structural examinations at bridges carrying roads over railways.

Preface

- 1 The sole purpose of a Rail Accident Investigation Branch (RAIB) investigation is to prevent future accidents and incidents and improve railway safety.
- 2 The RAIB does not establish blame, liability or carry out prosecutions.
- 3 This report is limited to addressing the consequences of the initiating road accident and its effect on the bridge and operational railway. There was no defect found on the vehicle or road surface. It does not determine why the road accident occurred as this was the responsibility of Surrey Police.

Key Definitions

- 4 References to left and right are made relative to the direction of travel of trains travelling on the *up line* (ie towards London) and vehicles travelling southbound on the A244 (the same direction as the lorry involved in this accident was travelling).
- 5 All dimensions and speeds in this report are given in metric units except speed, and locations on Network Rail, which are given in imperial dimensions, in accordance with normal railway practice. For speeds, the equivalent metric value is also given.
- 6 The report contains abbreviations and technical terms (shown in *italics* the first time they appear). These are explained in appendices A and B.

The accident

Summary of the accident

- 7 On Friday 5 November 2010 at approximately 15:29 hrs, a lorry fell from a road over rail bridge NGL 15/11 (Bridge 11) near Oxshott station and struck the roof of train 2G46, the 15:05 hrs service from Guildford to London Waterloo via Cobham, which was passing below. The train had departed from Oxshott station less than one minute earlier.
- 8 The lorry, fitted with a truck mixer body loaded with concrete, had been travelling southbound on the A244 when it struck the north end of the bridge's east parapet. After travelling across the bridge for a further 10-15 metres, it collided with the east parapet for a second time. The parapet collapsed allowing the lorry to slip sideways over the unprotected edge and onto the railway.
- 9 The impact of the lorry damaged the rear three coaches of the train and derailed the rear *bogie* of the last coach. This distorted the track and displaced the *conductor rail*.
- 10 Of the 36 passengers on the train, one was seriously injured and five were slightly injured. The lorry driver was also seriously injured.

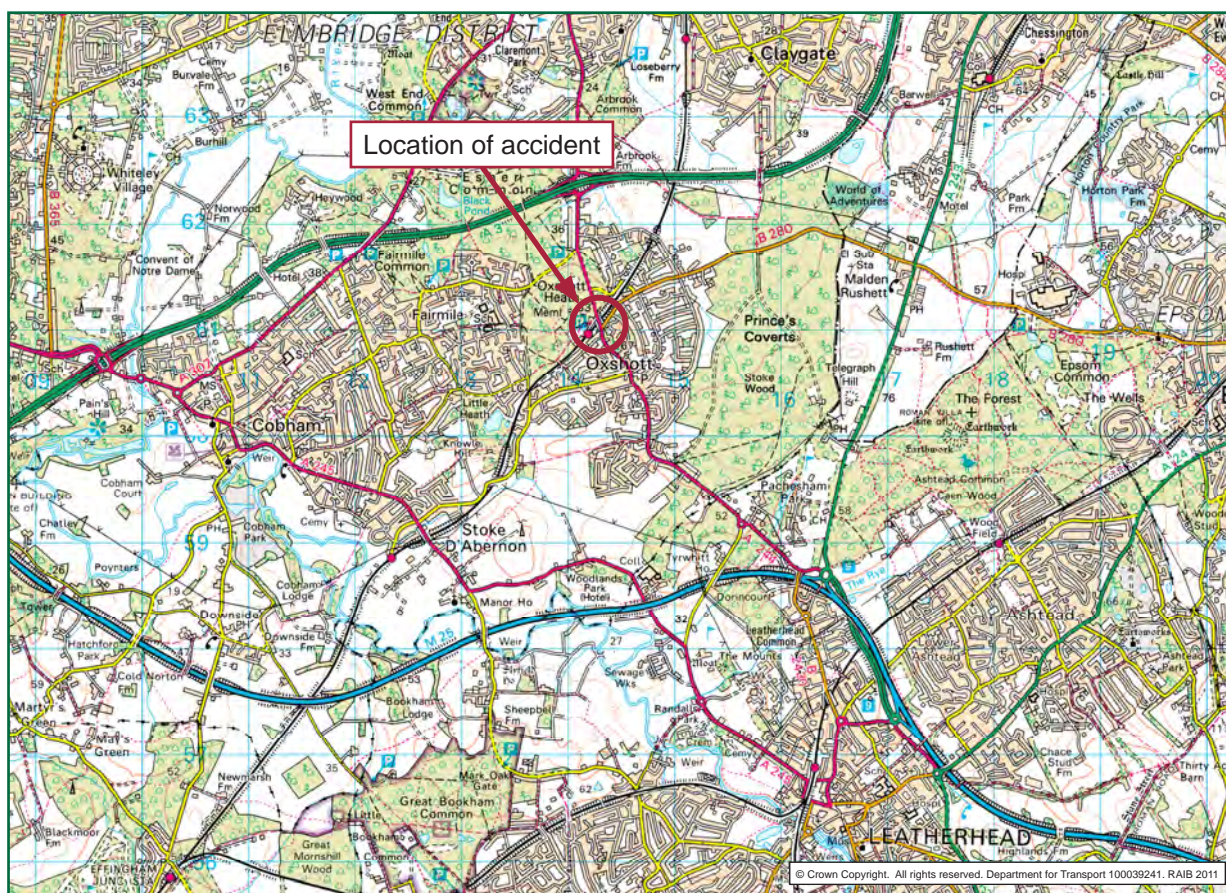


Figure 1: Extract from Ordnance Survey map showing location of accident

Organisations involved

- 11 Train 2G46 was operated by South West Trains.
- 12 Network Rail owns and maintains the track and infrastructure, including the bridge and parapet through which the lorry fell.
- 13 Surrey County Council, as the local highway authority, was responsible for highway inspection and maintenance including control of vegetation where this may create a hazard, signs and reflective marker posts where provided. It was also responsible for assessing Bridge 11 against the risk of road vehicle incursion onto the railway.
- 14 All parties freely co-operated with the investigation.

Location

- 15 Bridge 11 is located 16 miles 72 chains¹ from London Waterloo, between Claygate and Oxshott on the line from Hampton Court junction to Guildford (via Cobham). This line forms part of Network Rail's Wessex Route. The bridge is 58 metres east (London side) of the end of the up platform at Oxshott station. The railway at this location is situated in a deep wooded cutting.
- 16 Bridge 11 is located on the north side of Oxshott village, and carries the A244 (Warren Lane) which links the A3 at Esher Common to the M25 at Junction 9. The A244 has a statutory speed limit of 30 mph (48 km/h) commencing 160 metres north of the bridge and continuing through Oxshott village. At the north end of the bridge there is a road junction with Station Approach, giving vehicular access to Oxshott station and Oxshott Common. At the south end of the bridge there is a junction with the B280 (Fair Oak Lane) which is controlled by traffic lights (figure 1).
- 17 The A244 approaches the bridge from the north on a 1 in 19 (5.2%) falling gradient with footpaths on both sides, followed by a short 18° left-hand bend which extends onto the bridge (figure 2). The north end of the bridge's east parapet is located at the edge of the carriageway, close to the apex of the curve. The footpath on the left-hand side of the road stops just before the north end of the bridge.

External circumstances

- 18 The weather at the time of the accident was dry, but the road surface was wet following earlier rain. The accident occurred in daylight.
- 19 There were no other vehicles involved.

Road vehicle involved

- 20 The lorry involved was a DAF 75 CF three-axle rigid chassis *large goods vehicle* (LGV), first registered in 2005 and fitted with a truck mixer body (figure 3). It had a valid MOT certificate, and examination of the vehicle by an inspector from the vehicle and operator services agency (VOSA) found no pre-existing defect which could have caused or contributed to the accident.

¹ One chain is equal to 22 yards (20 metres)



Figure 2: View of approach to bridge 11 for southbound traffic showing left-hand bend. The parapet end struck by the lorry is hidden by vegetation, and is marked 'A' (photograph courtesy of Surrey Police)



Figure 3: Photograph of a lorry similar to that involved in the accident (photograph courtesy of Kingman Services)

- 21 The mixer drum fitted to a lorry of this type is designed to revolve as the vehicle is travelling to keep the still-fluid concrete moving pending delivery to prevent it from hardening.
- 22 At the time of the accident, the lorry was travelling between a concrete batching plant at Byfleet, Surrey, and a construction site located near Epsom station, a distance of 13 miles (21 km). The lorry was following its planned route and carried a full load (six cubic metres) of concrete weighing 14.0 tonnes. Weighbridge records for 5 November indicate that the lorry's gross vehicle weight was 25.6 tonnes. This was less than the vehicle's total permitted weight of 26 tonnes, as indicated on the vehicle's *plating certificate*.

Bridge 11

- 23 Bridge 11 was built in preparation for the opening of the railway in 1885. It was constructed as a three arched brick structure spanning the railway cutting with a total length of 50 metres. It carries the road 10.5 metres above track level. The bridge deck is 7.8 metres wide at road level and there is a 1.2 metre wide footpath provided on the west side. There is no kerb or footpath on the east side of the carriageway on the bridge, the kerb ending 3 m north of the parapet end.
- 24 The parapet walls vary slightly in height along their lengths but are a minimum of 1050 mm high (3ft 6") and 350 mm thick. They are constructed of common brick laid in *English bond*.

Train involved

- 25 Train 2G46 was formed of two 4-car Class 455 electric multiple units. The rear unit, number 455913 comprising vehicles 77837, 62838, 71726 and 77838 was built in 1985.
- 26 Unit 455913 had returned to service following heavy overhaul in October 2010. The RAIB has found no evidence to link the maintenance, overhaul, or driving of the train with the cause of this accident.

Staff involved

- 27 The driver of the lorry obtained his Large Goods Vehicle (LGV) driving licence in October 2010, and at the time of the accident, had been employed as a LGV driver for just under three weeks. This period included two weeks of driver mentoring which he had successfully completed. The accident occurred during his first week of unaccompanied driving.
- 28 The driver and guard operating train 2G46 were employed by South West Trains. The guard was travelling in the fifth coach² when the accident occurred and witnessed masonry hitting the train. Neither member of staff was injured in the accident.

² In this report the coaches are numbered from 1 to 8, with coach 1 being at the head of the train.

Railway infrastructure involved

29 The railway at this location is double track plain line equipped with the 750 V DC *third rail* electrification system. The maximum permitted line speed is 70 mph (113 km/h) in both directions. Train 2G46 was travelling on the up line. The Woking area signalling centre controls three-aspect colour light signals in this area.

Events preceding the accident

- 30 Train 2G46 departed from Oxshott station on time at 15:28 hrs. In the 38 seconds which elapsed between the train leaving the station and it being hit by the lorry, it had accelerated to 28 mph (45 km/h). Although there were only 36 passengers on the train, 14 passengers and the train's guard were travelling in coach 5 and ten passengers were travelling in coach 6, both of which were affected by the accident. There were two passengers travelling in coach 7 and none in coach 8.
- 31 The lorry approached Bridge 11 southbound on the A244, travelling at less than 30 mph (48 km/h) and followed by several vehicles. As the lorry negotiated the left-hand bend onto the bridge, its front left-hand wheel struck the north end of the bridge's east parapet. The rear of the vehicle also made contact with the parapet end (figure 4).



Figure 4: North end of the east parapet which was struck by the lorry

- 32 Skid marks on the road surface indicate that the lorry continued to travel close to, and parallel with, the east parapet for a further 10-15 metres. The lorry then steered slightly to the left and collided with the side of the parapet. The parapet broke off below road level, leaving an unprotected edge (figures 5, 6 and 12). The lorry's left-hand wheels slipped over the edge, dragging the vehicle sideways to the left.



Figure 5: Photograph of bridge deck showing missing section of parapet and skid marks denoted 'M'

Events during the accident

- 33 The impact of the lorry demolished a 14.3 m section of parapet which fell from the bridge. Most of the brickwork fell onto the cutting slope, but some sections struck the roof and left-hand side of coach 5 of the train which was passing beneath the bridge at the same time. Within this coach, bags were knocked from overhead luggage racks, although there was no penetration of the passenger area or injury caused.
- 34 The lorry struck the upper left-hand corner (*cantrail*) of Coach 6 ahead of the leading doors (figure 7). The cantrail became detached from the *corner pillar* at the front of the coach and moved downwards and inwards with the deforming roof. This deformation caused the lorry to rapidly fall off the train to the left and onto the ground beside the track.

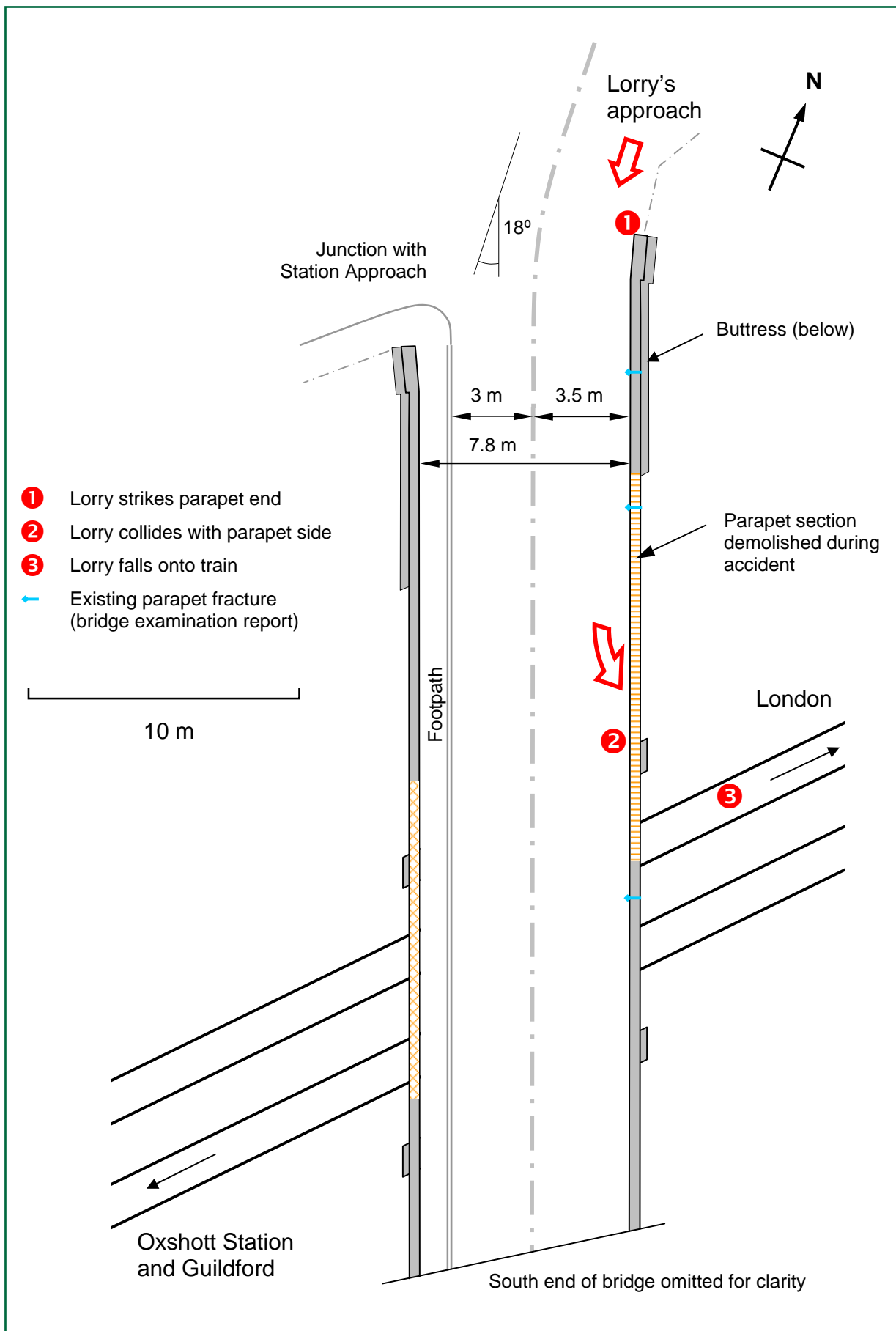


Figure 6: Schematic diagram of bridge deck showing path of lorry



Figure 7: View of coach 6 (leading end) which sustained a vertical impact from the falling lorry

- 35 The train coasted for four seconds before the brakes automatically applied without intervention by the train driver, and stopped approximately 14 seconds after time of impact. South West Trains has been unable to find positive evidence as to precisely what caused the train's brakes to apply, although the most likely cause is damage to a brake supply wire following the initial impact.
- 36 Four of the five passengers travelling in the leading end of coach 6 were able to escape from the damaged part of the train without assistance. The fifth passenger was trapped. This person, a 60 year old male, sustained serious injuries including fractures to his lumbar vertebrae and hip. A further ten seats in coach 6 were affected by bodywork distortion or flying debris. None of these seats was occupied (figure 11).
- 37 The lorry landed on its left side with the mixer drum against the slope of the cutting. Parts of the chassis and heavy rear axle assembly, trapped between the heavy mixer drum and train, continued to make contact with the train as the lorry broke up, shattering the windows on either side of the rear doors on coach 6 and puncturing the steel outer skin of coach 7.
- 38 The most severe secondary impact occurred to coach 8. The disintegrating lorry chassis made contact with the leading doors of coach 8 causing significant damage and intrusion into the passenger area (figure 8).
- 39 The lateral force imposed on coach 8 was sufficient to move the track approximately 350 mm to the right, and towards the down line (figure 8). The rear bogie of coach 8 was knocked off the rails and landed 300 mm to the right. The train remained upright throughout.



Figure 8: View of coach 8 which sustained a side impact from the disintegrating lorry chassis



Figure 9: View of damaged lorry and train. Note displaced track and conductor rail

Events following the accident

- 40 The train driver, who had heard a loud bang, contacted the guard once the train had stopped. He then made an emergency radio call to the signaller who ensured that no other train was able to approach the area. After briefly examining the scene, the driver requested that the signaller to block both lines, isolate the electrical supply and contact the emergency services.
- 41 The guard, who from his position in coach 5 was aware that the train had been struck by heavy objects, informed the driver that the *overbridge* had come down on the train. He then made an announcement to passengers using the train's public address system and contacted South West Trains' control room.
- 42 At 15:31 hrs, Surrey Fire Brigade, which had received emergency calls from members of the public, notified Network Rail's control office of the accident, stating that a lorry had gone over Station Approach bridge at Oxshott and may be on the line. This was followed almost immediately by a similar notification from Surrey Police. Several members of the public, who had witnessed the accident, climbed down from the bridge to provide initial assistance to the lorry driver who remained trapped in his cab pending the arrival of the emergency services.
- 43 The guard obtained a ladder from the train's cab and assisted passengers in coaches 5, 6 and 7 to leave the train in order to move forwards to the front four coaches which were undamaged. An off-duty police officer, who was a passenger on the train, assisted the guard and the seriously injured passenger who remained trapped in coach 6. A paramedic team was on site within 18 minutes of the accident and attended to injured passengers.
- 44 Passengers were evacuated to Oxshott station at 17:18 hrs once road transport had been arranged for them. Five passengers were taken to hospital and a further eight received medical attention for minor injuries including shock and whiplash. Non-injured passengers were taken to a reception centre established by Elmbridge Borough Council.
- 45 Network Rail's incident log records that the lorry driver had been removed from his cab by 17:18 hrs and was confirmed as seriously injured. He remained in hospital for two days.

The Investigation

Sources of evidence

- 46 The following sources of evidence were used:
- a. Network Rail's bridge maintenance records;
 - b. Surrey County Council's road vehicle incursion (RVI) assessment records;
 - c. Department for Transport's documentation on the road vehicle incursion risk assessment protocol including its development;
 - d. Surrey County Council's highway inspection, maintenance and accident records;
 - e. RAIB's examination of unit 455913;
 - f. in train CCTV;
 - g. on train data recorder (OTDR) records;
 - h. witness statements taken from road users by Surrey Police;
 - i. road accident analysis by Surrey Police; and
 - j. VOSA's vehicle examination report.

Key facts and analysis

Identification of the immediate cause³

47 **The lorry collided with the bridge parapet which collapsed, allowing the lorry and parts of the parapet to fall onto the railway.**

Identification of causal factors⁴

48 Witnesses travelling in other vehicles on the A244 describe the lorry as travelling slowly as it approached the bridge, but too close to the left-hand side of the road. The scope of the RAIB's investigation did not encompass consideration of the manner in which the lorry was being driven. This has been the subject of a separate investigation by Surrey Police.

Visibility of the parapet end

49 **The parapet end was not sufficiently visible to approaching traffic as the processes for identifying this as a maintenance requirement were not effective. The lack of conspicuity of the parapet end was possibly a causal factor.**

50 The parapet end was obscured by vegetation growth on the inside of the bend (figure 2), and a reflective marker at the parapet end was missing after its supporting post had collapsed as a result of previous damage. These defects were not identified during routine highway safety inspections and as a consequence, no corrective action had been taken or was planned.

51 The presence of skid marks on the approach to the bridge suggests that the driver became aware of the obstruction before striking the parapet end, but with insufficient time to take avoiding action (paragraph 58). Had the parapet end been more clearly marked, it is possible that the lorry driver would have become aware of it early enough to avoid it. Witness evidence from LGV drivers who use the A244 regularly suggests that for southbound vehicles, this can be a difficult bend to negotiate. The road geometry directs vehicles towards the end of the bridge's parapet, and oncoming traffic can require a large vehicle to approach close to the kerb and parapet end (paragraph 17).

52 The inspection of Bridge 11 is undertaken by two separate parties:

- a. Network Rail for all structural issues as the bridge's owner and maintainer (paragraph 70); and
- b. Surrey County Council, as the local highway authority, for the carriageway surface, kerbing, signage and hazards created by vegetation.

³ The condition, event or behaviour that directly resulted in the occurrence.

⁴ Any condition, event or behaviour that was necessary for the occurrence. Avoiding or eliminating any one of these factors would have prevented it happening.

- 53 The A244 is inspected on foot every three months by a qualified highway inspector employed by Surrey County Council. Bridge 11 is located at approximately the mid-point of a 1.28 km inspection length. The inspection remit includes locating and identifying defects on the highway and assessing the potential risk of damage and/or injury to highway users that may result from these defects. The inspection also includes vegetation if its presence creates a hazard, regardless of whether it is growing from within the highway boundary or on neighbouring land.
- 54 The inspection preceding the accident took place on 9 August 2010, and the highways inspector, who was familiar with the route, did not record any defects in the vicinity of Bridge 11. The highways inspector was not required to carry or refer to lists of features or defects during inspections, but rely on his local knowledge and experience. Hence, an inspector would only be aware that a reflector post existed if he could see it or could remember seeing it in the past.
- 55 The reflective marker was present although its supporting post was in poor condition in a photograph taken for Network Rail in January 2004 (figure 10). It was still present in a photograph taken when the bridge had its detailed examination in August 2006. However, there is no reference to signing or vegetation in the three-monthly highway safety inspection reports between August 2006 and August 2010, and the RAIB has not been able to determine for how long the reflective marker had been missing prior to the incident.
- 56 The risk mitigation provided by a visible and marked parapet end was rendered ineffective because the need to check its visibility was overlooked by the highway safety inspector due to weaknesses in the inspection process (paragraph 54). In this instance, the railway boundary fence is located close to the edge of the carriageway and the vegetation obscuring the parapet end was growing predominantly on Network Rail's property (figures 3 and 9). However, responsibility for checking visibility of the signs remained with Surrey County Council as the local highway authority.

The lorry and the bridge

57 The driver's inability to regain control of the vehicle after an initial collision with the parapet end was a causal factor in a second and more serious collision with the parapet.

- 58 The lorry driver braked sharply just before striking the parapet end, but the vehicle's momentum carried it onto the bridge, and the driver was unable to avoid colliding with the parapet for a second time 10 - 15 metres further on. By analysing skid marks left on the road surface, Surrey Police established that the driver commenced braking 1 to 1.5 seconds before the initial collision with the parapet end. The lorry had anti-lock braking fitted to the front and rear axles only (figure 3), and therefore most skid marks are assumed to have originated from the middle axle.
- 59 Surrey Police recovered part of a *wheel stud* close to the parapet end which was subsequently identified as belonging to the front left-hand wheel of the lorry. Evidence supports that the shearing of the wheel stud was a consequence of the lorry's wheel striking the parapet end.
- 60 Contact with the wall retarded the left-hand side of the vehicle and caused it to turn to the left. Witnesses separately observed the front and rear of the lorry making contact with the parapet end, and the lorry rocking as it veered to the left.

- 61 Once onto the bridge, skid marks on the road surface indicate that the lorry travelled parallel with, and close to the left-hand parapet (figure 5).
- 62 It is probable that the sudden and unexpected deviation of the vehicle to the left made it difficult for the driver to control. A truck mixer lorry has a relatively high centre of gravity when loaded, and the rotation of the drum also imposes a variable load on the vehicle which is affected by the consistency of the material in the drum, in this case concrete. The semi-fluid movement of the load may create a destabilising tendency which could affect the handling of the vehicle, particularly on bends.

The behaviour of the parapet

63 The force of the lorry's impact exceeded the parapet's capacity to contain it, and this was a causal factor.

- 64 Bridge 11 has brick parapets in common with many structures of similar age. Such parapets pre-date modern design requirements and cannot be relied on to contain heavier vehicles. Bridge 11 was built with 350 mm thick x 1050 mm high unreinforced masonry (brick) parapets. Unreinforced masonry parapets of this type provide impact resistance (*containment capacity*) by being sufficiently heavy to resist the force applied by a colliding vehicle, this force being a function of the vehicle's weight, speed, and collision angle (angle of impact). Conversely, the impact resistance of a parapet is a function of the mechanical strength, provided by adhesion between the bricks and mortar, and the use of *bonded joints* in the parapet's construction.
- 65 After striking the parapet end, the lorry struck the parapet for a second time at a point 10-15 m from its north end at a shallow angle (less than 5°). This imposed a sustained force causing the brickwork to break along horizontal mortar joints approximately 0.5 m below road level. The parapet failed in a predictable manner by shearing at its weakest point. This does not suggest a specific plane of weakness other than the natural weakness of the mortar joints.
- 66 An existing non-trunk road bridge with a 30 mph (48 km/h) speed limit requires either 'low' or 'medium' containment parapets, as defined by the recently withdrawn British Standard 6779 Part 4 'Highway parapets for bridges or other structures'. The level of containment required is dependent on whether there is a hazard, such as a railway, below the structure. A location such as Bridge 11 requires medium containment, as although the road is low speed, it carries the highway over a railway. Medium containment requires a parapet to be capable of resisting the impact from a 1.5 tonne car hitting at an angle of 20°, travelling at 70 mph.
- 67 Containment capacity graphs published in a guidance note⁵ by the County Surveyor's Society⁶ (CSS) suggest that a 350 mm thick unreinforced masonry parapet, 1 metre high is capable of containing a 1.5 tonne vehicle travelling at 50 mph (80 km/h), with a 20° angle of impact. On this basis, Bridge 11's parapets provide medium containment for traffic travelling within the statutory speed limit.

⁵ 'The assessment and design of unreinforced masonry vehicle parapets', published by the County Surveyors' Society 1994.

⁶ The CSS has been renamed 'Association of Directors of Environment, Economy, Planning and Transport' (ADEPT).

- 68 There is no current standard which specifies the performance requirements of unreinforced masonry parapets. BS 6779 Part 4 provides a specification for parapets of reinforced and unreinforced masonry construction, but has been largely superseded by BS EN 1317 which is a standard covering manufactured products and does not apply to a site-built brick parapet. To remedy this situation, the Department for Transport commissioned a project in 2009 to produce a single document to replace the CSS guidance and BS 6779 Pt 4, and develop a risk assessment model for masonry parapets. This report is due to be published by the Department's roads liaison group during 2011.
- 69 Network Rail's policy is to require high containment parapets for new bridges over railways. A high containment parapet is designed to resist the impact from a 30 tonne lorry travelling at 40 mph (64 km/h) at an angle of 20°, and would have been capable of preventing this accident.

Network Rail's structures examination regime

70 Network Rail's structures examination regime did not require the visibility of parapet ends to be checked, and the opportunity to mitigate the hazard presented by the parapet end was lost as evidence of repeated vehicle strikes was not reported to the relevant highway authority. This was a possible causal factor.

- 71 Bridge 11 was subject to Network Rail's normal structures examination regime comprising a detailed examination every six years and an annual visual examination. Specialist contractors undertake examinations on behalf of Network Rail's structures engineers, who review and if necessary act upon the findings of the reports. Examinations had been undertaken at the required frequency and the bridge was reported to be in good condition.
- 72 The purpose of these examinations was to detect and record changes in the condition of the structure. At the time of the last detailed examination in August 2006, Network Rail standard NR/SP/CIV/017 defined this process. This standard specified that for overbridges, the detailed examination should include the carriageway surface to check for cracking, potholes and other defects which could affect the structure's integrity, and identify significant accidental damage including that due to bridge strikes. The standard also required the presence, condition or absence of weight or width restriction signs to be recorded where provided. The standard defines a highway authority as the organisation responsible for the maintenance of the public highway and the provision of road signs.
- 73 The 2006 detailed examination report stated that the bridge was in good condition. It recorded vertical fractures to the full height of the east parapet at three locations, although this weakness did not contribute to the collapse of the parapet in the subsequent accident as the parapet failed elsewhere. The report also recorded damage to the north end of the east parapet where the *capping stone* and top course of brickwork was displaced by 100 mm. Network Rail's maintenance contractor had undertaken repairs to the east parapet brickwork in October 2005, suggesting that this damage occurred between October 2005 and August 2006.
- 74 The same capping stone was knocked off during a collision between a car and the parapet end in December 2003. A bridge strike report, commissioned as a consequence of this event, included a photograph noting 'new and longstanding damage' to the parapet end (figure 10).

- 75 Network Rail therefore had evidence that the same parapet end had been struck at least twice prior to January 2004, and again between October 2005 and August 2006. Repeated instances of damage by road vehicles should have triggered some investigation as to cause, and discussion with the highway authority. However, Network Rail's structures engineers had difficulty in recognising repeated patterns of damage because, until September 2007, paper records were used as the primary means of managing the structures portfolio and these were stored remotely.



Figure 10: Photograph of the north end of the east parapet showing 'new and longstanding damage' after a similar collision in December 2003 (photograph January 2004, courtesy of Network Rail)

- 76 Bridge 11 had received its most recent visual examination in June 2010. The bridge examiner did not recommend any action, indicating that the structure was in satisfactory condition. The examiner was not required to check whether the parapet end remained visible to oncoming traffic and made no comment about this.

Observations⁷

Assessment of sites for safety improvements

Road vehicle incursion risk assessment

- 77 The Department for Transport led the development of guidance for managing the risk of accidental obstruction of the railway by road vehicles in response to an accident at Great Heck near Selby in North Yorkshire in 2001 which resulted in the loss of 10 lives. The ensuing protocol⁸, published in February 2003, provides railway infrastructure managers and highway authorities with a method of calculating a risk-based 'road vehicle incursion' (RVI) score and identifying whether mitigation works are required.

⁷ An element discovered as part of the investigation that did not have a direct or indirect effect on the outcome of the accident but does deserve scrutiny.

⁸ 'Managing the accidental obstruction of the railway by road vehicles' Department for Transport, February 2003, (known as the road vehicle incursion protocol). Product code 03 RRLG 01000. www.dft.gov.uk/pgr/roads/network/policy/obstructionrailways.

- 78 The protocol clarified the legal responsibility to assess the risk and provide any mitigation measures to prevent accidental incursions by road vehicles onto railway property. It established that the highway authority leads in the risk ranking and assessment process, and for highway-related mitigation such as traffic calming and barriers, and the railway infrastructure manager leads if the measures required are associated with the railway.
- 79 Surrey County Council's structures engineers assessed Bridge 11 in 2002, one of 126 sites within the county, using the protocol's scoring system for single carriageway road vehicle incursions. The bridge was correctly given an initial score of 86 (which was reduced to 84 following the withdrawal of Mark 1 (slam-door) rolling stock from this route in 2005). A score of less than 90 put the bridge below the level at which mitigation work is normally considered cost effective. The assessment must be repeated if mitigation is installed and is also repeated before major planned changes to road or railway infrastructure or operation (Network Rail standards NR/L2/OPS/031 and NR/L2/SIG/30021 refer).
- 80 The protocol's output is numeric to promote consistency across a large group of users. However, this approach does not allow for any comment to be recorded about the presence of local safety hazards which may not be directly related to mitigating incursion risk. Although the protocol states 'if a low cost measure would obviously benefit a site, then the highway authority should consider it regardless of the ranking score', Surrey County Council's assessment of Bridge 11 did not consider mitigation as the score was below 90.

Options for safety improvements at this site

- 81 The north end of the east parapet is located on the inside of a bend, adjacent to the path of vehicles. It is vulnerable to being struck by any vehicle which fails to negotiate the bend safely, and tyre tracking marks on the road indicate that vehicles routinely pass close to it. Parapet ends are recognised by highway engineers as posing a hazard to vehicles through the potential for end-on impact.
- 82 The 'new and longstanding damage' recorded in January 2004 (paragraph 74), and further damage recorded in August 2006 (paragraph 73) provides evidence that the most recent accident was neither an isolated nor an unforeseeable event. However, Surrey County Council regarded this part of the A244 as having a relatively good accident history, and as a consequence, and no works were planned or considered necessary at this site.
- 83 In 2009, there were 22 recorded overbridge strikes in Britain which caused a parapet to become unsafe. RSSB estimates the overall risk from all bridge strikes to be 0.071 *fatalities and weighted injuries* per year (FWI/year), and overbridges account for just 12% of the total bridge strike risk (ie 0.009 FWI/year). Of the overbridge strikes recorded, 30% involved LGVs. The main hazard from overbridge strikes is the derailment of a train caused by debris, including parts of the parapet, landing on the track.

- 84 By comparison, the risk presented by road vehicle incursions onto the railway is 0.61 FWI/year, although only 10% of this figure relates to incursions from bridges (ie 0.06 FWI/year). The risk is higher than from overbridge strikes because the consequences of a train hitting a vehicle rather than debris are usually more serious. The estimated risk from all bridge strikes is therefore 0.069 fatalities and weighted injuries per year. However, this figure excludes injuries to road vehicle occupants, as these are not included unless the person involved ends up on railway property. That is, if they are injured when their vehicle strikes a bridge, but they remain on the road, their injuries are not counted in the risk model.
- 85 There have been no passenger injuries due to vehicle incursions from bridges since the high-speed collision between a train and a road vehicle at Great Heck (paragraph 77). Trains have struck vehicle incursions from bridges on two occasions since 2001, but neither of these accidents involved a parapet failure or caused passenger injury. The most recent occurrence was at Broken Cross between Salisbury and Grateley in September 2009 (RAIB bulletin 03/2010)⁹.
- 86 In determining whether safety improvements should be made at a particular site, Surrey County Council and/or Network Rail would need to consider the costs and benefits associated with any improvement proposals. The safety benefits obtained from improvement measures at Bridge 11 would be the avoidance of injuries and fatalities to road and rail users. In considering options for making safety improvements at Oxshott to reduce the probability of a similar accident occurring in the future, a number of factors associated with the costs and benefits of each option would need to be taken into account:
- Safety benefits (avoidance of injuries and deaths) can be expressed as a monetary value. The Department for Transport's guideline figure for the 'value of preventing a road fatality' is currently £1,585,510¹⁰. The railway industry currently uses a figure of £1,674,000¹¹ as its value of preventing a fatality. The use of 'weighted injuries' allows major and minor injuries to be accounted for in cost benefit analysis, as well as fatalities. The estimated risk from all bridge strikes of 0.069 FWI/year (paragraph 84) equates to an expenditure of £115,000 per year on measures to mitigate the total risk from bridge strikes (ie on measures at all sites where bridge strikes that affect the railway could occur), and therefore a much smaller sum of money for individual sites.
 - The costs of replacing Bridge 11 and realigning the road to improve the northern approach would substantially exceed the guideline figure of £115,000 and only provide risk mitigation at a single site. Although other factors may be taken into account when judging whether a specific risk-reduction measure is reasonably practicable, the disparity between costs and benefits makes the adoption of high-cost risk mitigation measures unlikely in this case unless the bridge was being re-built for other purposes, in which case safety enhancements to reduce the risk to the railway could be built into the scheme.
 - Consideration would need to be given as to whether strengthening the existing parapets of the bridge might result in a more serious outcome in circumstances similar to those that occurred on 5 November 2010. This is because a larger section of the bridge could fail if the parapets were unable to break-off in smaller sections.

⁹ http://www.raib.gov.uk/publications/bulletins/bulletins_2010/bulletin_03_2010.cfm.

¹⁰ Last adjusted in 2009.

¹¹ Last adjusted in June 2010.

- Consideration would also need to be given as to whether other measures designed to protect the parapets might reduce the likelihood of parapet damage and incursion onto the railway, but increase the risk to road users by diverting vehicles into oncoming traffic.

87 The RAIB considers that Bridge 11 and its approaches should be assessed to consider whether cost-effective improvements can be made which might provide a measure of risk mitigation. To date, the parapet end marker has not been reinstated (July 2011) and Surrey County Council has not provided any other means of protecting or marking the parapet end.

Actions taken following the accident

88 Surrey County Council and Network Rail have reviewed the road vehicle incursion score for this structure and confirmed that it is unchanged at 84.

89 The east parapet of Bridge 11 has been re-built on a like-for-like basis, with no change to the level of containment provided for road vehicles. One of the factors in this decision was to allow the road to fully reopen as quickly as possible after the accident. The RAIB notes that the installation of a high containment parapet would require substantial and disruptive works to strengthen the bridge, and that any mitigation proposed at this site needs to avoid transferring risk onto road users.

90 Vegetation at the parapet end was cut back to improve visibility following the accident, but a more permanent solution is required to discourage its re-growth.

Structural performance of the train

91 The RAIB examined unit 455913 following the accident, and assessed the behaviour of internal components during the accident using CCTV images (figures 11 and 12). The following observations are made:

- The roof structure on coach 6 took the brunt of the impact with the lorry which landed on the leading end of the vehicle offset to the left-hand side in the direction of travel. As a result of the impact, there was extensive damage to the roof and bodyside structure on coach 6.
- Since 1994, Railway Group Standard GM/RT2100 has required the roof structure of new vehicles to be able to withstand the impact of a 100 kg block of concrete being dropped from 3 m above the roof. This requirement was introduced in recognition of the risk posed by vandalism. The *kinetic energy* for a 100 kg concrete block dropped from a height of 3 m is 2.9 kJ. For comparison, the kinetic energy imparted by the lorry as it struck the roof of the train was approximately 2,300 kJ, almost 800 times greater. Parts of the parapet also fell in large blocks (figure 13).
- The welded connection between the cantrail and corner pillar at the leading edge of coach 6 failed at an early stage in the deformation, leaving the corner pillar relatively undamaged. This prevented the corner pillar assisting in absorbing energy. This is unlikely to have made a significant difference to the overall damage in the context of the energy of this impact. There was no evidence of excessive corrosion which would have weakened the joint.

- d. A minimum of around one metre of survival space was maintained between the collapsed roof and the floor under the point of impact on coach 6. As a result, the passenger who was sat in this area survived the accident and the other four passengers sat in the vicinity escaped serious injury.
 - e. The hinged door header trim panel on the left-hand door of coach 6 furthest away from the point of impact dropped down to head height creating a hazard to evacuating passengers. This occurred because of deformation of the bodyside rather than failure of the lock mechanism. There was no secondary retention system provided.
 - f. Coaches 7 and 8 suffered significant bodyside damage as they made contact with the lorry chassis which was lying close to the track after the initial vertical impact. In vehicle 8, a complete assembly of a straight grab pole and glazed partition at the leading left-hand doorway became detached from the bodyside and was propelled across the vehicle. The detachment of the glazed partition arose directly from damage caused by the lorry penetrating and pushing in the side of the vehicle. The forces required to fracture the grab pole fixings to the floor and ceiling were in excess of the current design load case for grab poles, specified in current structural standards for the vehicle interior (Railway Group Standard GM/RT2100 Issue 4). The design *loadcase* is based on maximum forces that could be applied to the grab pole by passengers and not from impacts with external objects.
 - g. Anti-graffiti film fitted to the glazing prevented the shattered glazed partition breaking up into small glass missiles.
 - h. Seats on all the vehicles remained attached even under large lateral displacement of the bodyside. This helped the containment of passengers and prevented the seats in the damaged areas acting as large unrestrained objects within the passenger compartment.
- 92 Generally the train performed well when exposed to the extreme circumstances of this accident. The side loading and penetration of vehicle bodysides arising from impacts with external objects (such as that seen in the case of vehicle 8) and/or roll-over, has been a feature of some past rail accidents and has been the subject of a previous RAIB recommendation, discussed further at paragraph 102.

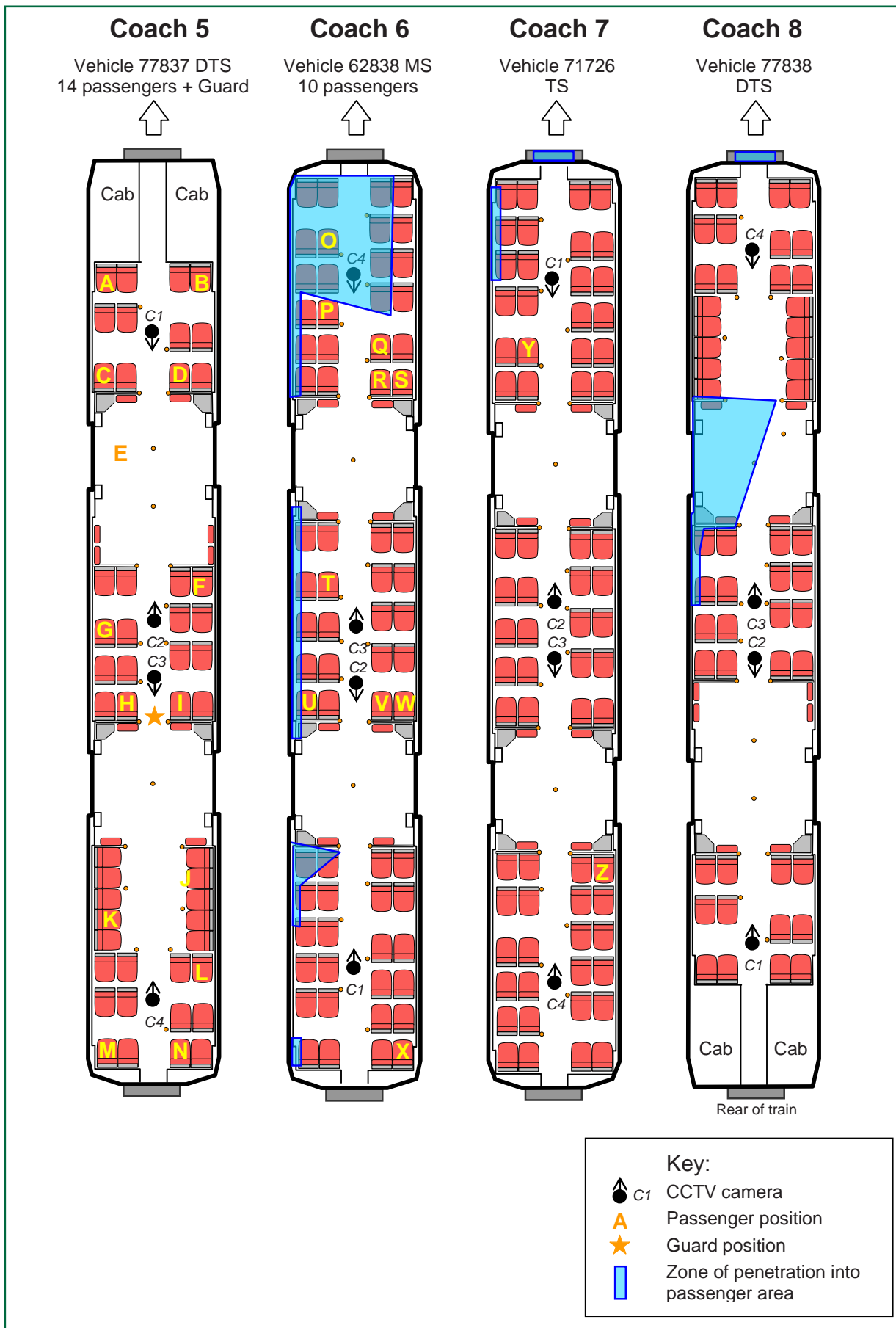


Figure 11: Diagram indicating the extent of damage to unit 455913 and the position of passengers on the train



Figure 12: Internal view of coach 6 looking towards the front of the train



Figure 13: View of bridge and missing parapet from track level. The parapet fell in sections weighing up to 1800 kg

Previous occurrences of a similar character

- 93 The RAIB has found no previous record of a road vehicle falling onto a moving train as a consequence of a bridge strike in Great Britain. This accident was therefore unusual if not unique.
- 94 In 2009, trains twice struck parapet debris which had fallen onto the track as a result of bridge strikes. Neither incident resulted in a derailment.
- 95 There have been two vehicle incursions from bridges since 2001 resulting in the road vehicle being struck by a train (paragraph 85).

Summary of Conclusions

Immediate cause

96 The lorry collided with the bridge parapet which collapsed, allowing the lorry and parts of the parapet to fall onto the railway.

Causal factors

97 The causal factors were:

- a. The lorry was travelling too close to the edge of the carriageway (**paragraph 48**);
- b. The lorry driver was unable to maintain control of the vehicle after it struck the parapet end (**paragraph 57**); and
- c. The force of the lorry's impact exceeded the parapet's containment capacity (**paragraph 63**).

98 In addition, the following factors were possibly causal:

- a. The parapet end was not sufficiently visible to the lorry driver as he approached the bridge as the processes for identifying this as a maintenance requirement were not effective (**paragraph 49, Recommendations 1 and 2**)
- b. Network Rail's structures examination regime did not require the visibility of parapet ends to be checked, and the opportunity to mitigate the hazard presented by the parapet end was lost as evidence of repeated vehicle strikes was not reported to the relevant highway authority (**paragraph 70, Recommendation 3**).

Observations

99 The RVI assessment process requires the examination of a series of elements at each site, to score individual features. This does not encourage a holistic view to be taken of the overall risk presented at a site.

100 Surrey County Council's RVI assessment of Bridge 11 did not consider whether any low cost measures would benefit the site, or identify the hazard presented by the parapet end. The RVI protocol does not provide guidance in this area (**paragraph 80, Recommendation 4**).

101 At the time of writing (July 2011) Surrey County Council has not reinstated the collapsed parapet end marker or provided any other means of protecting or marking the parapet end (**paragraph 87, Recommendation 5**).

Previous recommendations relevant to this investigation

- 102 The RAIB has previously made a recommendation to RSSB relating to a structural specification for roll-over strength and penetration resistance of rail vehicles (none exists currently), following the accident at Grayrigg on 23 February 2007 (Recommendation 25b, RAIB report 20/2008). The purpose of the recommendation was to ensure consistency of performance in accidents across all future fleets (paragraph 92).
- 103 Following discussion at the Rolling Stock Standards Committee, the RSSB expressed the view that it would be difficult to justify and gain acceptance for further crashworthiness requirements since vehicles built to current standards are considered to generally exhibit satisfactory performance in terms of penetration resistance.
- 104 In June 2011, the ORR reported to the RAIB, its conclusion that Grayrigg recommendation 25b had been implemented, having judged the RSSB response to be sufficient.

Recommendations

105 The following recommendations are made:¹²

- 1 *The purpose of Recommendation 1 is to promote the checking of visibility markings associated with road bridges over railways as part of the existing highway safety inspection regime.*

Surrey County Council should reinforce the requirement for regular checks to be made (for example, as part of safety inspections carried out by staff on the condition of highways) of the ends of parapets on bridges over railways to ensure that, where provided, markers or markings are maintained in good condition and free from obstruction by vegetation or other material. Any signs of damage should be reported to the risk owner for appropriate action (paragraph 98a).

- 2 *The purpose of Recommendation 2 is to provide highway authorities with guidance on the provision of visibility markings at railway overbridge parapet ends.*

The Department for Transport should issue guidance to highway authorities on highlighting the unprotected ends of parapets (for example by reflective markers, white paint, etc.) of bridges over railways where the end of the parapet presents a possible hazard to road users, the consequences of which could export risk to the railway (paragraph 98a).

continued

¹² 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 Regulation. Recommendations 1 and 5 are also addressed to Surrey County Council, and Recommendations 2 and 4 to the Department for Transport to enable each to carry out their duties under regulation 12(2) to:

- (a) ensure that recommendations are duly considered and where appropriate acted upon; and
- (b) report back to RAIB details of any implementation measures, or the reasons why no implementation measures are being taken.

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

- 3 *The purpose of Recommendation 3 is to incorporate checks of visibility markings protecting railway overbridges within the existing structures examination regime, and to promote the reporting of vehicular damage to aid the identification of sites where risk mitigation may be required.*

Network Rail should include, within its annual examination of rail overbridges, the requirement for the structures examiner to identify and record any highway features which may increase the risk to the railway such as absence, obscuration or poor condition of parapet end markers. Network Rail should also improve its management arrangements for reporting such issues to the relevant highway authority, and when it becomes aware of damage to structures caused by road vehicles (paragraph 98b).

- 4 *The purpose of Recommendation 4 is to promote the development of guidance which could enhance safety at bridges over railway lines where the Department for Transport's road vehicle incursion assessment process does not already address this.*

The Department for Transport, with highway authorities, should prepare guidance for highway authorities on identifying local safety hazards at bridges over railways which could be mitigated by measures such as signage, hazard marking, white lining or safety barriers, and include consideration of previous accident history and the causes of those accidents. This should include guidance on when the assessment should be undertaken and when such measures should be applied (paragraph 100).

- 5 *The purpose of recommendation 5 is for Surrey County Council to provide and maintain protection at Bridge 11 (Warren Lane, Oxshott).*

Surrey County Council, in consultation with Network Rail, should review the optimum means of protecting or marking the parapet ends at Bridge 11 (Warren Lane, Oxshott), and apply and maintain the chosen method (paragraph 101).

Appendices

Appendix A - Glossary of abbreviations and acronyms

ADEPT	Association of Directors of Environment, Economy, Planning And Transport (formally the County Surveyor's Society)
CSS	County Surveyors' Society (now renamed ADEPT)
FWI	Fatalities and weighted injuries
LGV	Large goods vehicle (formerly known as an HGV)
RSSB	Rail Safety and Standards Board
VOSA	Vehicle and Operator Services Agency

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.

Bogie	A metal frame equipped with two or three wheel sets and able to rotate freely in plan, used in pairs under rail vehicles to improve ride quality and better distribute forces to the track.*
Bonded joints	Brickwork where the vertical joints in adjacent courses do not align (ie each layer of bricks overlaps the layers above and below).
Cantrail	The point on a rail vehicle at which the side of the vehicle body meets the roof profile.*
Capping stone	A finishing or protective stone that forms the top of an exterior masonry wall.
Conductor Rail	An additional rail, used to convey and enable collection of electrical traction current at track level.*
Containment capacity	The maximum speed that an unreinforced masonry parapet may sustain from a saloon car (as defined for low or normal level containment) either to prevent full penetration or to limit damage to the vehicle and occupants to an acceptable level.
Corner pillar	A principal structural pillar forming the end of a rail vehicle to which the cantrail is attached.
English bond	A brickwork bond with two alternating courses of stretchers (brick laid flat with the long end of the brick exposed) and headers (brick laid flat with the short end of the brick exposed), with the headers centred on the stretchers, and each alternate row aligned vertically.
Fatalities and weighted injuries	<p>A measure of the collective risk expressed as fatalities and weighted injuries.</p> <p>When combining injury information into a composite measure, each fatality is given a weighting of unity and each major injury a weighting of 0.1. RIDDOR-reportable minor injuries and the more severe cases of shock and trauma are given a weighting of 0.005, with non-RIDDOR reportable minor injuries and less severe cases of shock and trauma being given a weighting of 0.001. The combined total is then expressed as 'fatalities and weighted injuries' (FWI).</p>
Kinetic energy	The kinetic energy of an object is the energy which is possesses due to its motion.
Large goods vehicle	A large goods vehicle (formally heavy goods vehicle or HGV) with a gross weight of over 3.5 tonnes.
Loadcase	A combination of different types of loads with safety factors applied to them.

Overbridge	A bridge that allows passage over the railway.*
Plating certificate	Large goods vehicles in the UK are required to carry a permanently fixed Department of Transport (DfT) plate and plating certificate (VTG7) indicating the total permitted weight of a loaded vehicle.
Third rail	Common term for a single conductor rail positioned on the sleeper ends.*
Up line	A track on which the normal direction of trains is in the Up direction (ie towards London).*
Wheel stud	Bolts which fasten the wheel of a vehicle onto a brake drum or disk hub. Wheels are secured onto a wheel stud with lug nuts.

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