Summary

1 On Friday 21st August 2009 at 18.23hrs, spans 4 & 5 of the Malahide Viaduct started to collapse as the 18.07hrs Balbriggan to Pearse passenger train was passing over it. The driver placed his power controller into the 'coast' setting which reduced the forces acting on the collapsing viaduct as the train passed over it.

2 All the post-incident emergency procedures were properly employed by operating staff. The driver made an emergency call as trained, the signaller promptly provided signal protection and the IÉ Incident Officer subsequently secured the site and carried out the appropriate duties correctly.

3 The collapse of the structure was due to the undermining of one pier's foundation caused by 'scour' erosion. The structure is unusual in that the piers did not extend down to the 'bedrock', but are instead founded within the manmade causeway/weir formed of large stone blocks (rip-rap) resting on the bed of the estuary. Thus the viaduct piers were prone to erosion or 'scour' damage.

4 Maintaining the causeway/weir was of paramount importance to ensure the integrity of the viaduct structure itself. In 1967 the superstructure of the viaduct was replaced and significant grouting work was undertaken to the causeway/weir, extending to a depth of two metres into the structure, to stabilize it. These works, it was believed, would generally reduce the need for on-going maintenance, particularly the unloading of rip rap stone which had been regularly carried out to maintain the causeway/weir profile by replacing stones washed away by the tides. Since this time the placing of rip-rap was more limited and appeared to be carried out only to protect the piers.

5 Over time, erosion of a section of the causeway/weir plateau between Piers 4 and 5 caused changes to the water flow under the structure, resulting in the majority of the water flowing in the deepened channel between these two piers, further increasing erosion. In a relatively short period of time, the weir 'crest' receded from the seaward side of these piers to beneath the span between them and, subsequently, onto the other (estuary) side of the viaduct. In the months prior to the collapse, the channel deepened further and the flow became ever stronger with standing waves and, latterly, a 'piping' mechanism causing further 'scour' action. Eventually Pier 4 became undermined and collapsed.

6 A number of days after the collapse of the viaduct, as the initial investigations proceeded, engineers established that the first challenge to be faced in rebuilding the viaduct was stabilisation and re-instatement of the weir, before any work on replacing the collapsed structure could commence.

7 A key finding of this investigation is that since the grouting works were undertaken on the causeway/weir in 1967, the engineering emphasis has been focussed on the maintenance of the viaduct structure itself. However the condition of the grouting in the causeway weir deteriorated over time and eventually the causeway/weir required maintenance. By this time, although protection of the pier foundations was still being undertaken, the importance of maintaining the weir profile was no longer fully appreciated. Prior to the collapse, therefore, it was no longer appreciated that the structure as a whole comprised two separate components: a causeway/weir and a viaduct.

8 It also appears that climatic, oceanographic and hydrological changes over recent decades have increased the hydraulic 'head' and hence the erosive effect of the water flowing into and, more especially, out of the Broadmeadow Estuary over the causeway/weir.

9 During the week before the collapse, a group leader of the Malahide Sea Scouts, who regularly canoe in the Broadmeadow Estuary, observed that a rock at the base of Pier 4 had been washed away and decided to contact IÉ to alert the company of this. On the 17th August the leader rang IÉ and reported the matter. Whilst the Sea Scouts Leader did not consider the structure had become unsafe, he was however concerned about the changing conditions and felt that the situation needed to be reported.

10 The information reported by this member of the public was dealt with in a professional manner by IÉ staff. However a misunderstanding appears to have developed so that the engineer delegated to inspect the viaduct on 18th August was looking primarily for cracks or missing stones in the pier structure rather than its foundations. He found the 'dressed' stonework of the viaduct to be in need of pointing and there were some cracked stones on a number of piers. Whilst none of these faults were of a serious structural nature, their presence appeared to him to explain the reason for the report from the canoeist. Therefore this visual inspection did not lead engineers to question the stability or the structural integrity of the viaduct.

11 IÉ has followed the recommendations of the previous IRMS and AD Little reports concerning inspections. A structural inspection standard has been issued which is a well written document with references to 'scour'. Efforts to ensure that all structural inspections were brought up to date since the publication of these reports appear to have been successful.

12 Malahide Viaduct had received routine two yearly 'thorough' inspections by IÉ in 2005 and 2007 and a 'special' underwater inspection by a specialist company in 2006. No serious faults were found and it was recommended that the piers should be re-pointed when convenient, as the mortar loss was not in need of timely repair. It was further recommended that the substructure units be

inspected underwater at intervals not to exceed six years and soundings taken after exceptional occurrences. It appears that none of the inspectors had any detailed knowledge of the particular foundation arrangements, although such information is often not available for a structure of this age.

13 The Track Recording Vehicle (TRV), a sophisticated track monitoring tool operated eight times over the viaduct (in each direction) in the previous two years. It last passed over the viaduct on the 20th August, the day before the collapse, and recorded the trackwork in good order. No defects were found and no significant changes in vertical or horizontal alignment, cross level or twist, which may have indicated distress in the structure, were identified.

14 The line was immediately closed after the incident and following the reconstruction of Pier 4, strengthening of all the other piers, replacement of the pre-cast beams and reinstatement of the weir, it was re-opened to traffic on 16th November 2009.

15 The Panel are pleased to report that a number of actions have already been completed in order to address particular issues which were highlighted as a result of this investigation. The Board of Inquiry has made nine recommendations as a result of the investigation into this incident.

16 The Panel would like to commend the public spiritedness of third parties who contacted IÉ prior to and subsequent to the incident. The information, freely given, has been of great help in assisting with this Inquiry.

Conclusions

1 At 18.23hrs on Friday 21st August, Spans 4 and 5 of the Malahide Viaduct collapsed due to undermining of one pier's foundation caused by erosion due to scouring.

2 The public spiritedness of third parties who contacted IÉ prior to and subsequent to the incident should be commended. It appears that, in the main, the information reported by the public was dealt with in a professional manner by IÉ staff, but the process could benefit from being documented and unified across the organisation.

3 Visual checks and inspections prior to the 21st August did not lead engineers to question the stability or structural integrity of the viaduct. The grouting works to the causeway/weir undertaken in 1967 had led engineers to believe that the weir needed little maintenance and, over time, the importance of maintaining the weir profile was not appreciated in the context of the hydraulic behaviour of the watercourse.

4 There is often a problem in identifying with any certainty the construction details of bridges that are of the age of most railway structures. Most railway administrations are faced with this issue. Foundations are a particular problem for structures over water because they are hidden. Foundation depths for bridge abutments and piers had not been determined for the Malahide Viaduct.

5 Whilst there is no guarantee that an original construction drawing shows a structure 'as built', it would be helpful to view such a drawing prior to making an inspection. However, access to historical records and drawings was difficult for engineers and normally only the bridge inspection cards with limited data were available to ADEs prior to carrying out an inspection. Such relevant drawings, documents and records could have been made available through IAMS.

6 It is probable that the effects of climate change and land development have had an effect on the water levels, flow rates and erosive force.

7 IÉ has followed the recommendations of the previous IRMS and AD Little reports concerning inspections. The structural inspection standard is a well written document but references to scour need to be reviewed, particularly with regard to the frequency of inspections. The need to define trigger conditions for exceptional tides and other water level changes also should be highlighted.

8 The primary task of track patrolmen is to inspect the track. The patrolling standard also requires patrolmen to note all aspects of the infrastructure on or about the railway. However track patrolling personnel do not have the expertise to identify pertinent structural issues particularly with regard to scour and foundations. Although the track patrolling frequency had exceeded the interval required by the standard, there was no evidence to suggest that the track patrolman would have identified any precursors to this incident as evidenced by the TRV run the day before the incident occurred.

Action taken or in progress since the incident

1 The Inquiry Panel are pleased to note that a number of actions have been taken since the incident.

2 The replacement Pier 4 is founded on piles and all the remaining existing piers have been retro-fitted with piled foundations. A bridge monitoring system has been installed on the Malahide Viaduct.

3 The list of structures susceptible to scour has been reviewed and is now more comprehensive. Pier and abutment depths are being established for all bridges on the scour list wherever practicable. Where this is not possible, other mitigating measures will be implemented.

4 There is one other structure on the IÉ network that has similar foundations to Malahide, Rogerstown Viaduct. This is on the same route as the Malahide Viaduct. Pier and abutment depths have been established for this structure and found to be deeper than for Malahide and are secure.

5 The Acting Chief Civil Engineer has initiated a full review of the systems in place for monitoring structures subject to scour and has commissioned consultants to look at international best practice for this with a view to implementing system improvements.

6 The driver of the 18.07hrs Balbriggan to Pearse train has been commended for his quick thinking in placing his power controller into the 'coast' setting which reduced the forces acting on the collapsing viaduct as the train passed over it. His actions to protect the line after the incident were also exemplary as were those of the CTC Signalman who has also been commended.

7 The need to maintain the causeway/weir of the Malahide Viaduct to an acceptable profile is now clearly understood. The weir has been reconstructed to its original profile. Furthermore an improved weir profile is being developed, in line with the outcome of the studies undertaken by UCC.

8 Information on the viaduct that is currently known, or can reasonably be collected including archived materials, is being assembled and will be made available through IAMS. Thus in future, IAMS will form the basis of the required inspection and maintenance process and staff will be better equipped to undertake these duties. Similar information will also be added, on a risk prioritised basis, for all other structures on IÉ.

9 Most of the bridges on the "scour inspection list" have been inspected (by engineer divers) and this work will be completed by April 2010. Following on from these inspections each structure will be given a risk rating and the inspection frequency will be based on this rating. Trigger levels will be defined for special additional inspections of the structure as required (e.g. exceptional tides) and/or its closure when conditions deteriorate. A re-opening process for each structure is also to be documented.

Recommendations

Recommendation 1

Complete all actions in "Action taken or in progress since the incident" section of this report.

Recommendation 2

The structures standard should be revised to include more information on 'scour', the erosive effects of different water conditions (e.g. standing waves), particularly in the context of the design of remedial measures.

Recommendation 3

The introduction of the revised structures standard should be supported by the running of a series of Structures Inspection Training Courses. The training should incorporate 'follow up' mentoring in the field by experienced, competent staff.

Recommendation 4

Roles and reporting lines for structures and track patrolling inspections should be reviewed and a 'hand-over' process should be put in place to ensure knowledge is not lost on staff movements within the organisation or when staff leave the service.

Recommendation 5

Flood and tidal warning arrangements, using information from Met Éireann and the Coast Guard, should be formalised throughout IÉ.

Recommendation 6

Consideration should be given to extending the installation of monitoring/warning equipment to structures susceptible to scour so that changing conditions at sites during adverse conditions can be monitored.

Recommendation 7

The bridge card system of monitoring the condition of structures should be expanded to incorporate all relevant information that needs to be recorded during an inspection. The records should cover each span or relevant element of the structure and these should be incorporated into an enhanced IAMS based system supported by photographs.

Recommendation 8

The process for dealing with reports from the public should be documented and unified across the organisation.

Recommendation 9

The effects of climate change, land and leisure developments in the Broadmeadow catchment area should be kept under review by IE so that the organisation is well placed to take informed action to mitigate any potential future adverse effects on the railway. In particular, it is recommended that dialogue is initiated with the relevant state agencies accordingly.