



Rail Accident Investigation Branch

Rail Accident Report



**Partial collapse of a wall onto open railway
lines, Liverpool
28 February 2017**

Report 17/2017
November 2017

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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Partial collapse of a wall onto open railway lines, Liverpool, 28 February 2017

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Summary

At about 17:38 hrs on Tuesday 28 February 2017, part of a wall at the top of a cutting 20 metres above the four track railway line between Liverpool Lime Street and Edge Hill stations, collapsed. Around 170 tonnes of masonry and other debris fell into the cutting in at least two separate falls, the last of which occurred at 18:02 hrs.

No trains were struck by the falling debris and there were no injuries. The overhead wires on some of the tracks were brought down and all lines were blocked by the debris. This led to severe disruption of train services. The lines were closed until 8 March 2017, during which time repairs were made to the wall, the overhead electrical supply system and the track.

The investigation found that there had been developments on the leased property adjacent to the cutting, which included the addition of a soil embankment immediately behind the top of the wall. A small portion of the developed land was owned by Network Rail and was not part of the leased property. The increase in ground level caused the wall to be subjected to higher loading. Heavy rainfall may also have played a role in triggering the collapse. Information recorded by Network Rail during its routine examinations was insufficient to detect the developments on adjacent land and the infringement of its property. The investigation also found that Network Rail did not have a suitable risk prioritisation process in place for retaining walls, such as the one that collapsed, that have a high potential safety consequence in the event of a failure.

The RAIB has made two recommendations to Network Rail. The first relates to being aware of those of its walls which have a potentially high safety consequence in the event of failure. The second is for Network Rail to review its assessment procedures for such walls, the use of open source data to identify changes in land use, and the provision of information on property boundaries to structures examiners.

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 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. Sources of evidence used in the investigation are listed in appendix C.

The incident

Summary of the incident

- 3 At about 17:38 hrs on Tuesday 28 February 2017, part of a wall at the top of a cutting a short distance from Liverpool Lime Street station (figure 1) collapsed. It fell from a height of around 20 metres, onto four open railway lines (figure 2). Around 170 tonnes of masonry and other debris fell onto the tracks in the cutting (figure 3) in at least two separate falls, the last of which occurred at 18:02 hrs.



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



Figure 2: The cutting following the collapse of the retaining wall



Figure 3: The debris on the track following the wall collapse

- 4 No trains were struck by the falling debris and there were no injuries. However, train services were severely disrupted and two trains close to the area of the collapse had to be evacuated because they were unable to be moved as a result of damage to the overhead power supply. The lines were closed until 8 March 2017, during which time repairs were made to the wall, the overhead electrical supply system and the track.

Context

Location

- 5 Lime Street cutting runs approximately west to east from a terminal station, Liverpool Lime Street, to Edge Hill station. There are four railway lines in the cutting, each one with its own overhead electrical supply (figure 4). The four lines, from the north side of the cutting to the south side are the up slow, the down slow, the up fast and the down fast. The up direction is towards Edge Hill.
- 6 All lines have a maximum speed limit of 30 mph (48 km/h) except the up slow line for which the limit is 40 mph (64 km/h).
- 7 The portion of the wall that collapsed was located 0.8 miles (1.3 km) to the east of Liverpool Lime Street station and on the north side of the cutting between Smithdown Lane to the west and Mason Street to the east (figure 4).

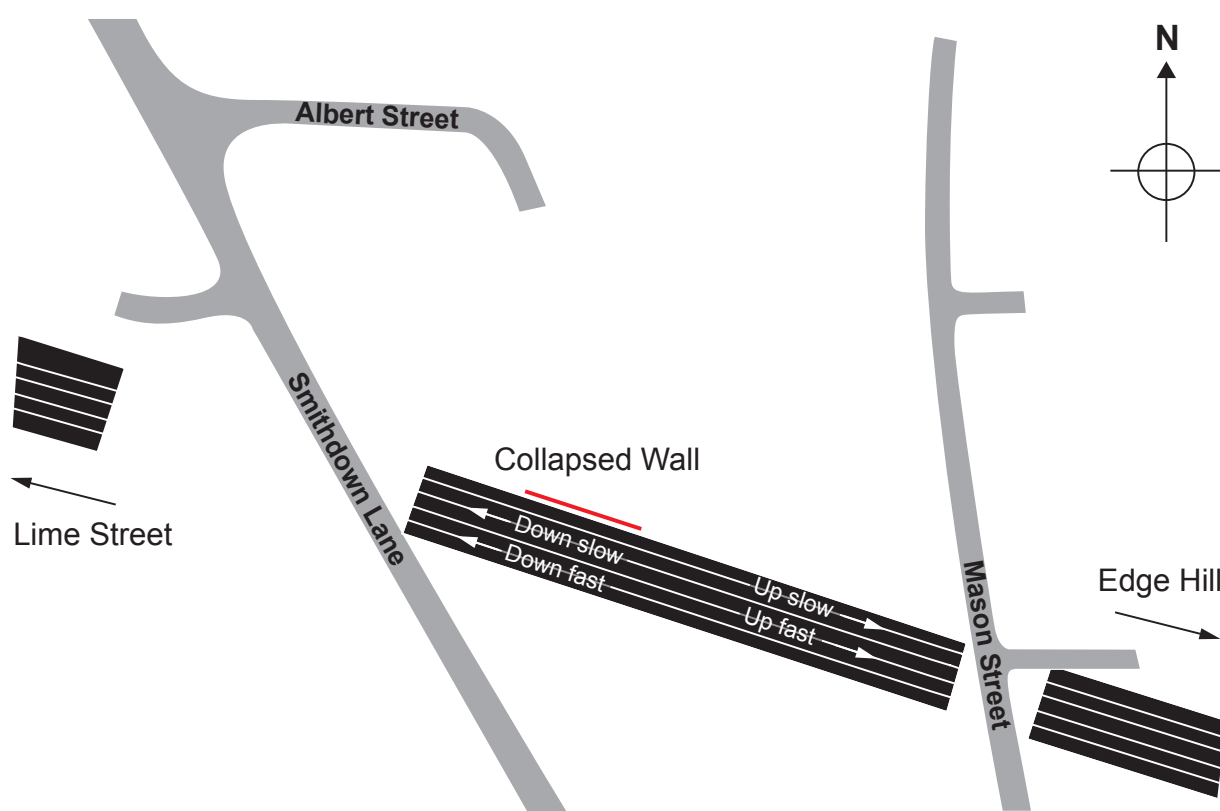


Figure 4: The lines at the site

Organisations involved

- 8 Network Rail is the owner and maintainer of the railway and the cutting wall, including a strip of land that runs directly behind the wall at the top of the cutting. The signalling of trains in the area is controlled by Network Rail signallers at Edge Hill and Liverpool Lime Street. The electrical supply to the overhead line equipment (OLE) is controlled by the Network Rail Electrical Control Room Operator (ECRO) at Crewe.
- 9 Liverpool City Council was the owner of the land adjacent to the wall in the area of the collapse, except for the narrow strip of land directly behind the wall.

- 10 A private individual (hereafter referred to as 'the lease holder') had leased the land from Liverpool City Council. The lease holder was registered with HM Land Registry as the 'Title Goods Proprietor' from 7 October 2003 and had been in control of the use of the land up to the time of the incident.
- 11 All parties freely co-operated with the investigation.

Trains involved

- 12 Although many train services were affected by delays and cancellations as a result of the incident, there were three trains in the vicinity of the collapse that were at risk of being struck by the falling debris:
 - train 1F91, the 16:40 hrs Northern Railway service from Manchester Airport to Liverpool Lime Street;
 - train 2C07, the 17:03 hrs Northern Railway service from Wigan North Western to Liverpool Lime Street; and
 - train 1A60, the 17:47 hrs Virgin Trains (West Coast) service from Liverpool Lime Street to London Euston.

External circumstances

- 13 At the time of the incident, it was becoming dark. The official sunset time on that day was 17:48 hrs.
- 14 It had been raining constantly from 02:00 hrs that day until around 18:00 hrs. The cumulative rainfall over this period was one of the five highest daily totals in the preceding twelve months. The previous peak had been in November 2016. The effect of rainfall is discussed at paragraphs 37 to 39.

The sequence of events

Events preceding the incident

- 15 At 17:12 hrs a *circuit breaker* protecting the OLE on the up fast line in the area of the collapse, opened (ie it 'tripped'). The reason why this circuit breaker tripped is unknown, but is discussed further at paragraph 34. At about 17:14 hrs, the circuit breaker was reclosed by the ECRO, as is normal practice.

Events during the incident

- 16 At about 17:38 hrs, the driver of train 1F91 which was travelling on the down slow line close to Edge Hill station, heard a bang and saw flashes ahead of his train. The train lost its electrical power supply from the OLE and the signal ahead changed from a yellow aspect to a red aspect, causing the driver to make an emergency brake application. The train overran the signal by approximately two metres. The driver contacted the signaller at Edge Hill to report these events.
- 17 The loss of power was due to the tripping of a circuit breaker protecting the OLE of the down slow line. The circuit breakers associated with the up slow and the up fast lines also tripped at this time. Some signalling *track circuits* in the area showed occupied, although no trains were present. It was one of these that caused the change of aspect in the signal on the down slow line which train 1F91 overran. Other track circuits, one close to the section of the collapsed wall on the down fast and another on the up fast line towards Edge Hill, were also showing occupied.
- 18 At 17:52 hrs, following a conversation between the ECRO and the signaller, the three circuit breakers which had tripped were reset. Two of them remained closed, but the circuit breaker associated with the up slow line failed to reset and remained open, leaving the associated OLE de-energised.
- 19 At about 17:55 hrs, the signaller at Edge Hill instructed the driver of train 1F91 to *proceed at caution* and examine the line ahead. The train approached the east end of the cutting leading to Liverpool Lime Street station. At about 18:02 hrs, the driver again heard a loud bang and saw flashes ahead of his train. The train lost electrical power as the circuit breaker on this line tripped again. The driver reported to the signaller at Liverpool Lime Street that an overhead wire was dangling ahead of his train. The signaller instructed him to remain at a stand and await further instructions.
- 20 At about 18:10 hrs, the signaller at Liverpool Lime Street requested that the driver of train 1A60, which was departing for London Euston around 20 minutes late, proceed at caution and examine the line, in accordance with normal operating practice. The signaller's instruction to the driver was at the request of the ECRO. Train 1A60 was on the up fast line which, like the down fast line, was still energised. At about 18:20 hrs, the driver stopped the train on the approach to the section of the cutting with the collapsed wall and reported to the signaller that all lines were blocked with rubble.

Events following the incident

- 21 At 18:45 hrs there was an initial inspection of the condition of the cutting by a Network Rail OLE engineer. There were three trains (paragraph 12) within the overhead line electrical sections immediately affected by the collapsed wall which were stopped. At 18:58 hrs the *Rail Incident Officer* (RIO) decided to fully isolate the overhead lines on all four tracks to enable passengers from two of the three stopped trains to detrain and be escorted back to the nearest stations. This decision was taken by the RIO because of the state of the blocked lines, concerns over possible further falls of material into the cutting and the condition of the OLE. Isolating a shorter section of OLE closer to the fallen debris to enable the trapped trains to move was not possible because of the way the OLE was sectioned.
- 22 Passengers began to detrain from train 1F91 at 19:41 hrs, and from train 2C09 at 19:57 hrs. At 21:04 hrs, once all the passengers were clear of the area, power was restored to both fast lines, and at 21:33 hrs train 1A60 was driven back to Liverpool Lime Street station, arriving at 21:40 hrs. This movement occurred at extreme caution, following a line inspection on foot by an operations manager, because there had been a report that three passengers had left this train and had walked along the track to Liverpool Lime Street station.
- 23 At 23:00 hrs, full inspections of the track, the overhead lines and the cutting wall began. All four lines were closed until 8 March 2017 while repairs were carried out to the track and the OLE. The land adjacent to the collapsed wall was also stabilised.

Key facts and analysis

Background information

- 24 Network Rail classifies the cutting wall as a natural rock cutting and a retaining wall. It was built in the 1880s when the cutting was dug to replace the original 1836 two-track tunnel, to allow for the current track layout. The lower part of the cutting side at the location where the wall collapsed comprises a 15 metre high natural, vertical, sandstone rock face (figures 2 and 3). On top of this is a 6 metre high wall constructed from sandstone blocks held together by mortar. The thickness of the wall is approximately 600 mm.
- 25 The sandstone block wall has two purposes: firstly to retain the ground adjacent to it and prevent it falling into the cutting, and secondly to prevent access onto the railway. The upper part of the wall was around 1.5 metres higher than the land immediately behind it before the land was developed by the lease holder. This upper part acted as a parapet wall to prevent ingress into the cutting and to protect users on the adjacent land. When it was originally built there was no additional fencing above the wall. Photographic evidence shows that the metal palisade fencing had been erected on the western section of the wall by 2004 (figure 5). The lease holder believes that the fencing was erected before 2000. During subsequent developments on the land, the lease holder erected palisade fencing on the eastern section of the wall.



Figure 5: The land adjacent to the wall prior to development in 2004 (photograph courtesy of Williamson Tunnels Heritage Centre)

- 26 Figure 6 shows an extract of a plan of the area dating back to 1959. The approximate position of the portion of wall that collapsed is indicated. The area marked 'A' shows a shallow slope rising from the wall up to the ground level of the surrounding land. This slope ensured that the upper part of the wall was not loaded by any ground behind it. The plan indicates that there was no such slope in the area marked 'B'. At 'C', the ground reaches a concrete terrace wall which meets the railway wall at an angle of approximately 45 degrees and which retains ground along its eastern side. It is not clear from the available evidence whether the ground between 'B' and 'C' was level, as indicated by the plan in figure 6, or rises towards 'C' as suggested by the increasing height of the wall (to maintain its parapet function relative to the rising ground level) in figure 5.

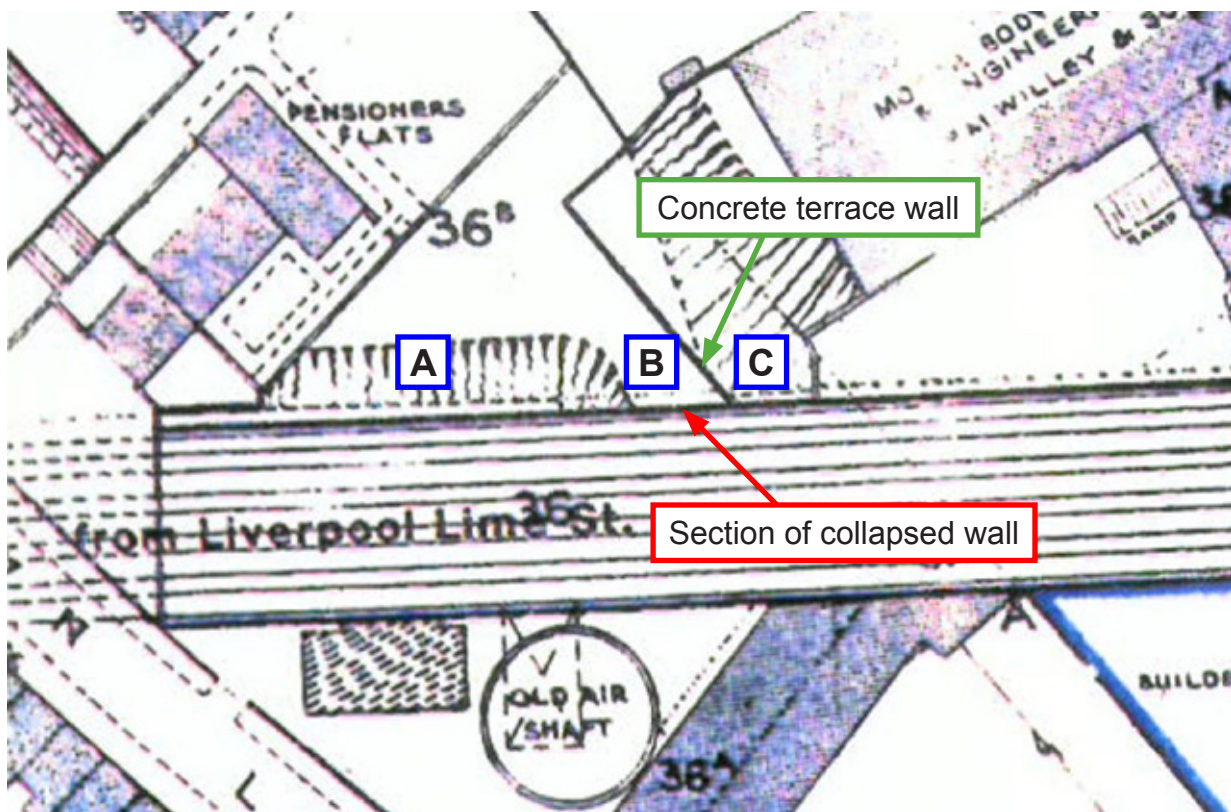


Figure 6: Plan of the land adjacent to the wall in 1959 (image courtesy of Network Rail)

- 27 In 2004 the land was as shown by figure 5 and the concrete terrace wall was visible. Around this time the upper part of the terrace wall was demolished, and the terrace levelled. This reduced the height of the terrace wall by approximately 1 metre. However, a short length of this wall, immediately adjacent to the retaining wall, was left at its original height (figure 7). The RAIB has estimated from photographs and measurements, that the level of the ground to the west of the concrete terrace wall was then around 1.6 metres lower than the top of the original terrace wall.
- 28 By September 2005 a metal storage shelter and five 40 foot shipping containers had been brought onto the property (figure 8). The ground immediately behind the retaining wall, and to the west of the terrace wall, was likely to still have been at its original level, as photographs indicate that this area was undeveloped and there was no concrete slab present.

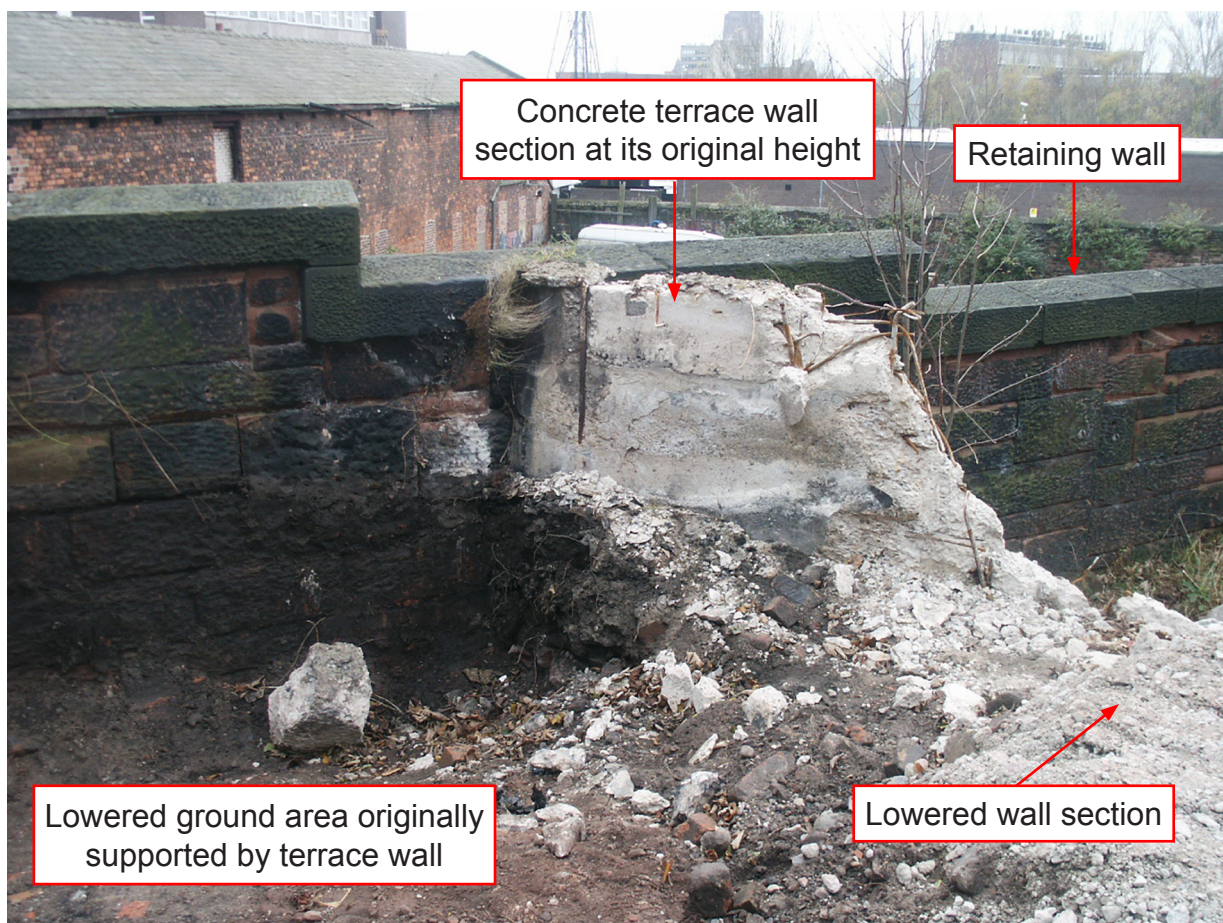


Figure 7: The short section of the concrete terrace wall adjacent to the railway wall which remained at its original height (photograph courtesy of Williamson Tunnels Heritage Centre)



Figure 8: Aerial image of the site taken on 2 September 2005 showing metal storage shelter and shipping containers. The red circle indicates the short section of remaining full height section of the concrete terrace wall (courtesy of Getmapping PLC).

29 By June 2009 there were six containers on the property, rearranged and double stacked (figure 9). The containers had been placed on a concrete slab approximately 100 mm thick which was supported by an earthwork that had been built out from the terrace wall towards the west of the property (figure 10). The concrete slab also extended beyond the footprint of the containers to meet the railway retaining wall (figure 11) which by this time was additionally surcharged. Also by this time, the lease holder had erected additional palisade fencing against this eastern section of the wall.



Figure 9: Google Street view image of the double stacked containers, the raised supporting earthwork and additional fencing (photograph dated on Google Street View as September 2008, but date is approximate)

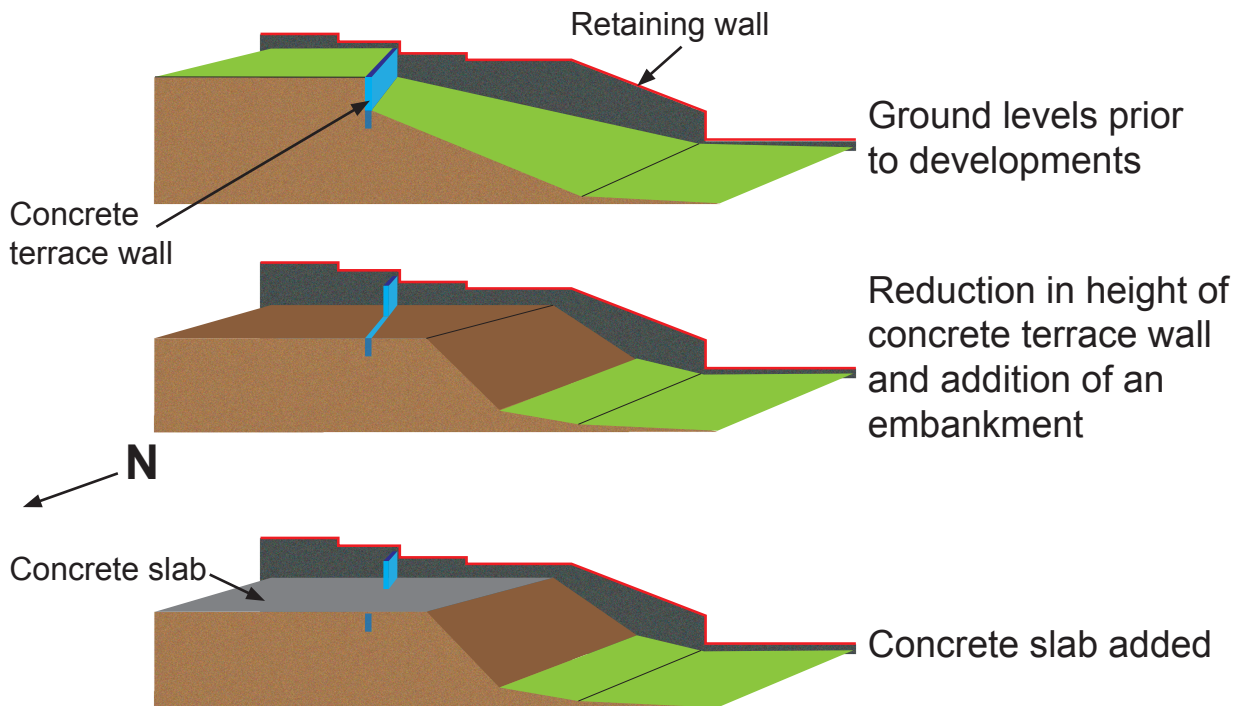


Figure 10: Diagram showing the changes on the property behind the retaining wall (not to scale)

- 30 By July 2014 the upper level of containers had been removed leaving the three single storey containers present at the time of the collapse. At the time of the collapse, one container had racking within it which carried washing machine parts, in another was a kitchen and a toilet area, and the third contained worktops and furniture parts. The weight of the contents was reportedly not significant relative to the empty weight of the containers, of around 4 tonnes each.
- 31 The top surface of the concrete slab was estimated by RAIB using an aerial *photogrammetric survey* to be 1.5 metres above the adjacent flat ground in the centre of the property. The ground level from the slab's supporting earthwork had been raised against the retaining wall, resulting in additional *surcharge* to it, discussed in paragraph 35.



Figure 11: Aerial image of the site taken on 24 June 2009 showing the concrete slab meeting the railway wall (courtesy of Getmapping PLC)

Identification of the immediate cause

- 32 **The wall collapsed because it could not withstand the loads from the additional surcharge.**
- 33 The disposition of the fallen masonry blocks, including many capping stones, on the two tracks furthest from the north side retaining wall (figure 3, left-hand image) indicates that the wall failed by overturning (or toppling). In this action, the wall rotated about a pivot point just above the interface between the wall and the sandstone rock (figure 12). The estimated weight of the blocks, soil and concrete that fell into the cutting is around 170 tonnes.



Figure 12: The upper part of the cutting wall following the collapse (red circle indicates a drain chamber - see paragraph 39)

- 34 The collapse probably occurred in two main stages, the first at 17:38 hrs and the second at 18:02 hrs. The tripping of the OLE circuit breakers at 17:12 hrs (paragraph 15) on the up fast line (the third line from the wall) is unlikely to have been due to an earlier fall of material. Had there been such a fall, it is likely that any significant amount of material would have been seen by the driver of at least one of the 13 trains travelling over this section of track between 17:12 hrs and 17:38 hrs.

Loading on the wall

35 The wall had been in place since the 1880s and for it to have overturned and collapsed, there must almost certainly have been a change in the forces acting on it. The RAIB has assessed the change in horizontal loading to the wall from the additional surcharge resulting from the regrading work undertaken on the adjacent land (paragraph 29). The increase in ground height at the point where the concrete slab met the retaining wall, is estimated to have been between 0.9 metres and 1.5 metres (figure 13). This range in values is due to the uncertainty surrounding the actual level of the ground at this point before the surcharge was added (paragraph 26). This range of surcharge results in an increase of between 160% and 237% of the overturning moment about the base of the masonry wall (ie its interface with the sandstone rock) due to the additional soil weight. This loading does not take into account any effects from the recent rainfall that fell in the area, discussed later at paragraph 37.

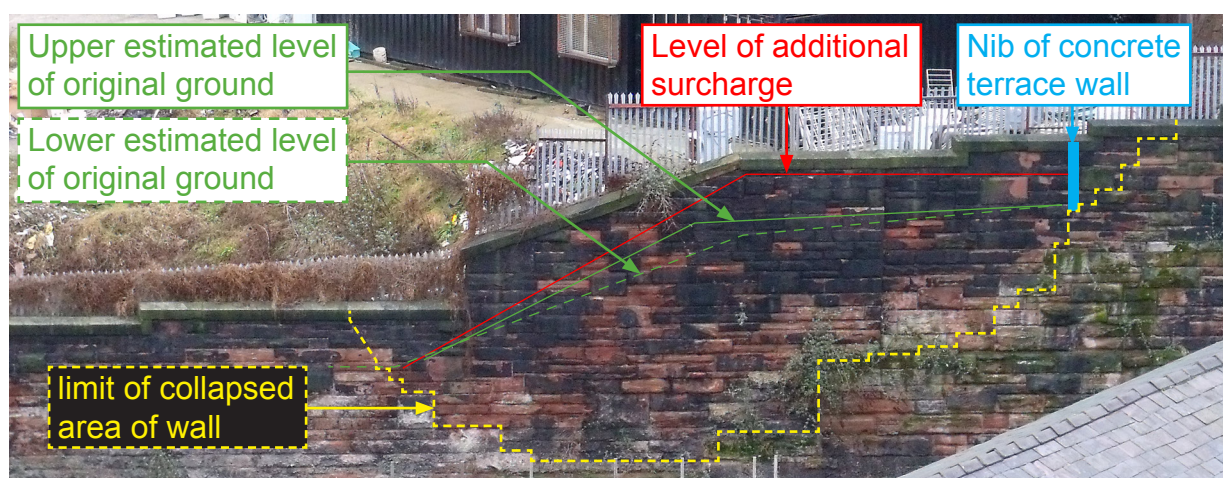


Figure 13: Photograph of the wall taken around 2011 overlaid with estimated change to the wall surcharge and the area of wall that collapsed (photograph courtesy of Williamson Tunnels Heritage Centre)

36 There were cracks in some areas of the remaining concrete slab following the collapse (figure 14). The discolouration of the cracked edges of the concrete slab and the vegetation growing through the cracks indicate that the ground had previously experienced some movement from settlement of the soil. Any previous settlement was likely to have been due to the soil's own weight, together with additional loads from the containers and the concrete slab. The lease holder reported to the RAIB that he had not noticed this cracking prior to the collapse.

The effect of recent rainfall

37 There had been persistent rainfall on 28 February 2017 up to the time of the incident (paragraph 14) and this is likely to have triggered the collapse of the wall. Historical records indicate that the average rainfall for February in the Liverpool area was approximately 45 mm. On the day of the collapse, the cumulative rainfall recorded by a weather station, 700 metres to the south-west of the site, was around 24 mm. This was the greatest amount of daily rainfall recorded by this weather station between 2016 and 2017, although within this period there had been daily rainfalls in excess of 20 mm and therefore the rainfall on the day of the collapse was not exceptional.



Figure 14: The soil embankment following the collapse showing pre-existing cracks in the concrete slab

- 38 The ground levels of the neighbouring properties to the east are approximately 3 to 6 metres higher than the lease holder's property. These adjoining properties do not appear to have any surface water drains, and it is likely that some rain water ran towards the property on which the wall collapsed. Many of the properties are vacant with no buildings, and have concrete hard standing over most of their surfaces. Within the lease holder's property the containers were supported by the concrete slab. All of these concreted areas had reduced the available area for rain water to soak into the ground. This may have been exacerbated by the lowering of the concrete terrace wall (paragraph 27) which previously retained a large volume of soil to the east of it, into which rain water would have soaked.
- 39 A drain chamber, located around 6 metres from the wall, had been constructed by the lease holder to service the kitchen and toilet within the containers and drain away water from the testing of washing machines (red circle, figure 12). The lease holder has stated to the RAIB that the drain was fully connected to the main sewer running behind the building on the west side of the property. Network Rail reported to the RAIB that during the recovery work no connecting pipes were unearthed leading from the chamber, and that it appeared to be a soakaway. It is possible that, had this been a soakaway drain, then water from it may have contributed to the instability of the surrounding land. However, given the rainfall at the time and the potential for rainfall run-off from adjoining land, the RAIB considers it unlikely that this drain, played a significant role in triggering the collapse of the wall.

Identification of causal factors

- 40 The incident occurred due to a combination of two causal factors:
- a) the lease holder had built an earthwork against the retaining wall without assessing the effect of the additional surcharge (paragraph 41); and
 - b) Network Rail took no action because it was unaware that the wall had been additionally surcharged, and it had not identified the infringement of its land adjacent to the retaining wall (paragraph 52).

Each of these factors is now considered in turn.

The surcharge of the wall

41 The lease holder had built an earthwork against the retaining wall without assessing the effect of the additional surcharge.

Development of the land adjacent to the wall

- 42 In November 2004 the lease holder submitted a planning application to Liverpool City Council to build student accommodation on the undeveloped site. Planning permission was granted in January 2005 subject to compliance with Local Planning Authority conditions. One of the conditions stipulated by the council was that the permission did not give approval to build or develop on land, including party boundaries, which was not fully owned, or controlled by the applicant. It stated that adjoining land owners should give their agreement prior to works commencing on the site.
- 43 In November 2004, the city council's Development Control Division wrote to Network Rail to inform it of the planning application as part of the Council's duty to consult neighbours on proposed developments. At that time Network Rail was not a statutory consultee, but has since become one following changes to planning legislation in 2015 which applies to all developments within 10 metres of a railway boundary¹. Network Rail has been unable to locate any records of actions that may have followed this notification.
- 44 The lease holder has stated that following the height reduction of the concrete terrace wall (paragraph 27), the ground to the east of the terrace wall was lowered and a 0.6 to 0.9 metre thick layer of 'MOT sub-base'² material was added to level the area. The particular grade of this sub-base is not known, but photographs taken following the collapse show that the surcharge against the retaining wall was not granular but consisted of soil contaminated with bricks, and metallic and plastic debris.
- 45 The lease holder has stated that the containers were to be a temporary site office while the student accommodation was being constructed and the concrete slab was laid for road access to the rear of the planned buildings. At some time between September 2005 and June 2009, the containers were double stacked on the concrete slab supported by the raised earthwork.

¹ Provision 16 of the The Town and Country Planning (Development Management Procedure) (England) Order 2015 and The Town and County Planning (Developmental Management Procedures) (Scotland) Order 2013.

² MOT refers to a superseded Ministry of Transport standard for the Specification for Highway Works which specified the type of granular sub-base material to use depending upon the intended use of the development.

- 46 The planning permission expired in January 2010 with no work on the new buildings having begun. By July 2013 the upper level of containers had been removed following enforcement action by Liverpool City Council.
- 47 The lease holder has stated that he did not seek professional civil engineering advice on the effect that the earthwork being constructed might have on the wall, in particular the ability of the retaining wall to withstand the loading from the additional surcharge (paragraph 35).

Ownership of the land adjacent to the wall

- 48 The lease holder had developed land directly behind the retaining wall which was the property of Network Rail.
- 49 Historical records indicate that the land occupied by the lease holder was originally owned by the former London and North Western Railway and the majority of it was sold in 1922. At some time since, Liverpool City Council became the owner and leased it to the current lease holder. The lease holder was registered with HM Land Registry as the Title Goods Proprietor from 7 October 2003 and remained so up to the time of the collapse.
- 50 The land plan referred to in the property lease (figure 15) shows a strip of land immediately behind the retaining wall which was outside the boundary of the lease holder's property. Although the land plan is not sufficiently detailed to give an accurate measurement of the width of the strip of land, it shows that the property's boundary is not at the face of the railway wall. The lease holder has stated that the boundary of his property was 1 metre from the railway wall. Therefore the part of the raised earthwork adjacent to the wall, which caused additional surcharge to it, was built on land owned by Network Rail.

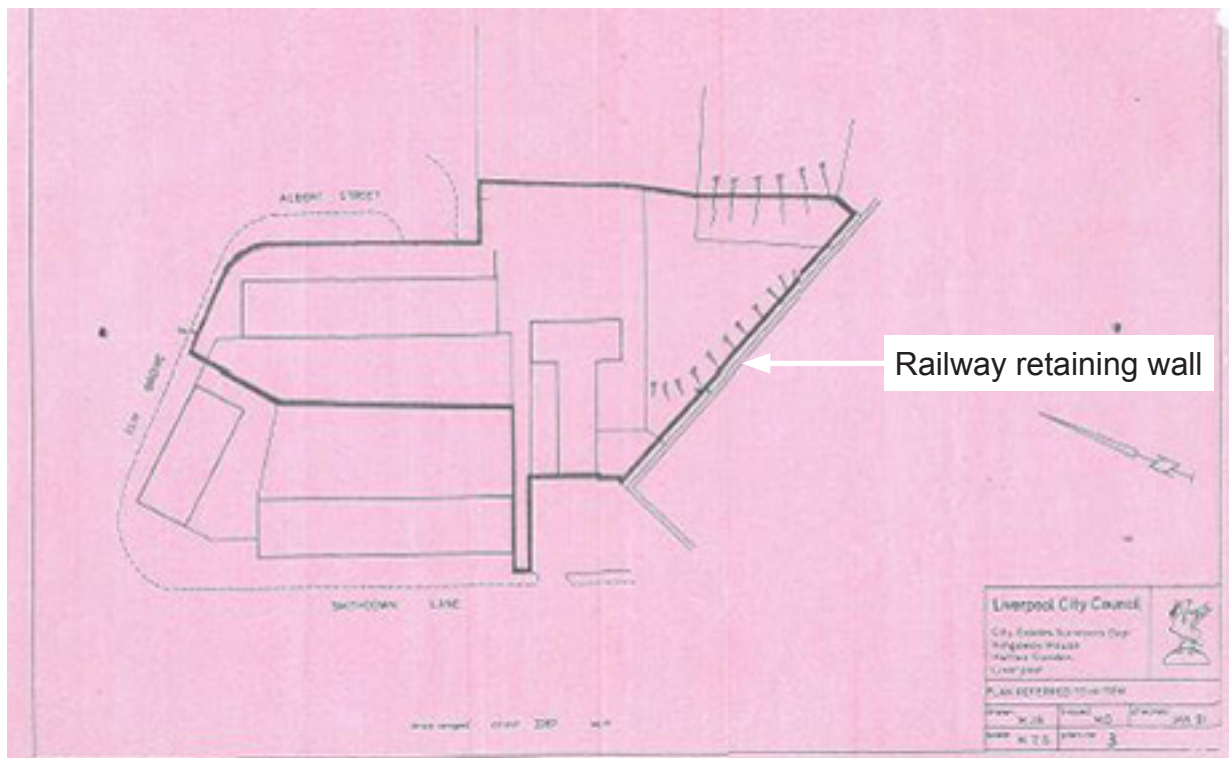


Figure 15: The land plan associated with the lease showing a space between the property boundary and the railway wall

- 51 Network Rail has stated that this land was retained by the railway when the rest of the site was sold and its purpose was to provide access to the north side of the wall for inspection and maintenance. Network Rail had access to this strip of land from Smithdown Lane but this was subsequently given up and access to the wall has more recently been via the gate at the end of Albert Street which is the main access to the lease holder's property (figure 4). The RAIB has found no evidence that access to the wall for inspection and maintenance purposes was any problem for Network Rail once a request had been made to the lease holder.

Identification of the changes to the land adjacent to the wall

- 52 Network Rail took no action because it was unaware that the retaining wall had been additionally surcharged, and had not identified the infringement of its land immediately behind the wall.**

Retaining wall examination process

- 53 The retaining wall is principally managed by Network Rail's Structures asset function within the London North Western (LNW) Route. The LNW Geotechnical and *Off-track* asset management functions also have responsibilities for inspection and maintenance of some of its parts (paragraph 71).
- 54 Network Rail company standard NR/L1/CIV/032, 'The management of structures' defines the requirements for the management of its structures. Further specific detail is given in standards NR/L3/CIV/006/5A, 'Retaining walls' and NR/L3/CIV/006/1B, 'Handbook for the examination of Structures'. These documents specify the types of examinations to be undertaken on retaining walls.
- 55 The Lime Street cutting wall was classified as a retaining wall and was under a routine management regime involving both detailed and visual examinations. NR/L3/CIV/006/1C, 'Handbook for the examination of Structures – Part 1C: Determining the Examination Regime', defines the frequencies of these as six-yearly detailed examinations and annual visual examinations. A relaxation of the standard inspection frequencies can be made if justified, and additional examinations can be requested as necessary.
- 56 The purpose of a detailed examination is to identify and record the uses to which the structure is being put, and to record other factors that could affect its safety or performance. It requires that certain observations are made and recorded, and that previous reports are reviewed. For retaining walls, the standard requires checking for any evidence that they are subject to loading as a result of surcharge, for signs of overloading from material stored on or behind the structure, and for any evidence of building or other development works adjacent to the wall. The tactile checking required as part of detailed examinations on the Lime Street cutting walls is carried out using either track-mounted mobile elevated platforms, or by roped access from above the cutting.
- 57 The purpose of the annual visual examinations is to review the previous assessment reports, inspect for any change in defects previously identified, and record any new defects found. Visual examinations at Lime Street cutting were carried out predominantly from track level, or from the other side of the cutting with the aid of binoculars.

58 Detailed and visual site examinations are carried out by a 'structures examiner' and an electronic report is stored within the Civils Asset Register and Reporting System (CARRS). For detailed examinations of retaining walls on deep, steep cuttings such as Lime Street, specialist contractors who have the necessary competence in working at heights, are employed as structures examiners. Site reports are then reviewed by a 'reviewing engineer', whose role is to assess the integrity of the wall based on the state of any defects found during the examinations. The reviewing engineer is able to review defects found in previous examinations, any remedial works done to rectify them, and make recommendations for any further remedial works.

Examinations of the cutting wall

- 59 The structures examination records for the affected section of the cutting wall, show that there had been four detailed examinations since 1997: in March 1997, February 2002, November 2007, December 2014; and two visual examinations, in January 2016 and December 2016. The December 2014 detailed examination was in place of the annual visual examination for that year. Network Rail was unable to provide evidence of any annual visual examinations prior to 2014.
- 60 The examining engineers and the reviewing engineers involved in the more recent visual assessments were all deemed qualified and competent by Network Rail.
- 61 The 1999 and 2002 detailed examinations were carried out prior to the developments on the land adjacent to the wall. Both contained photographs, but neither specifically shows the area of land that was later developed. The 2007 detailed examination report included one photograph taken from the other side of the cutting. This did not include the area on which there would have been containers present by this time, possibly in their double stacked condition. Although the soil surcharge from the raised land immediately behind the wall, may, or may not have been present at this time, there was no reference in this report to changes in land use and development since the previous 2002 report. There is also no record of whether the 2002 report, or any intervening annual reports, were reviewed during the 2007 detailed examination.
- 62 The examiner who undertook the most recent detailed examination in December 2014 accessed the adjacent land. A photograph taken at the time shows the containers present and the soil embankment against the wall. This surcharge to the wall was not identified by the examiner, probably because by this time it was overgrown with no indications of recent development. The reviewing engineer made no comment on it during the review. The previous detailed examination report (from 2007) was not reviewed by the reviewing engineer due to problems with retrieving it at the time. A common feature across all the detailed examination reports at this location was insufficient photographs with which to make comparisons between examinations to identify the changes in land use or the surcharge.
- 63 The reviews of the detailed examinations prior to 2014 recommended no remedial works, with the exception of the 1999 examination, the review for which recommended the removal of vegetation growth on the south (railway side) face of the wall. Network Rail has provided evidence to show that vegetation removal has taken place on a regular basis since then.

- 64 The 2014 detailed examination review rated the 128 metre section of cutting wall to be in a fair condition with some weathering noted to the faces of the masonry blocks in some areas. The report made three recommendations. One was to address the growing vegetation on the south face of the wall and another was to repaint the metalwork of supports to the OLE. The third recommendation was to rake out and repoint the mortar on an estimated 11 square metres, distributed across various sections of the lower brickwork, along the wall. These areas were not in the section that collapsed which was made of sandstone blocks.
- 65 The reports from the visual examinations undertaken in January and December 2016 noted that the recommended actions from the detailed examination in 2014 had not been completed. However, comparing the photographs in these two visual examination reports with those of the 2014 detailed report indicates that the vegetation growth had been removed by January 2016, although in December 2016 the reviewing engineer had noted that the vegetation was beginning to grow back. Network Rail was unable to confirm whether the recommendations to repaint the OLE metalwork and to repoint the mortar (both not relevant to the collapse) had been done before the time of the collapse.
- 66 In neither of the 2016 visual examinations, did the examiner access the land behind the wall. In both cases, most of the examination involved looking for defects in the cutting wall facing the railway with the assistance of binoculars from track level. Both visual examinations also included observations of the retaining wall from above the cutting, by looking over the fence on Smithdown Lane. The examiner in January 2016 has stated that he could not get access to the land as none had been arranged for him.
- 67 The December 2016 examination report included a photograph of the wall, but this is not sufficiently detailed to show the state of the adjacent land. In both examinations, the previous detailed examination report of 2014 was reported as having been reviewed. A comparison between the 2014 and 2016 report photographs indicates there were no significant differences in the development of the land during that period.

Retaining wall dimensional recording sheet

- 68 Network Rail standard NR/L3/CIV/006/5A contains a diagram showing a cross-section of a cutting including a retaining wall at the crest and an adjacent building on the higher ground (figure 16). The standard requires that certain dimensions on this diagram are recorded if this has not been done before, or if 'significant change' is noted during a visual exam. The dimensions on this diagram had been completed during the four detailed inspections, albeit that the earlier versions, in 1999 and 2002, did not require a measurement of the distance from the retaining wall to the closest structure or building. The form associated with the 2014 detailed examination was completed, but the distance recorded from the railway to the nearest adjacent building was that to the residential property on the land and not to the containers.

Appendix A: Report Form

DETAILS OF RETAINING WALLS										
NETWORK RAIL						Examining Organisation:				
ELR:		Route:				Date:				
Start mileage:		m	yds		End mileage		m	yds		
Structure No:				OS Ref:		GPS ref:				
Location name:										
Overall Length		m	Height:		m	Side of Line: Up / Down				
DIMENSIONS - To be quoted in metres to stated accuracy										
	A	B	C	D	E	F	G	H	J	K
	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-
	100	1m	100	1m	100	100	100	100	100	100
	mm		mm		mm	mm	mm	mm	mm	mm
Maximum										
Minimum										

Figure 16: Retaining wall dimension recording sheet

69 Network Rail was unable to explain the purpose of this diagram. However, one reviewing engineer stated that it gave an overall impression of the scale of a retaining wall. There is no evidence that this diagram was reviewed during the two most recent visual examinations, and one examiner told the RAIB that this was only required to be reviewed during detailed examinations. The diagram does not contain any prompts for examiners to record any dimensions that would indicate the ground profile behind a wall. Consequently any changes to the surcharge at Lime Street were not being monitored by Network Rail’s examiners.

Previous fall of debris

- 70 In October 2013 a train driver reported debris on the up slow line in this location. A rapid response structural examination from track level was carried out at night which found broken masonry block pieces and vegetation on the track. The examiner recommended that an immediate detailed examination be undertaken, including the removal of any loose stonework if found. There is no evidence that this additional examination was carried out before the scheduled detailed inspection in December 2014. Network Rail stated that arranging a roped access examination of the wall required lines to be blocked and the OLE isolated and was not possible in short timescales. Although the location of this previous fall from the wall relative to the section that collapsed is not accurately known, it is possible that had an additional visual examination been done, it might have provided an opportunity to identify the additional surcharge and land developments that were present by this time.

Other examinations of the site

- 71 The role of Network Rail's LNW Geotechnical section in managing the cutting is to inspect it as an earthwork, as it is classified as a rock cutting within its asset management system. Examination records provided to the RAIB indicate that these geotechnical inspections were solely concerned with the integrity of the rock face and did not include the condition of any brickwork or retaining walls which are the responsibility of the Structures function. The adjacent embankment sloping down to the western end of the wall, part of which is on Network Rail property, was not classified as an asset that was to be inspected by the Geotechnical section, as it fell outside the requirements of its standards and no previous concerns had been raised over it.
- 72 One of the duties of Network Rail's LNW Off-track section is to ensure the prevention of unauthorised access to the railway. As such, they had an interest in the top of the retaining wall. The normal cycle for routine inspections is annually. There is only one inspection record from February 2016 relating to this section of the cutting, as it had not previously been registered as an asset on the Off-track section asset management system. However, it was not a prescribed requirement to report any change to the adjacent land, or possible surcharge to a wall, during inspections of the security of boundaries. None were recorded.

Use of railway boundary information and open source (OS) data during examinations to identify infringement of, and changes to, the land

- 73 Network Rail did not identify the infringement of its land adjacent to the wall.
- 74 Examiners are not required by Network Rail procedures to identify where its land has been infringed. Structure examiners do not have ready access to information relating to the positions of boundaries and land ownership details when carrying out examinations. Provision of this information on the examination form might have assisted examiners in identifying that the land directly behind the wall had been developed by the lease holder.

75 During the course of this investigation, the RAIB has made use of aerial images available from open source data including Google Earth, Google Street View, Bing Maps, and others, to assist in investigating the extent of changes to the land adjacent to the wall. The current Network Rail examination process does not advise examiners to use such open source data to assist in their work. Examiners have also reported that there is limited use of Network Rail's Routeview system, which contains aerial images of the railway network. Network Rail has advised the RAIB that open source information is used if an issue has been identified as requiring further investigation.

Identification of underlying factors

Risk based approach to structures examinations

76 Network Rail did not have a suitable risk prioritisation process in place to guide the scope and depth of the structures examinations carried out on the retaining wall.

77 The collapse of the retaining wall had the potential to derail and/or crush a passing train with the consequent high risk of loss of life and serious injury. The high risk arose not only because of the additional surcharge the wall was subjected to (paragraph 35), but also because of the weight of the material involved and the height above the busy tracks from which it fell. Failure of such walls has a potentially high safety consequence.

78 Network Rail standard NR/L3/CIV/006/1C states that detailed examinations undertaken on a retaining wall shall be commensurate with the use, type and condition of the wall. Standard NR/L3/CIV/006/11A, 'Handbook for the examination of Structures Part 11A: Reporting and recording examinations of Structures in CARRS', contains a 5 by 5 matrix to assess the risk from any pre-existing or new defect identified during examinations (figure 17). The likelihood of any defect having an effect on a structure within the subsequent twelve months, and the related consequence, gives a defect risk score of between 1 and 25 using the matrix. The consequence is assessed by the reviewing engineer using a severity factor which ranges from reputational damage at the low end, to safety hazard (ie potential to cause fatalities or injury) at the high end.

79 Although the consequence severity factor takes into account the safety of trains, the risk scoring system in NR/L3/CIV/006/11A applies only to structures with known defects. If a retaining wall had no significant defects it would be ranked as low risk even if the consequences of a structural collapse on the safety of trains, caused by other means such as overloading, could be high. More generally, the likely consequence of failure of some structures, such as the retaining wall in this case, would be higher than some other retaining walls. Ranking the risk of a failure of a retaining wall in this way would allow more emphasis to be placed on the scope and depth of the examinations of structures where failure is likely to lead to higher safety consequences.

	Consequence (Examining Engineer's judgement of consequences if defect is not rectified within <u>1 year</u> from date of examination)	Severity Factor					
			Very Unlikely	Unlikely	Possible	Likely	Certain
SAFETY	Structure unsafe and may cause fatalities and/or injury	5	5	10	15	20	25
LINE / ROAD CLOSURE	Structure not able to fully function in current condition	4	4	8	12	16	20
CAPABILITY	The asset will have a reduced capacity to sustain its intended loading if this particular defect is not rectified	3	3	6	9	12	15
COST	Further structural deterioration or commercial or business implications - may require remedial actions	2	2	4	6	8	10
REPUTATION	Onset of accelerated degradation of material or public complaints	1	1	2	3	4	5
Risk Score = Severity x Likelihood of Occurrence			Very Unlikely 1	Unlikely 2	Possible 3	Likely 4	Certain 5
			Likelihood Of Occurrence				

Figure 17: Structure defect risk matrix from Network Rail standard NR/L3/CIV/006/11A

Examination and assessment processes

80 The current examination process does not require the consistent recording of sufficient information to monitor the change in the risk to retaining walls.

81 The lack of consistent information recorded during previous examinations meant that useful comparisons to detect changes were not possible. This made it difficult for examiners and reviewers to identify changes in the use of the land adjacent to the retaining wall, and resulted in the additional soil surcharge not being detected. Even if all the annual visual examinations had been carried out (paragraph 59), it is unlikely the surcharge would have been detected without the examiners having access to consistent and sufficient information.

82 The current two part examination and reviewing process provides for an evaluation by the reviewing engineer, to apply professional engineering judgement to the observations recorded. However, although reviewing engineers can request further information, they take the view that the structures examiner has conducted a thorough examination and only reports on items of concern. Reviewing engineers rarely visit sites, other than to conduct audits. Evidence provided to the RAIB indicates that their workload on the LNW route involves reviewing around 5000 structures reports per year, which allows them around 10 to 15 minutes per report. Many structures, such as bridges, are more complex and require more time to assess. Given the short amount of time that reviewing engineers have to assess a retaining wall, it is important that the scope and depth of the information they receive readily enables them to make a sufficiently thorough assessment.

- 83 The detection of relevant changes relies on comparisons between observations during examinations and comparison with previous records. This could be from photographs, diagrams, measurements, or the use of physical markers (paint, ground level marker posts, etc.). Examinations and subsequent reviews of a particular structure can be undertaken by different people, and so consistency of information to make comparisons relies on the quality of information provided in each report. This could be enhanced by using open source data (eg Google Earth) to identify whether there have been changes to adjacent land that could affect the integrity of a structure (paragraph 75).
- 84 The RAIB found that there was a lack of clarity among the examining and reviewing engineers on the requirements expected in examinations. There were differences of opinion as to whether the land behind a retaining wall should be accessed during visual examinations, the need to take photographs from the top of a retaining wall (and the usefulness of such photographs), and the requirement to use the dimensioned diagram (paragraph 68) to identify the proximity of adjacent buildings and/or surcharge.
- 85 There is a requirement in standard NR/L3/CIV/006/11A 'Handbook for the Examination of Structures - Part 11A: Reporting and Recording Examinations of Structures in CARRS' that any parts of a structure that have not been examined are identified and a reason given for not examining them, together with any recommendations for further investigation. The investigation found that there were differences in understanding as to what should be reported as 'not examined'. In both visual examination reports it was recorded that all of the structure had been viewed when it had not.
- 86 One examiner stated that he had not been briefed on this standard at all.

Summary of conclusions

Immediate cause

87 The wall collapsed because it could not withstand the loads from the additional surcharge (paragraph 32).

Causal factors

88 The causal factors were:

- a) The lease holder built an earthwork against the retaining wall without assessing the effect of the additional surcharge (paragraph 41, no recommendation)
- b) Network Rail took no action because it was unaware that the retaining wall had been additionally surcharged, and had not identified the infringement of its land adjacent to the retaining wall (paragraph 52, **Recommendations 1 and 2**).

Underlying factors

89 The underlying factors were:

- a) Network Rail did not have a suitable risk prioritisation process in place to guide the scope and depth of the structures examinations carried out on the retaining wall (paragraph 76, **Recommendation 1**).
- b) The current examination process does not require the consistent recording of sufficient information, to adequately monitor the change in the risk to retaining walls (paragraph 80, **Recommendation 2**).

Actions in progress relevant to this report

- 90 Network Rail is undertaking a project known as CSAMS (Civils Strategic Asset Management Solution) with the aim of integrating its Geotechnical and Structures databases and software tools to better manage these infrastructure assets.
- 91 In parallel with this, Network Rail has developed a system for prioritising the risk to its retaining walls. This gives an individual retaining wall a risk score based on its method of construction and its condition, so that examination, assessment and maintenance activities can be better targeted. The system is capable of considering the safety consequence of a wall collapse, in terms of potential harm to passengers and trains (paragraph 76). However, this is not currently in use. Network Rail reports that this project is currently awaiting the implementation of CSAMS, which has been delayed due to software problems.

Recommendations and learning points

Recommendations

92 The following recommendations are made³:

- 1 *The intent of this recommendation is that Network Rail is aware of which of its walls have a potentially high safety consequence (eg derailment or significant damage to passing trains) in the event of failure, so that the scope and depth of examinations can be set appropriately to minimise risk to the railway.*

Network Rail should review its wall assets and identify those which have a potentially high safety consequence should they fail (eg train derailment, or large amounts of debris falling on to trains). These should be clearly identified in its database of assets (paragraph 91a).

- 2 *The intent of this recommendation is that for those walls identified (from Recommendation 1) as having a potentially high safety consequence in the event of failure, Network Rail enhances its wall examination and assessment processes to mitigate the additional risk.*

Network Rail should review its structures examination and assessment procedures for its walls that have a high potential safety consequence in the event of failure (identified in response to Recommendation 1 above). This review should include:

- a) The level of detail in the information (including photographs) that is currently being collected in both detailed and visual examinations and the sufficiency of this information to allow subsequent examiners and reviewers to make thorough assessments on both condition and changes in loading;
- b) The need for additional checks to be done in examinations, including, but not limited to:
 - detailed inspections from the tops of cuttings and the non-railway side of walls;
 - checks for relevant changes in adjacent land use; and

³ 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.

- potential additional surcharge (eg using photographs and physical markers).
- c) The potential for greater use of open source data (eg Google images) and Network Rail's aerial images, to facilitate comparisons between examination reports, where changes in adjacent land use may have an adverse impact on a wall.
- d) Provision of information to examiners pertaining to railway boundaries, to enable them to monitor encroachments into Network Rail property.

Network Rail should then take steps to implement the identified improvements to its wall examination and assessment procedures.

Learning points

93 The RAIB has identified the following key learning point⁴:

- 1 Following the application for planning permission in 2004, Liverpool City Council notified Network Rail of the proposed development on the land (paragraph 43). At that time there was no statutory duty to do so, but the council consulted as it considered the railway as a neighbour to the property. Since then, local planning authorities have a statutory duty to serve notice to the infrastructure manager of a railway, where a development is proposed, which is within 10 metres of a railway's (relevant) property. This is a provision of The Town and Country Planning (Development Management Procedure) (England) Order 2015 and The Town and County Planning (Developmental Management Procedures) (Scotland) Order 2013. This incident illustrates why compliance is so important.

⁴ '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

ECRO	Electrical Control Room Operator
LNW	London North Western
OLE	Overhead Line Equipment
RIO	Rail Incident Officer

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.

Circuit breaker	An automatic device which prevents the flow of an electrical current when an electrical fault is detected.
Off-track	Functions related to activities that are not on the track.
Photogrammetric survey	A survey carried out by analysing many photographs to capture accurate spatial information. For this investigation the photographs were taken by an aerial drone and analysed using photogrammetric software to generate a 3D model of the site.
Proceed at caution	A formal instruction to a driver to proceed at such a speed that will allow the train to be safely stopped within the distance they can see to be clear ahead.*
Rail Incident Officer	A Network Rail employee who takes charge of the overall management of railway operations at the scene of a rail incident or accident.
Surcharge	Any loading on a retaining wall above the ground level
Track circuit	An electrical or electronic device used to detect the absence of a train on a defined section of track using the running rails in an electric circuit.*

Appendix C - Investigation details

The RAIB used the following sources of evidence in this investigation:

- information provided by witnesses;
- site photographs, measurements and photogrammetry;
- Network Rail structures and geotechnical examinations and review records;
- a train driver's report;
- Network Rail data on train movement data;
- Electrical Control Room and Network Operations Centre logs;
- open source aerial images;
- images from an aerial survey provider;
- historical photographs from Williamson Tunnels Heritage Centre;
- Land Registry records;
- Liverpool City Council and the lease holder's property lease records;
- weather reports and observations at the site; and
- a review of previous RAIB investigations that had relevance to this incident.

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