Railway Accident Investigation Unit

Ireland

INVESTIGATION REPORT

Structural failure of a platform canopy at Kent Station, Cork

18th December 2013

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Reader guide

All dimensions and speeds in this report are given using the International System of Units (SI Units). Where the normal railway practice, in some railway organisations, is to use imperial dimensions; imperial dimensions are used and the SI Unit is also given.

All abbreviations and technical terms (which appear in italics the first time they appear in the report) are explained in the glossary.

Descriptions and figures may be simplified in order illustrate concepts to non technical readers.

Report preface

The RAIU is an independent investigation unit within the Department of Transport, Tourism and Sport (DTTAS) which conducts investigations into accidents and incidents on the national railway network, the DART network, the LUAS, heritage and industrial railways in Ireland. Investigations are carried out in accordance with the Railway Safety Directive 2004/49/EC and the Railway Safety Act 2005.

The RAIU investigate all serious accidents. A serious accident means any train collision or derailment of trains, resulting in the death of at least one person or *serious injuries* to five or more persons or *extensive damage* to rolling stock, the infrastructure or the environment, and any other similar accident with an obvious impact on railway safety regulation or the management of safety.

The RAIU may investigate and report on accidents and incidents which under slightly different conditions might have led to a serious accident.

RAIU investigations are conducted for the purpose of accident and incident prevention which includes the gathering and analysis of information, the drawing of conclusions, including the determination of causes and, when appropriate, the making of safety recommendations in order to prevent accidents and incidents in the future and improve railway safety.

It is not the purpose of an RAIU investigation to attribute blame or liability.

Report summary

At approximately 15:01 hours (hrs) on Thursday 18th December 2013 the canopy over Platforms 1 and 2 at Kent Station, Cork, was exposed to unusually high winds and collapsed. The canopy consisted of a mainly timber cantilevered roof supported by seventeen cast-iron columns which were braced longitudinally by *lattice girders*. The design of each column included a decorative feature at the base of the column at which fourteen of the seventeen columns fractured. This feature acted as a stress raiser and therefore an inherent weak point in the design. A structural dynamics and wind loading study was undertaken by Fluvio R&D Limited (Fluvio) to determine the collapse mechanism. This work concluded that the structure initially failed at the end furthest away from the station and then the columns fractured sequentially towards the station. This model was supported by witness statements and CCTV footage. The work also calculated that a peak wind speed of between 39 metres per second (m/s) and 50 m/s would be required to initiate the collapse and concluded that speeds of this magnitude would be associated with a rare event.

The *immediate cause* of the accident was a significant increase in wind speed leading to greater pressure acting on the canopy over Platforms 1 and 2 resulting in the rapid failure of the cast-iron columns.

Contributory Factors (CFs) associated with the accident are as follows:

- CF-01 – The use of cast-iron and the decorative details in the column meant that the design of the structure contained inherent weaknesses;
- CF-02 – Weather conditions in the vicinity of Kent Station included unusually high winds.

Underlying Causes (UCs) associated with the accident are as follows:

- UC-01 – IÉ CCE did not have a weather management protocol in place which included actions to be taken to protect structures at risk from adverse weather conditions.

The following *Additional Observation* (AO), not relating to the cause of the accident, was made during the investigation:

- AO-01 –The canopy had not received an inspection that met the structural requirements of IÉ standards I-FBD-8100, CCE-SMS-001 or the superseded standard I-STR-6510. In addition to this a number of the Annual Inspections undertaken did not contain the required signatures.

As a result of this investigation, the RAIU have made three safety recommendations:

- IÉ IM should identify all cast-iron structures on the network. From this, a risk-based approach should be taken in relation to the inspection of these assets, during routine inspections, in terms of any risks associated with cast-iron;

- IÉ IM should establish a formalised procedure for managing the risk associated with the adverse effects of high winds;

- IÉ IM should review the structural and annual inspection regimes for Building and Facilities (B&F) to ensure all assets are inspected in accordance with the prescribed standards and any associated documentation is completed appropriately.

Contents

The accident

Summary of the accident

1 From approximately 14:15 hrs on the 18th December 2014 the weather in the vicinity of Kent Station, Cork, became cloudy with spells of wind and rain (see Figure 1 for location of accident). The rain became persistently heavy from approximately 14:40 hrs.

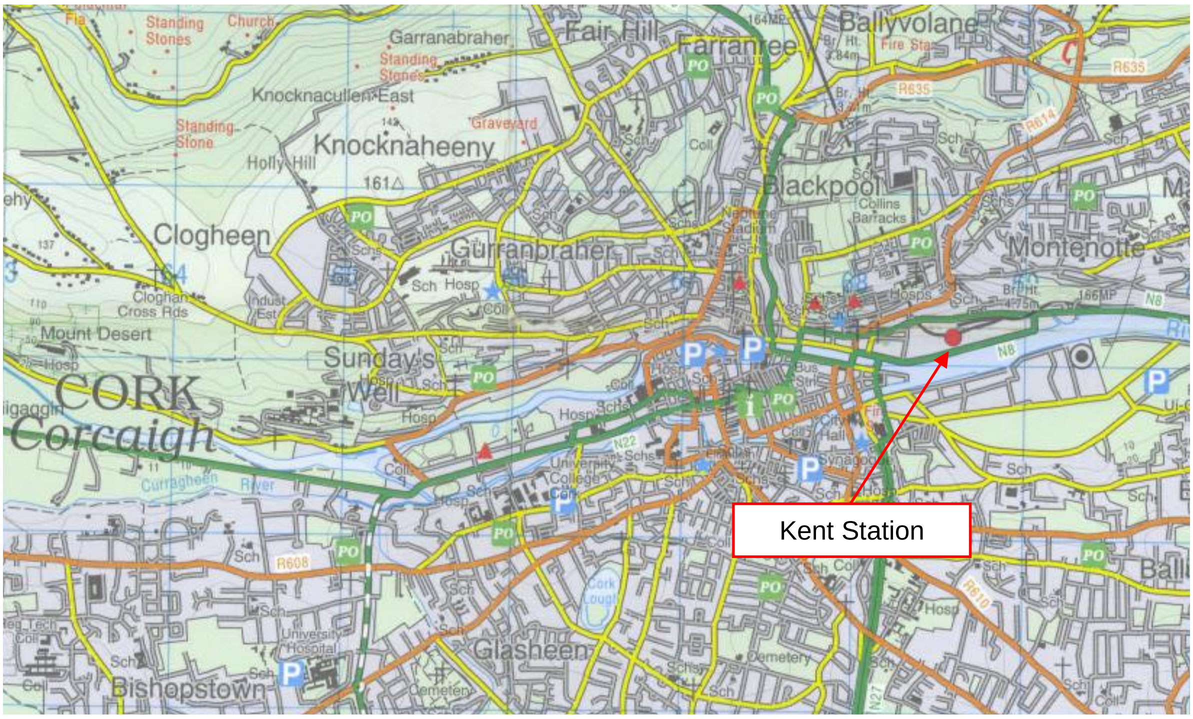


Figure 1 – Location of accident

2 Three people were on Platforms 1 and 2 waiting for the 14:45 hrs service from Midleton which was due to arrive into the station at 15:08 hrs.

3 The wind and the rain increased in intensity and a section of roof felt was carried by the wind from the canopy over Platform 4 onto the ground beside Platform 2. At 15:02 hrs the canopy above Platforms 1 and 2 started to sway and the supporting columns began to fall at the end of the platform furthest from the concourse. Sequentially the columns fell and this resulted in the canopy collapsing.

4 The canopy sections and debris fell onto the platform, the unoccupied track at Platform 1 and onto an empty stationary train stabled on the adjacent 'engine road'. Additionally debris from the roof structure was blown into the car park damaging some vehicles (see Figure 2).

Figure 2 - Collapsed canopy and resultant debris

5 As the structure fell a section struck one of three people on the platform in the back knocking them to the ground.

6 At 15:03 hrs IÉ station staff escorted the three individuals from Platforms 1 and 2 into the station concourse, and the emergency services were called.

7 At approximately the same time the Station Manager activated the station Local Emergency Plan (LEP) and with the assistance of the other IÉ staff the station was evacuated. All train movements in and out of the station were terminated.

8 At approximately 15:09 hrs the emergency services arrived on site.

General description of the railway

Infrastructure

9 Constructed in the late 1800s Kent Station in Cork City is situated at the 165 ½ mile post (MP) on the Cork to Dublin mainline, see Figure 3. Mile posts are measured from Dublin Heuston (0 MP).

Figure 3 –Kent Station

10 There are five platforms in Kent Station, numbered 1 – 5. Platforms 4 and 5 are used for all trains arriving and departing to and from Dublin, Mallow and Kerry. Platforms 1, 2 and 3 (bay Platforms) are used for commuter services to and from the Cobh and Midleton lines, shown in Figure 4.

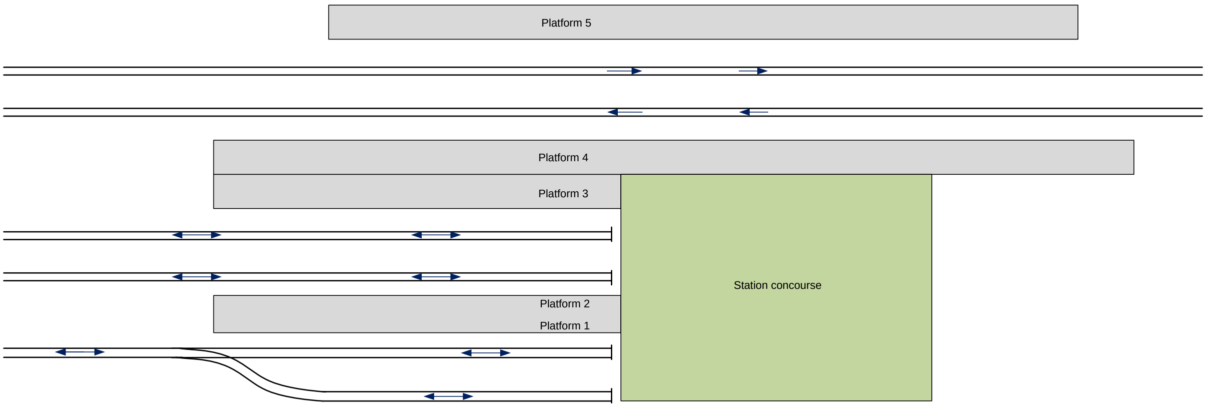


Figure 4 –Kent Station layout

11 All rails are laid on timber sleepers in Platform Bays 1, 2 and 3 and on concrete through Platforms 4 & 5 (mainline).

12 The original construction of the station included a canopy placed over Platforms 1 and 2, shown in Figure 5. The construction of the canopy will be discussed in more detail later in this report.

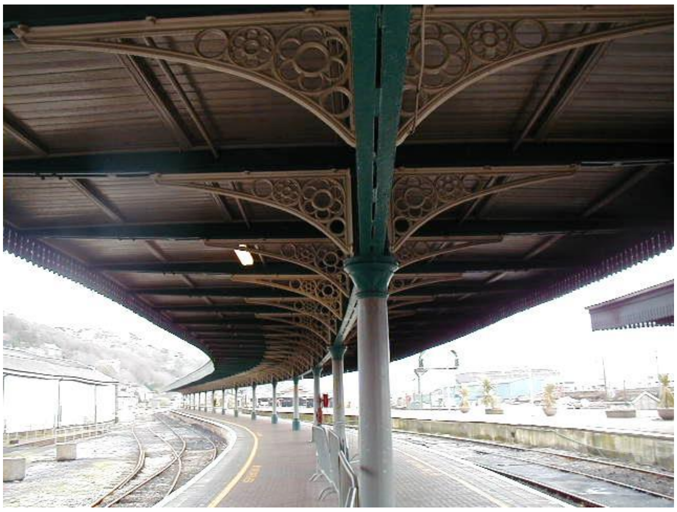


Figure 5 – Canopy above Platforms 1 and 2

Rolling stock

13 The following trains were involved in this accident:

- The 15:00 hrs passenger service from Cork to Cobh (train identification number D247). This was previously the 14:30 hrs service from Cobh which arrived into and left from Platform 2;
- The 14:45 hrs passenger service from Midleton to Cork (train identification number P282), was due into the station at 15:08 hrs. Due to the accident the train was held at Little Island station where the passengers were detrained;
- In addition to these two services a train was stabled in a siding between Platform 1 and the car park. When the canopy collapsed the train was trapped under the roof debris. One train was also held on Platform 3 and sustained minor damage.

14 All four trains were two carriage Class 2600 Diesel Multiple Units (DMU). The Class 2600s entered passenger service in 1994.

15 No factors in relation to the condition of the rolling stock were found to have contributed to the accident.

Signalling and communications

16 Platforms 1, 2 and 3 are signalled using *semaphore signals* and movements through Platforms 4 and 5 are signalled using two and three aspect *colour light signals*. All of these movements are controlled by the Signalman based in Cork cabin. *Track Circuit Block (TCB)* regulations apply to these routes.

17 The means of communication between train drivers and the Signalman in Cork cabin is via train radio.

Operations

18 All train drivers operating trains related to this accident were passed as competent.

Fatalities, injuries and material damage

Fatalities and injuries

19 One person on the platform sustained injury as a result of the falling canopy. This injury required hospitalisation on the day of the accident and further treatment after release from hospital.

Material damage

20 Every supporting column of the canopy over Platforms 1 and 2 fractured leading to the collapse of the structure and subsequently it sustained extensive damage throughout. The following damage was caused by the falling canopy and resultant debris:

- Two sets of railcars were damaged. One of the sets had minor damage when the unit was struck by debris and the engine fire extinguishing system was triggered on the underside;
- There was also damage to the drivers drop light window. This unit was stabled on Platform 3 at the time of the accident;
- The second railcar was the unit stabled in the siding adjacent to Platform 1 and 2 and was struck and mostly covered with debris from the canopy;
- There was damage to a number of road vehicles in the car park adjacent to the accident.

Figure 6 – Collapsed canopy and resultant debris

21 Additional damage caused to the immediate environment was:

- Cork cabin is a two storey timber framed building. The building did not suffer any structural damage. However, some superficial damage was identified including a broken window on the first floor, a dislodged internal Perspex panel and a broken door bracket;
- An advertising hoarding near the perimeter wall on the south side of the station was damaged as shown in Figure 7A. The structure was supported by steel columns which bent over due to the force of the wind;
- A concrete block infill in the former goods yard of a previous entrance off Horgan's Quay was blown over and landed as shown (Figure 7B) onto a disused siding;
- Both the goods store and the locomotive shed are large buildings with tiled roofs. A number of tiles were removed from both structures by the wind. It was also observed that a number of houses on Lower Glanmire road adjacent to the station also had tiles removed from their roofs Figure 7C;
- A large section of roof felt was removed from the main canopy and landed on the ground next to Platform 2. In addition to this glass panes failed near the centre of the structure with the glass being blown out through the top of the roof Figure 7D.

Figure 7 – Additional damage in vicinity of Kent Station

Parties and roles involved in the accident

Parties involved in the accident

22 IÉ is the *railway undertaking* (RU) that owns and operates mainline railway services in Ireland. IÉ is also the railway *infrastructure manager* (IM), managing the design, installation, testing, inspection, maintenance, renewal and operation of the railway's physical assets. The IÉ departments associated with this accident are the:

- Intercity and Commuter Network Department (ICCN) – responsible for the operation of trains on the mainline, excluding the DART network. This includes the supervision of train drivers; ICCN is also responsible for station management and operations staff;
- Chief Civil Engineers (CCE) Department – responsible for the design, inspection, maintenance and renewal of the railway's structural infrastructure. This includes the B&F Department and the related assets;
- B&F Department – responsible for all aspects of the management of inspection, maintenance and repair activities within a number of CCE Locations. For example, office buildings, CCE buildings, station buildings, car parks and station platforms (up to the platform coping).
- New Works – Operates independently of, but in cooperation with, the Engineering Division of IÉ and has the responsibility for the delivery of infrastructure capital projects.

Other parties not directly involved in the accident

23 Fluvio are a research and development consultancy, with expertise in the field of civil engineering. They were commissioned by IÉ to undertake a study involving the creation of a dynamic structural model so that simulations of collapse involving wind load estimations, static and dynamic load testing could be undertaken. In addition to this a review of the canopy design against the current Wind Code (I.S.EN 1991:1-4:2005) was also undertaken. The subsequent report 'Structural dynamics and wind loading study to determine collapse mechanism' was published in June 2014 and shall be referred to as the Fluvio Report for the remainder of this report.

Roles involved in the accident

24 The roles involved in the accident are as follows:

- Station Manager – responsible for the day-to-day management of the safety of passengers and staff at stations within the station building concourse and on platforms;
- B&F Manager – responsible for all aspects of the management of maintenance and repair activities within a number of CCE Locations. The B&F Manager is accountable for the aspects of occupational safety and safety of buildings and facilities. This includes working with the

B&F Maintenance Managers to implement the appropriate periodic inspection and maintenance plans. The B&F Manager is responsible for ensuring issues raised from these inspections in the relevant risk register. There is also a number of responsibilities specifically related to stations, for example platform markings, repairs and all safety-related essential system certifications and compliance with all safety signage;

- B&F Maintenance Manager – responsible for all aspects of the management of maintenance and repair activities within a CCE Location. The B&F Maintenance Manager is accountable for the aspects of Occupational Safety and Safety of Buildings & Facilities;
- B&F Technical Executive – reports to the B&F maintenance manager and undertakes a range of duties including inspection of B&F assets.

External Circumstances

Weather

25 An estimate of the weather conditions in the vicinity of Kent Station at approximately 15:00 hrs on the 18th December 2013 was obtained from Met Éireann and is shown in Figure 8.

Weather	Cloudy with spells of heavy rain, clearing by 15:30 hrs approximately
Temperature	10-12 degrees Celsius, falling to 7 or 8 degrees by 15:30 hrs
Wind	Gale force southerly winds with severe gusts, 60 – 75 kilometre per hour (km/h) (16.7 m/s – 20.8 m/s) gusting 100 – 115 km/h (27.8 m/s – 31.9 m/s), veering southwesterly and decreasing fresh to strong 35-45 km/h (9.7 m/s – 12.5 m/s) by 15:30 hrs approximately.
Visibility	Moderate in rain becoming good, 2-5 km becoming 10 km or more

Figure 8 – Estimate of weather conditions for Kent Station at approximately 15:00 hrs

26 Data was also available of the recorded weather conditions at both Cork Airport (which is approximately 6 km away from Kent Station in a southwesterly direction) and Roches Point (which is approximately 16 km away from Kent Station in a South-Easterly direction). This showed that the mean speed at these locations was 70 km/h (19.4 m/s), the highest gust was 107 km/h (29.7 m/s) and the highest wind speed was 80 km/h (22.2 m/s). Rainfall between 15:00 hrs and 16:00 hrs was measured at 7.2 millimetres (mm) at both of these stations which was 61% of the rainfall for the day.

27 Persons in the vicinity at the time of the accident identified that weather conditions prior to the accident included high winds and heavy rain. These weather conditions increased in intensity in the minutes immediately prior to the accident with the rain being described as “horizontal”.

28 This is supported by CCTV for the area near the accident which shows consistent rain in the area increased in intensity at approximately 15:01 hrs with persistent heavy rain and gusts of wind of sufficient force to move debris. An illustration of this is shown in Figure 9 which shows the CCTV from the locomotive shed, wood and other debris can be seen being carried by the wind.

Figure 9 – CCTV from locomotive shed near the location of the accident

RAIU Investigation

RAIU decision to investigate

29 In accordance with the Railway Safety Act 2005 the RAIU investigate all serious accidents. Under slightly different conditions, this accident may have led to a serious accident where there would have been potential for fatalities, multiple serious injuries and extensive damage. Due to the movement of passengers immediately prior to the canopy collapse there was potential for fatalities and other possible consequences, therefore the RAIU made the decision to investigate this accident.

Scope of investigation

30 The RAIU must establish the scope of the investigation to ensure that only pertinent information is recovered and reviewed. Therefore, for this accident, the RAIU have defined the following scope:

- Establish the sequence of events;
- Establish the immediate cause, root causes, contributory factors and underlying causes;
- Examine the relevant elements of the safety management system (SMS);
- Examine any other significant safety deficiencies identified as a result of this investigation.

Investigation and evidence

31 The RAIU was notified of the accident at 15:25 hrs on the 18th December 2013 and immediately mobilised to the site of the accident to conduct an on-site investigation. During the on-site and off-site investigation the RAIU collated and logged the following evidence:

- Photographic record of accident site;
- In-situ surveys for positioning of structure and resultant debris;
- Witness testimonies from parties involved in the accident;
- Other testimonies from members of the IM with information pertaining to the accident;
- Inspection and maintenance records for inspections carried out on the structure;
- Elements of the CCE SMS;
- IM standards, procedures and other documentation;
- Standards, procedures and documentation from other relevant bodies;
- The Fluvio Report.

Evidence

Canopy over Platforms 1 and 2

General description

32 The canopy was approximately 156.5 m long consisting of a timber roof *cantilevered* over Platforms 1 and 2 which was supported through the centre by a single row of 17 cast-iron columns which were 2.74 m in height. These columns were approximately 10 m apart and braced longitudinally by lattice girders (See Figure 10).

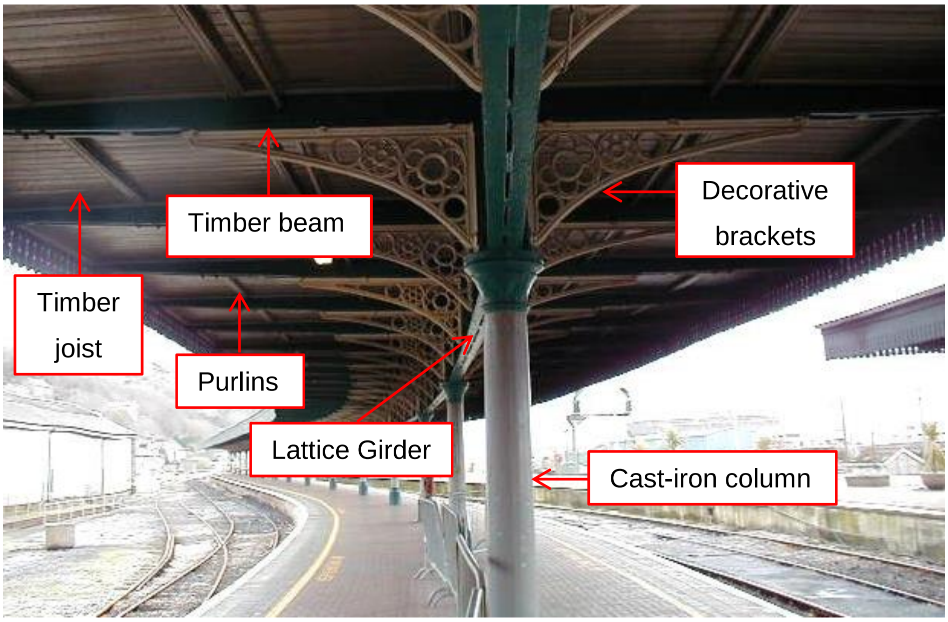


Figure 10 – Canopy above Platforms 1 and 2

33 Each column was hollow which allowed for the passage of water through them into the drainage system 0.43 m below platform level. The columns were connected to the drainage system by a cast-iron hopper.

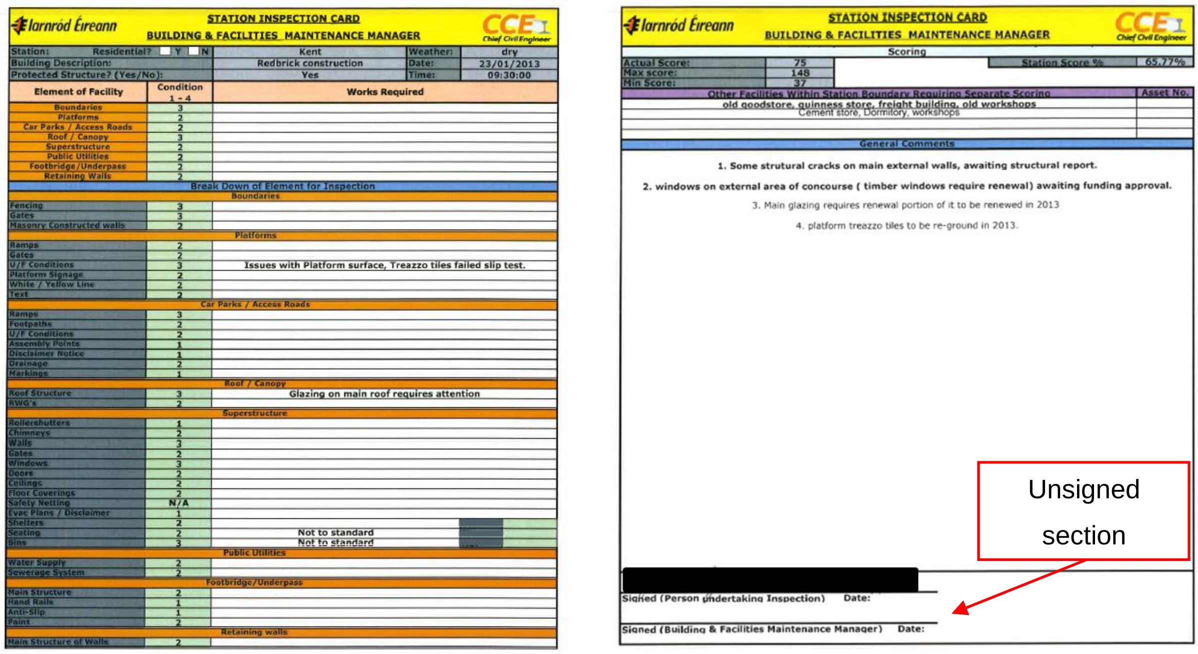
34 The roof structure consisted of a tapered timber balanced cantilevered beam 0.25 m thick that spanned 3.96 m each side. This beam was connected to the column head by a decorative column brace of cast-iron, which supported the cantilever over a length of 1.58 m each side. The canopy roof construction included some small decorative metalwork angles as brackets; however, the majority of the elements were timber joists, boards and *purlins* with zinc covering to the boarding.

35 The single column cantilevered arrangement of the canopy over Platforms 1 and 2 differed from the double column non-cantilevered arrangement of the Canopy over Platforms 3 and 4 which experienced minor damage during the accident.

Inspection procedures

36 At the time of the accident the inspection requirements for this type of structure were prescribed in I-FBD-8100, ‘Guidance on the Condition Surveys of Iarnród Éireann Property within the Operational Boundary’ and CCE-SMS-001, ‘CCE Safety Management System’.

37 I-FBD-8100 requires B&F staff to arrange for a surveyor to undertake an inspection of an asset and sets the parameters for this work with documented forms to complete. This standard was introduced on the 23rd December 2004. However, as of July 2010 no inspections had been carried out. A review of this standard commenced in late 2010 by B&F management personnel and a new ‘Annual Inspection Card’ was created and implemented within the B&F Department to establish the condition of their assets (see Figure 11).



Iarnród Éireann — STATION INSPECTION CARD — BUILDING & FACILITIES MAINTENANCE MANAGER — CCE Chief Civil Engineer

Station: Residential? Y N	Kent	Weather:	dry
Building Description:	Redbrick construction	Date:	23/01/2013
Protected Structure? (Yes/No):	Yes	Time:	09:30:00

Element of Facility	Condition 1 - 4	Works Required
Boundaries	3	
Platforms	2	
Car Parks / Access Roads	2	
Roof / Canopy	3	
Superstructure	2	
Public Utilities	2	
Footbridge / Underpass	2	
Retaining Walls	2	
Break Down of Element for Inspection		
Boundaries		
Fencing	3	
Gates	3	
Masonry Constructed walls	2	
Platforms		
Ramps	2	
Gates	2	
U/F Conditions	3	Issues with Platform surface, Treazzo tiles failed slip test.
Platform Signage	2	
White / Yellow Line	2	
Text	2	
Car Parks / Access Roads		
Ramps	3	
Footpaths	2	
U/F Conditions	2	
Assembly Points	1	
Disclaimer Notice	1	
Drainage	2	
Markings	1	
Roof / Canopy		
Roof Structure	3	Glazing on main roof requires attention
RWG's	2	
Superstructure		
Rollershutters	1	
Chimneys	2	
Walls	3	
Gates	2	
Windows	3	
Doors	2	
Ceilings	2	
Floor Coverings	2	
Safety Netting	N/A	
Evac Plans / Disclaimer	1	
Shelters	2	
Seating	2	Not to standard
Bins	3	Not to standard
Public Utilities		
Water Supply	2	
Sewerage System	2	
Footbridge/Underpass		
Main Structure	2	
Hand Rails	1	
Anti-Slip	1	
Paint	2	
Retaining walls		
Main Structure of Walls	2	

Iarnród Éireann — STATION INSPECTION CARD — BUILDING & FACILITIES MAINTENANCE MANAGER — CCE Chief Civil Engineer

Scoring

Actual Score:	75	Station Score %	65.77%
Max score:	148		
Min Score:	37		

Other Facilities Within Station Boundary Requiring Separate Scoring	Asset No.
old goodstore, guinness store, freight building, old workshops	
Cement store, Dormitory, workshops	

General Comments

1. Some strutural cracks on main external walls, awaiting structural report.
2. windows on external area of concourse (timber windows require renewal) awaiting funding approval.
3. Main glazing requires renewal portion of it to be renewed in 2013
4. platform treazzo tiles to be re-ground in 2013.

[redacted]
Signed (Person undertaking Inspection) Date:
Signed (Building & Facilities Maintenance Manager) Date:

Figure 11 – Annual inspection card

38 These B&F Annual Inspections are visual inspections undertaken by the B&F Maintenance Manager or the Technical Executive. Staff undertaking these inspections were required to have a minimum of Civil Engineering/Architectural or Building Surveying Diploma.

39 The B&F Annual Inspection was carried out for Kent Station (which included the roof / canopy structures) in 2011, 2012 and 2013. The assets were given a score based on their condition from one to four (one being very good and four being poor). Figure 12 shows the scores and comments recorded in these inspections.

Date of inspection	Condition 1 – 4	Works Required
23/01/2013	3	Glazing on main roof requires attention
20/01/2012	3	Glazing on main roof requires attention
22/04/2011	4	Main canopy roof, works planned to be carried out 2011

Figure 12 – Details from inspection card 2011 – 2013

40 The "Works Required" comments given in Figure 12 show that although the general scores were high regarding the condition of the roof and canopy structures this was due to issues relating to the main canopy. Whereas no defects were identified on the canopy over Platforms 1 and 2.

41 The forms for Cork Kent supplied to the RAIU did not have the appropriate signature from the B&F Maintenance Manager with this area left blank as shown in Figure 11. Additional samples submitted to the RAIU for different locations were also missing this signature and the signature of the person undertaking the inspection.

<u>Structural inspections</u>

42 Prior to 5th July 2010 the requirements for structural inspection of station canopies were prescribed in I-STR-6510 'Structural Inspections' originally produced in 2005 and then revised in 2008 and 2009.

43 The inspection requirements with regards to station canopies in each of the standards are shown in Figure 13.

Version	Operational date	Inspection requirement for station canopies
1	5th July 2005	Ground Level Inspection (GLI) – carried out on five year cycle;
2	23rd October 2008	Ground Level Inspection (GLI) – carried out on five year cycle; Subject to thorough inspections as required.
3	1st October 2009	General Engineering Inspection (GEI) – Max interval every five years; GEI including Additional Examination Measures – As required.

Figure 13 – Historical inspection requirements of I-STR-6510

44 Figure 13 shows the requirement for a GLI or GEI at least every five years. These inspections are carried out by completing the buildings inspection card in the appendix of the appropriate standard. Figure 14 shows the buildings inspection card for station canopies prescribed in the third version of I-STR-6510.

Iarnród Éireann Structural Inspections

Iarnród Éireann CCE Department
Buildings Inspection Card
(Page 2 of 2)

Location		**Line**		**Up or Down**	
Building		**Type of Inspection**			

Description of Structure: ______
Photograph Ref: ______
Usage: ______ No of Floors: ______ Form of Construction: ______ Services Present: ______
Access Arrangements: ______ Weather Conditions: ______

Location	**Materials**				**Additional Components**					**Apparent Distress**									
	Reinforced Concrete	Structural Steel	Masonry	Timber Framed	Fixtures/Fittings	Finishes	Services	Drainage	Fire Protection	Rotation	Settlement	Deflection	Buckling	Spalling	Cracking	Corrosion	Insect Attack	Rot	Water Staining

G = Good R = Requires repair E = Element requires further examination (e.g. opening up)

DATE	**NOTES**	**D[1]**	**C[2]**	**D[3]**	**AEM[4] req'd**	**Inspected by**	**Approved by**

[1]Design Rating [2]Condition Rating [3]Deterioration Rating
[4]Additional Examination Measures Required? Indicate Yes or No

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Figure 14- Inspection card from I-STR-6510

45 This version of the standard requires both an examination of the separate elements of the structure but also defined scores with regards to design, condition and any deterioration. It can also be observed from Figure 14 that cast-iron is not identified in the materials section of the form.

46 I-STR-6510 was withdrawn from operation in July 2010. There were no records of the Structural Inspections detailed in any version of I-STR-6510 being undertaken on the canopy over Platform 1 and 2. There was also no other evidence of an earlier Structural Inspection being undertaken on this asset prior to July 2010.

47 From the 5th July 2010 CCE-SMS-001 was made operational. Sections 3.4.1.2 and 3.4.1.3 of this standard places the following requirements on the B&F Manager:

- Doing ten-yearly structural assessments of all those Building and Facilities assets and addressing any structural Safety issues that are found, and for;
- Maintaining a live Buildings and Facilities “B&F Structural Risk Register” per CCE Location, in accordance with CCE Safety Management Standard CCE-SMS-006 – “Hazards and Risk Assessments”, to identify, record, track, resolve and mitigate any structural Hazards or Structural Risks.

48 In 2012 the ten-yearly Structural Inspection regime identified in CCE-SMS-001 was implemented for B&F assets. Structural Inspections were being undertaken as a part of a risk based regime

over the ten years identified in CCE-SMS-001. Structures were prioritised using the findings recorded in the relevant Annual Inspection Cards detailed in paragraph 38. 225 assets were identified at the time of the accident, of these forty had received a full Structural Inspections.

49 In addition to this from 2011 thirty-eight assets received a structural inspection on an element of them as potential issues identified from the Annual Inspection Cards.

50 The Structural Inspections were undertaken by suitably qualified members of the CCE department, for example the New Works, or external consultants.

51 A Structural Inspection of Kent Station (which would include the canopy over Platforms 1 and 2 was initially planned for 2012. This inspection was due to be undertaken by New Works personnel on the 10th January 2013 and should have entailed a visual examination of all visible and inspectable parts of all of the B&F assets (e.g. which would include the canopy). Due to resource availability in New Works only some of the B&F assets were structurally inspected on the 10th January 2013. The canopy over Platform 1 and 2 was not inspected at this time, with no return date scheduled for the inspection of the remainder of the B&F assets. Therefore, at the time of the accident a Structural Inspection of the canopy over Platform 1 & 2 had not taken place.

Maintenance and risk management

52 Maintenance that had been undertaken on the structure in the last ten years included the repainting of the main support columns, roof trusses, timber decking of canopy roof and valance fascia in 2006 and cyclical drainage clearing which had been executed since 2011. In 2013 the canopy drainage was cleared on the 4th March and the 28th July.

53 The B&F Structural Risk Register, at the time of the accident, did not include any risks associated with the canopy over Platforms 1 and 2. This may have been as a result of no Structural Inspection being undertaken, or due to the fact that there were no obvious structural defects identified prior to the collapse of the structure. The B&F Annual Inspections had not identified any defects with the canopy; and there was also no record of any structural faults in the assets operational life of over a hundred years.

54 The canopy over Platforms 1 and 2 was on the B&F Risk register as a possible fire hazard in relation to canopy overhang and train carriage interface requiring a response in the event of high temperatures and a cooling down of the canopy felt. This occurred on the 15th & 16th July 2013.

Post accident inspection

55 The initial site inspection identified that all of the seventeen supporting columns of the canopy over Platforms 1 and 2 had failed.

56 The canopy itself had been displaced to varying degrees to the north away from its original position. A number of wooden panels and related debris had further displaced in a northern direction spreading into an adjacent car park.

Metallurgical inspection

57 For the purpose of this report the columns of the canopy are numbered from one to seventeen starting at the station building end of the platform, see Figure 15.

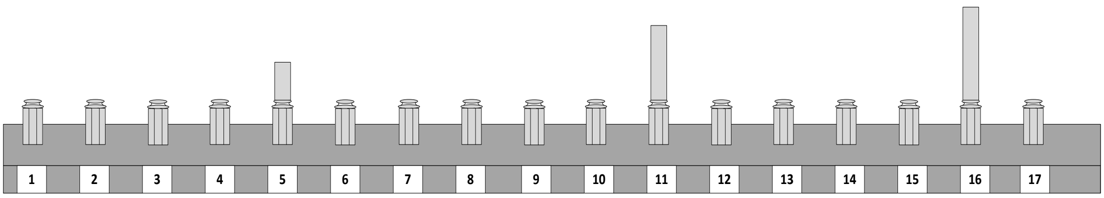

Figure 15 – Schematic of supporting columns post-accident

58 Fourteen out of seventeen of the columns failed at a circular feature in the lower part of each column also shown in Figures 15, 16 and 17. This feature acted as a decorative transition between the octangular base section and the narrow tubular section.

Figure 16 – Point of failure at decorative feature

Figure 17 – View of collapsed canopy

59 The decorative feature was comprised of an upper and lower ring structure with an intervening concave groove. A sharp radius marked the transition between the rings and the concave section (Figure 16). Sharp radii such as these are known as stress raisers.

60 Examination of the fracture faces showed that they exhibited brittle fracture patterns with no apparent *plastic deformation*. The fracture faces for the columns that failed in this area were essentially flat, which is indicative of *brittle overload* consistent with the application of the maximum tensile stress. With a brittle fracture, crack propagation is very fast with the crack propagating almost perpendicular to the direction of applied stress. In addition to this no evidence of pre-existing cracks was observed in any of the columns.

61 A layer of corrosion was observed through the centre of each column created by the water flowing through this area and column seventeen also contained sediment indicating a blockage in the drainage. However, there was no evidence of corrosion cracking in any of the columns.

62 Measurements were taken on a number of the columns which identified that the wall thickness varied through each individual column and also between columns. Values ranged between approximately 17.8 mm to 36.9 mm.

63 The variation in each individual column is probably due to the original manufacturing technique. As the columns were cast horizontally, the molten cast-iron moves the core liner within the mould. As the core liner is less dense than iron and therefore it tends to float between the internal restraints in the mould. This results in a thinner section to the upper part of the column wall.

64 Measured values for the column thickness were also affected by the width of the internal layer of corrosion within each column.

65 Columns five, eleven and sixteen did not fail at the decorative feature at the base of the column. All three failed at different heights. Column eleven failed a similar decorative feature near the top of the column. Whereas columns five (Figure 18) and sixteen failed nearer the middle of the columns. Both of these columns demonstrated *porosity* in the fracture surface which may have weakened the columns at these points (Figure 19). Porosity in the column would again be due to inconsistencies within the original manufacturing techniques.

Figure 18 – Column five

Figure 19 – Areas of porosity in column 16

Calculation and modelling of failure mode

FE modelling of column

66 As discussed previously independent experts were commissioned by IÉ to examine this event. This work predominately involved calculation of structural dynamics and a wind loading study. This work is detailed in this section.

67 A *Finite Element* (FE) model was created for the circular decorative feature (Figure 20) which was identified as a stress raiser in the post accident analysis. A *pure uniaxial stress* field of a 100 Mega Pascal (MPa), was applied to the column cross-section and a linear analysis was carried out. Figure 21 presents the axial stress distribution on the section showing the area of high stress.

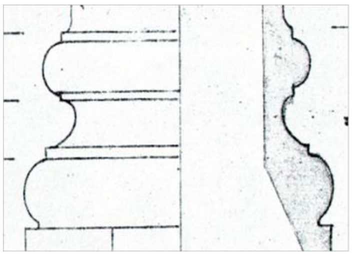

Figure 20 – Decorative feature near base of column
Fluvio (2014)

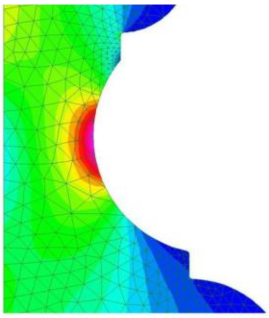

Figure 21 – Area of stress concentration
Fluvio (2014)

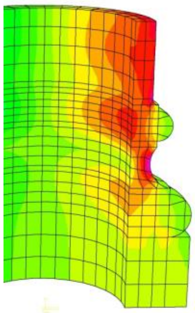

Figure 22 – 3D FE model of stress concentration
Fluvio (2014)

68 The area shown in red and pink illustrates where the maximum tensile stress of 191 MPa occurred. Due to the field of 100 MPa being applied this means that a stress concentration factor of 1.9 applies in this area. Using simple *beam theory* the moment capacity of the column was calculated as 161 kilo newton metre (kNm). Therefore the net effect of this feature is that the moment capacity of the section was reduced by this factor (1.9) from 161 kNm to 85 kNm.

69 To further confirm the capacity of the column section at the base, a 3D FE model developed as shown in Figure 22. From this analysis, the moment capacity was confirmed as 85 kNm. From this analysis it was also deduced that a rotation occurred at this moment. This was later used in the development of the full 3D model of the canopy.

FE modelling of canopy

70 A single bay of the canopy was created by Fluvio using FE modelling as shown in Figure 23. This element was then used to create a model of the entire structure.

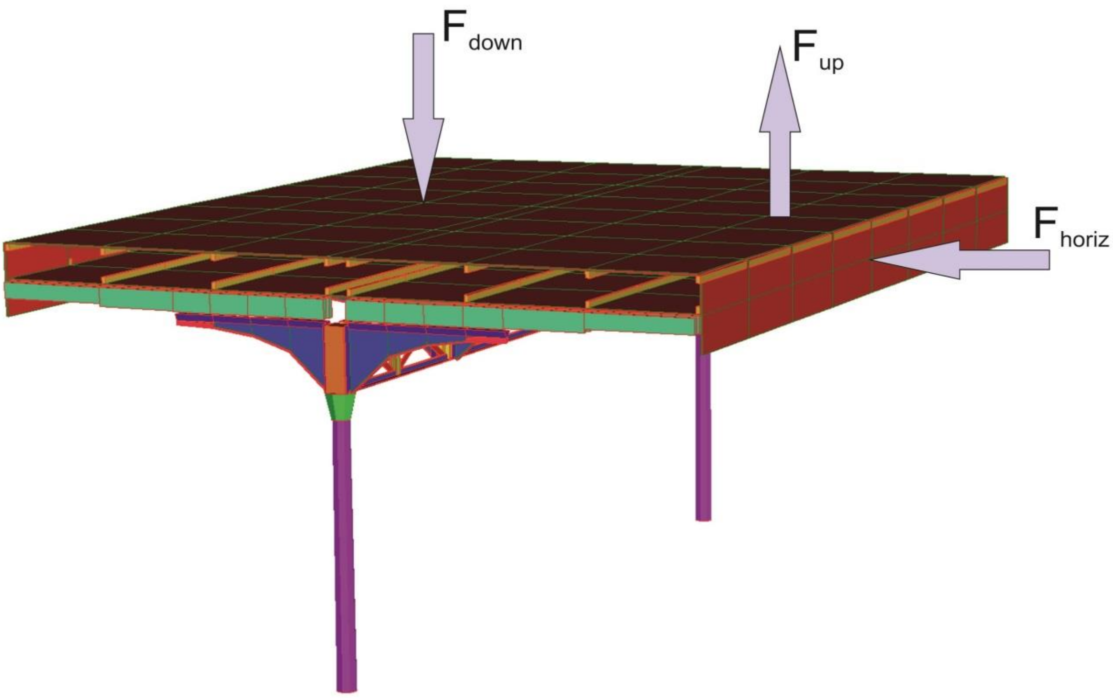

Figure 23 – Single bay used for FE analysis, Fluvio (2014)

71 A nominal pressure distribution was applied to the plate elements modelling the upper skin of the timber roof (F_{up} and F_{down}) and the plate element modelling the vertical timber sheeting were also subject to a uniform loading ($F_{horizontal}$). This wind pressure was ramped at a rate of 300 MPa/s until the structure collapsed fully.

72 The model was run for 4 s in total with time step intervals every 0.05 s. Data shows that the first column fails at 1.84 s and then the columns fail sequentially from the far end of the platform in the space of 0.80 s.

73 Figure 24 shows five images which best represent the displacement response of the canopy (Figure 24 has the columns numbered 1 – 17, from left to right, as illustrated in Figure 24A).

- At 0.02 s the canopy is in its equilibrium state (Figure 24 A);
- At 1.84 s the first column fails (Figure 24 B);
- At 2.64 s the last column fails (Figure 24 C);
- At 3.48 s the north-eastern corner of the canopy impacts the ground (Figure 24 D);
- At 3.80s more of the structure impacts the ground as the time progresses (Figure 24 E).

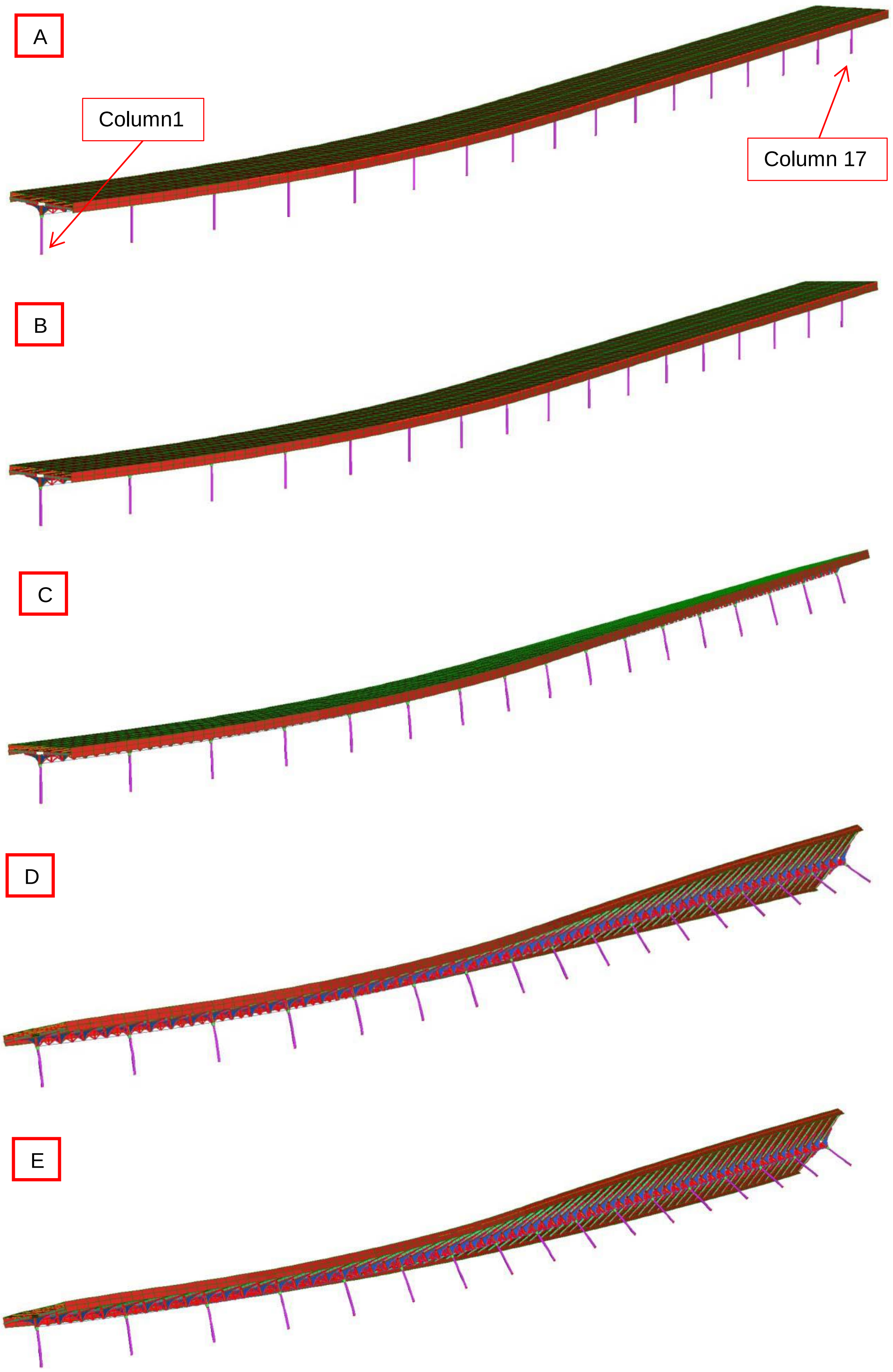

Figure 24 – Selected moments from simulation of canopy collapse, Fluvio (2014)

74 From the FE model a wind speed of 38.9 m/s was calculated. To account for the variability of the cast-iron material and compute a credible possible maximum wind speed that would be necessary to cause collapse, the maximum credible flexural stress (195 MPa) in cast-iron was used to scale up the computed collapse wind speed. The model now produced a wind speed of 50 m/s.

75 The other structural response that is of interest is the displacement at the column head when the first column fails. From the analysis it was found that the maximum lateral displacement at the top of a column at the point of failure was 94 mm. Taken in the context of a 2.4 m high column, this represents a span / deflection ratio of 25. This means that a vibration could be visible to the naked eye but would not be alarming in a structure of this scale. A static deflection of this magnitude would not be noticeable.

76 At the time of the last column failing, the most eastern column, i.e. the first column to fail, had displaced over 1m. At this stage progressive collapse had been initiated. This result ties in with the eye-witness accounts that indicated that the canopy collapsed progressively from the far end of the platform.

Calculation using Wind Code and its National Annex: 2103

77 Computation of the wind speed required to induce failure loading in the structure was undertaken using the Wind Code, its National Annex: 2103 and a paper by Rani et al (2013) regarding wind tunnel tests on rectangular flat panel roofs and generated pressure coefficient contours for varying wind directions. This work produced an equation from which MS Excel was used to compute a value of the mean speed. It was computed that a mean speed of 26.9 m/s with a peak speed of 45 m/s was required to induce failure. It is important to note that these speeds are conservative, as they are based on the code of practice for design.

78 IÉ also commissioned Fluvio to undertake a review of the canopy design to current design Wind Code (I.S.EN 1991:1-4:2005). The subsequent report identified that the design moment due to wind loading for a new build structure was calculated to be 177 kNm. Therefore the canopy did not satisfy modern design requirements, either from the point of view of adequate factors of safety or the material choice for the primary structural members. The report also stated that the structure was constructed in the late 1800s and its adherence to the current Eurocode design is not expected.

Historical weather

79 Hourly wind speed data was also analysed by Fluvio to determine the annual maxima and show these as a time series values (Figure 25). The highest recorded hourly annual maximum in the 52 year period for Cork Airport was 28.8 m/s in 1974. By comparison the highest hourly wind speed recorded in 2013 was 18.6 m/s.

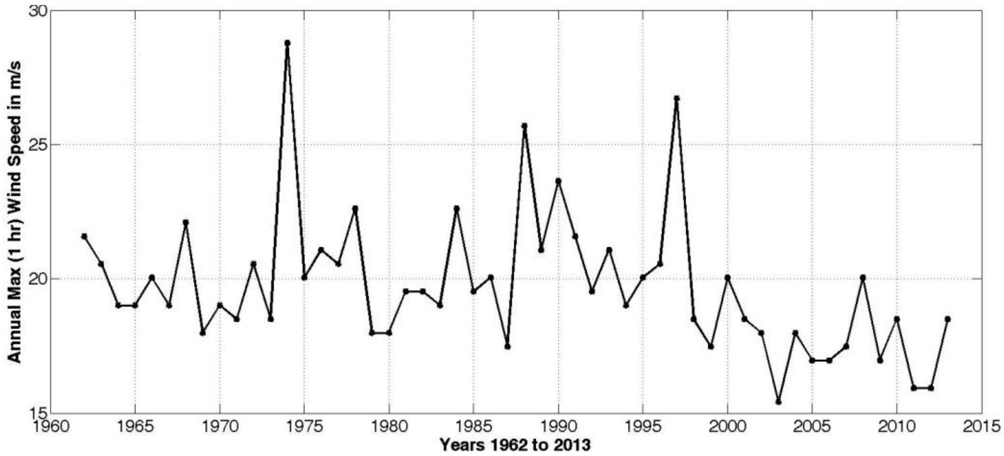

Figure 25 – Annual Maximum (1 hour) wind speed at Cork airport 1962 to 2013, Fluvio (2014)

80 The 3 second wind gust speed was also analysed relative to the hourly wind speed to show the relationship. This analysis calculated the 3 second gust, over this period, was close to 1.75 times that of the hourly wind speed.

81 On December 18th 2013, the hourly wind was recorded as 13.4 m/s with a peak gust of 30.8 m/s giving a much higher gust factor than normal of 2.3.

82 The annual maximum (1 hr) data was analysed to determine the wind speeds for different return periods. The results of this analysis are shown in Figure 26 and give return periods of 5 year, 30 year, 50 year and 100 year.

Return Period Years	Hourly Wind Speed m/s	3 second Gust Speed m/s
5	21.3	37.3
30	26.5	46.4
50	29.0	50.8
100	33.5	58.6
Cork Airport 18th December 2013	13.4	30.8

Figure 26 – Return period analysis of the annual maximum (1 hourly) wind speed at Cork Airport 1962 – 2013, Fluvio (2014)

Weather management IÉ

83 IÉ received seven weather warnings from Met Éireann on the 18th September 2014 prior to the accident. These included warnings of severe southwest winds in Connaght, Donegal, West Ulster, Cavan, Roscommon, Clare, Galway, Leitrim, Mayo and Sligo. The winds were predicted to be strongest in exposed coastal areas with Connaght and West Ulster forecast to forecast damaging gusts of 120 km/h to 150 km/h. The warnings stated that it would be very windy through the rest of the country with very strong and blustery south veering southwest winds and gust of 90 km/h to 110 km/h.

84 The IÉ Weather Management Protocol – Central Traffic Control (CTC) for 2013 was approved by both the Head of Operations and Engineering departments in November 2012. This document is a CTC document, with one of its chief aims being "to reduce the impact of poor weather on our services and mitigate any delays our customers may encounter as a result".

85 In the event of high winds this protocol identifies the need for a conference call to take place between Operations and CCE departments to decide on the appropriate course of action. This may include following responses: (list not exhaustive)

- The need for proving trains;
- Impose a TSR in the affected area;
- 'At Risk' trees near the line to be checked;
- CCE personnel travel on proving train or first service train;
- Caution first services;
- A mixture of the responses above.

86 On the 18th December 2013 IÉ took the following actions across the network to mitigate the effects of the adverse weather conditions:

- *Temporary speed restrictions* were placed on a number of track sections, as the adverse weather pattern moved throughout the country. Sections restricted included the Mallow to Cork line;
- Significant tree cutting activities were carried out throughout the network at the affected areas;
- Staff were deployed throughout the network at affected areas watching for vulnerabilities as the weather pattern moved throughout the country;
- Route proving exercises were undertaken.

87 These actions primarily focus on the safe running of trains and actions to be taken to prevent delays due to poor weather.

88 IÉ CCE at the time of the accident did not have a weather management protocol. However, there was a B&F Structural Risk Register in place which identified two structures requiring actions in the event of high winds or similar adverse weather conditions. No actions were taken to protect the canopy structure at Kent Station as it was not identified on the Structural Risk Register and not seen as vulnerable in high winds.

Events before the accident

89 From approximately 14:15 hrs on the 18th December 2014 the weather in the vicinity of Kent Station, Cork, became cloudy with spells of wind and rain. The rain became persistently heavy from approximately 14:40 hrs.

90 At 14:54 hrs Train D247 arrived from Cobh onto Platform 2. Passengers alighted the train and passed through the station concourse. Passengers travelling to Cobh on the 15:00 hrs service left the concourse and boarded the train. Three people were left on Platforms 1 and 2 waiting for the 14:45 hrs service from Midleton which was due to arrive at the station at 15:08 hrs.

91 At 15:01 hrs Train D247 to Cobh was dispatched from Platform 2. The wind and the rain increased in intensity and a section of roof felt was carried by the wind from the canopy over Platform 4 onto the ground beside Platform 2.

Events during the accident

92 Exposed to the intense weather conditions at 15:02 hrs the canopy started to sway and the supporting columns began to fall at the end of the platform furthest from the concourse.

93 Sequentially the columns fell and this results in the canopy collapsing.

94 As the structure fell a section struck one of the people on the platform in the back knocking them to the ground.

Events after the accident

95 At 15:03 hrs IÉ station staff escorted the three individuals from Platforms 1 and 2 into the station concourse, and the emergency services were called.

96 At approximately the same time the Station Manager activated the station LEP and with the assistance of other IÉ staff the station was evacuated.

97 Staff in the signal cabin stated they believed the signal cabin to be swaying due to the high wind and made arrangements were to close the cabin at 15:03 hrs. All train movements in and out of the station were terminated.

98 At approximately 15:09 hrs the emergency services arrived on site.

Similar occurrences

99 There is no record of an event where a similar structure has collapsed during high winds on the IÉ network.

Analysis

Canopy over Platforms 1 and 2

General

100 Cast-iron was used to fabricate the supporting columns and was a common construction material in the late 1800s (paragraph 32). By its very nature cast-iron is a brittle material, offering no ductile behaviour that could give warning of imminent failure. This characteristic means that cast-iron is designed predominately to act in compression not tension.

101 Each column contained a decorative detail at the base which consisted of two rings and a concave section. These features act as stress raisers within each column as tension was applied (paragraphs 58).

102 The columns capacities are under designed with respect to modern codes of practice. The columns have a capacity of 85 kNm (paragraph 68) and the design moment due to wind loading is 177 kNm (paragraph 78).

Inspection and maintenance

103 There was no evidence of any inspections being undertaken in accordance with IÉ standards I-FBD-8100 or the superseded standard I-STR-6510 on any B&F assets (paragraph 37).

104 Changes to the inspection regime introduced in 2010 meant that all registered B&F assets received a visual B&F Annual Inspection using a prescribed template from 2011 (paragraph 37). From these inspections B&F personnel produced a Structural Inspection regime which began in 2012 (paragraph 48).

105 B&F Annual Inspections of the canopy over Platforms 1 and 2 were undertaken in 2011, 2012 and 2013. No defects were identified with the structure during these inspections (paragraphs 39 and 40).

106 The Annual Inspections undertaken for Cork Kent did not contain the required signature from the B&F Maintenance Manager. Samples of other Annual Inspection, reviewed by the RAIU, also did not contain the signature of the person undertaking the inspection (paragraph 41), indicating that this is a consistent issue.

107 A Structural Inspection of the canopy over Platforms 1 and 2 was planned for 2012. However, the inspection was not done at this time. There was also no other evidence of an earlier structural inspection being undertaken on this asset (paragraph 51).

108 Maintenance that had been undertaken on the structure in the last ten years included the repainting in 2006 and cyclical drainage clearing which had been executed since 2011. (paragraph 52).

109 Due to no structural issues being identified the canopy was not entered onto the live B&F Structural Risk Register (paragraph 53).

Post accident inspection

110 Fourteen out of seventeen of the columns failed at a circular feature in the lower part of each column which acted as a stress raiser (paragraphs 58 and 59).

111 The fracture faces for the columns that failed in this area were essentially flat, which is indicative of brittle overload consistent with the application of the maximum tensile stress. The fracture patterns are also indicative of a rapid failure in the direction of the applied stress (paragraph 60)

112 There was no evidence of pre-existing cracks observed in any of the columns during the metallurgical inspection (paragraph 60).

113 A layer of corrosion was observed through the centre of each column. However, there was no evidence of corrosion cracking in any of the columns (paragraph 61).

114 Inconsistencies with the original manufacturing techniques are the most probable reason for the variations in wall thickness through each individual column and the porosity identified in columns five and sixteen. These inconsistencies may have also affected the tensile strength of the columns in localised areas (paragraph 64 and 65).

Calculation and modelling of failure mode

115 The decorative detail at the base of the column substantially reduced the cast-iron column's moment capacity by 47% (paragraph 68).

116 Using a FE modelling in a reverse engineering process, it was identified that a peak wind speed of between 39 m/s and 50 m/s, would have initiated the collapse (paragraph 74). In addition to this calculations based on the current Wind Code (I.S.EN 1991:1-4:2005) show that a mean wind speed of 27 m/s with a peak speed of 45 m/s could have initiated the collapse (paragraph 77).

117 A three second gust of 50 m/s has a return period of approximately 50 years (paragraph 82). The analysis is based on wind velocities perpendicular to the canopy. From calculations, if the wind speed was not perpendicular to the canopy (i.e. less than 90° to the canopy) the return period would be between 50 and 100 years. It is not possible to give an exact return period for the storm event due to the lack of local wind data. However work undertaken by independent experts stated that the wind velocities which caused collapse were associated with a rare event.

118 The model showed that at the time of the last column failing, the most eastern column, i.e. the first column to fail, had displaced over 1m. At this stage progressive collapse had been initiated. This result corroborates in with the eye-witness accounts that indicated that the canopy collapsed progressively from the far end of the (paragraph 76).

Weather

119 Witness and CCTV footage identified that the persistent wind and rain present in the vicinity of Kent Station significantly increased in intensity immediately prior to the canopy collapsing. Gusts of wind can be observed moving felt from the roof of Platform 4 and debris in front of the locomotive shed near the station (paragraphs 27 and 28).

120 Data received from Met Éireann shows that the estimate for weather conditions in the area states gale force southerly winds with severe gusts, 60 – 75 km/h (16.7 m/s – 20.8 m/s) gusting 100 – 115 km/h (27.8 m/s – 31.9 m/s), veering southwesterly and decreasing fresh to strong 35-45 km/h (9.7m/s – 12.5 m/s) by 15:30 hrs approximately (Paragraph 25).

121 Significant damage was observed to the local area with building roofs, signage boards and the perimeter wall of Kent Station all being affected (paragraph 21).

122 Examination of the historical data shows that the gusting factor 2.3 recorded on the day would be higher than what would be predicted. In addition to this winds in excess of 46.4 m/s and 50.8 m/s would be classed as a 30 and 50 year event, respectively (paragraph 82).

Weather management IÉ

123 IÉ received seven weather warnings from Met Éireann on the 18th December 2014 prior to the accident with severe winds being forecast. IÉ took a number of actions in accordance with the CTC weather management protocol to mitigate the risk of the adverse weather conditions (paragraph 83 and 84).

124 IÉ CCE did not have a similar weather management protocol in place. However, there was a B&F Structural Risk Register in place which identified a number of structures requiring actions in the

event of high winds or similar adverse weather conditions. This did not include the canopy at Kent station (paragraph 88).

Conclusions

Canopy over Platforms 1 and 2

Design and manufacture

125 Cast-iron is known to be a brittle material that is weak in tension. The design of the structure meant that is was susceptible to sudden failure when exposed to tensile stress (paragraph 100).

126 Inherent stress raisers were incorporated in the original design through decorative features at the base of the column. These features reduced the moment capacity of the section by 47% (paragraph 101).

127 Inconsistencies with the original manufacturing techniques led to porosity defects and variations in wall thickness in a number of columns (paragraph 114).

Inspection and maintenance

128 There was no evidence of any inspections being undertaken in accordance with IÉ standards I-FBD-8100 or I-STR-6510 on any B&F assets. However, B&F Annual Inspections had taken place since 2011 and no defects had been identified with the any of columns (paragraph 103 and 105).

129 B&F Annual Inspection Cards submitted to the RAIU did not contain the required signatures (paragraph 106).

Weather management

130 IÉ received seven weather warnings from Met Éireann on the 18th December 2014 prior to the accident with severe winds being forecast. IÉ took a number of actions throughout the network to mitigate the risk of the adverse weather conditions in accordance with the CTC weather management protocol. CCE did not have a similar protocol in place however B&F assets requiring actions in the event of high winds or similar adverse weather conditions were identified in the B&F Structural Risk Register (paragraph 124).

Weather and failure mechanism

131 Data received from Met Éireann shows that the estimate for weather conditions in the area states gale force southerly winds with severe gusts, 60 – 75 km/h (16.7 m/s – 20.8 m/s) gusting 100 – 115 km/h (27.8 m/s – 31.9 m/s), veering southwesterly and decreasing fresh to strong 35-45 km/h (9.7m/s – 12.5 m/s) by 15:30 hrs approximately (paragraph 120).

132 FE modelling in a reverse engineering process undertaken by independent experts concluded that a peak wind speed of between 39 m/s and 50 m/s combined with the cast-iron column low moment capacity, is a very likely cause of the collapse of the canopy. This is supported by calculations based on the current Wind Code show that a peak speed of 45 m/s could have initiated the collapse (paragraph 116).

133 Examination of the historical data shows that the gusting factor 2.3 recorded on the day would be higher than what would be predicted. In addition to this winds in excess of 46.4 m/s and 50.8 m/s would be classed as a 30 and 50 year event. It is not possible to give an exact return period for the storm event due to the lack of local wind data. However work undertaken by independent experts stated that the wind velocities which caused collapse were associated with a rare event (paragraph 117).

134 Fourteen out of seventeen of the columns failed at a circular feature in the lower part of each column which acted as a stress raiser. Examination of the fracture faces indicated a rapid brittle failure due to the application of the maximum tensile stress (paragraph 111).

135 There is no evidence to indicate that there were any pre-existing cracks in the canopy. Porosity was observed in two columns and this may have affected their failure mechanism. However, consistency in the failure mechanism of the other fifteen columns indicated that inherent weaknesses within the design of the canopy are far more likely to have contributed to the collapse of the structure.

Immediate cause, contributory factors and underlying causes

136 The immediate cause of the accident was a significant increase in wind speed leading to greater pressure acting on the canopy over Platforms 1 and 2 resulting in the rapid failure of the cast-iron columns.

137 CFs associated with the accident are as follows:

- CF-01 – The use of cast-iron and the decorative details in the column meant that the design of the structure contained inherent design weaknesses;
- CF-02 – Weather conditions in the vicinity of Kent Station included unusually high winds.

138 UCs associated to the accident are as follows:

- UC-01 – IÉ CCE did not have a weather management protocol in place which included actions to be taken to protect structures at risk from adverse weather conditions.

139 AOs associated to the accident are as follows:

- AO-01 – The canopy had not received an inspection that met the structural requirements of IÉ standards I-FBD-8100, CCE-SMS-001 or the superseded standard I-STR-6510. In addition to this a number of the Annual Inspections undertaken did not contain the required signatures.

Relevant actions taken or in progress

Actions taken by IÉ

140 At the time of publication of the this report IÉ have:

- A technical bulletin has been issued to all stakeholders on thresholds and guidelines as well as actions that may need to be undertaken in the event of adverse weather events, including for high winds;
- A review was undertaken of all canopies to see if there were similar structures on the network. One was found and a plan is in place for this structure;
- B&F assets potentially vulnerable to high wind events have been identified and placed on the relevant risk register with appropriate plans in place.

Safety recommendations

General description

141 In accordance with the Railway Safety Act 2005 (Government of Ireland, 2005a) and the European railway safety directive (European Union, 2004), recommendations are addressed to the national safety authority, the RSC. The recommendation is directed to the party identified in each recommendation.

142 As a result of the RAIU investigation three new safety recommendations are made, one relating to the accident and two relating to additional observations.

New safety recommendations related to the accident

143 The use of cast-iron material and the design of the decorative rings contributed to the failure of the canopy structure (CF-01), therefore the RAIU make the following safety recommendation:

IÉ IM should identify all cast-iron structures on the network. From this, a risk-based approach should be taken in relation to the inspection of these assets, during routine inspections, in terms of any risks associated with cast-iron.

144 At the time of the accident IÉ CCE did not have formalised procedures for managing the risks adverse effects high winds (UC-01), therefore the RAIU make the following safety recommendation

IÉ IM should establish a formalised procedure for managing the risk associated with the adverse effects of high winds.

New safety recommendations related to the additional observations

145 The canopy had not received an inspection that met the structural requirements of IÉ standards I-FBD-8100, CCE-SMS-001 or the superseded standard I-STR-6510 or. In addition to this a number of the Annual Inspections undertaken did not contain the required signatures (AO-01).

IÉ IM should review the structural and annual inspection regimes for B&F to ensure all assets are inspected in accordance with the prescribed standards and any associated documentation is completed appropriately.

Additional information

List of abbreviations

B&F	Building and Facilities
°C	Degrees Celcius
CCE	Chief Civil Engineers
CF	Causal factor
CoF	Contributory factor
CWR	Continuous Welded Rail
DMU	Diesel Multiple Unit
IAMS	Infrastructure Asset Management System
ICCN	Intercity and Commuter Network Department
IM	Infrastructure Manager
LEP	Local Emergency Plan
kg	Kilogram
km/h	Kilometres per hour
kN/m	Kilo newton per metre
MPa	Mega Pascal
MPa/s	Mega Pascal per second
m	Metre
m/s	Metres per second
mm	Millimetre
MP	Mile Post
No.	Number
RAIU	Railway Accident Investigation Unit
RSC	Railway Safety Commission
RU	Railway Undertaking
s	Second
SI Units	International System of Units
SMS	Safety Management System
TCB	Track Circuit Block
TSR	Temporary Speed Restriction
UC	Underlying cause

Glossary of terms

Accident	An unwanted or unintended sudden event or a specific chain of such events which have harmful consequences including collisions, derailments, level-crossing accidents, accidents to persons caused by rolling stock in motion, fires and others.
Causal factors	Any factor(s) necessary for an occurrence. Avoiding or eliminating any one of these factors would have prevented it happening.
Cantilever	A beam supported at one end.
Continuous welded rail	Sections of rail that are welded together.
Contributory factor	Factors relating to actions taken by persons involved or the condition of rolling stock or technical installations.
Elastic	Materials return to their original shape and position on release of applied stress.
Extensive damage	Damage that can be immediately assessed by the RAIU to cost at least €2,000,000 in total.
Immediate cause	The situation, event or behaviour that directly results in the occurrence.
Incident	Any occurrence, other than an accident or serious accident, associated with the operation of trains and affecting the safety of operation.
Infrastructure Asset Management System	Database in which details of IÉ assets (including level crossings) are recorded. It also encompasses a Condition Monitoring Module, a Fault Management System, Work Order Processing and a Geographical Information System.
Infrastructure Manager	Organisation that is responsible for the establishment and maintenance of railway infrastructure, including the management of infrastructure control and safety systems.
Lattice Girder	A support beam where the flanges are connected by a lattice web.
Temporary speed restriction	A speed restriction imposed, generally for a short time, usually as a result of engineering work, to guarantee the safe passage of trains.
Mile Post	A post used to denote a location on a railway line using miles from a fixed point known as the 0 milepost.
National safety authority	The national body entrusted with the tasks regarding railway safety in accordance with European directive 2004/49/EC.
Plastic deformation	Deformation that is permanent or non-recoverable after release of the applied load.
Purlin	Longitudinal structural element of a roof.
Railway Undertaking	Organisation that operates trains.
Rolling stock	Railway vehicles.
Serious accident	Any train collision or derailment of trains, resulting in the death of at least one person or serious injuries to 5 or more persons or extensive damage to rolling

	stock, the infrastructure or the environment, and any other similar accident with an obvious impact on railway safety regulation or the management of safety, where extensive damage means damage that can be immediately assessed by the RAIU to cost at least €2,000,000 in total.
Serious injury	Any injury requiring hospitalisation for over 24 hours.
Stress raiser	Location in an object where stress is concentrated, such as at notches, holes or sharp corners.
Tensile strength	The maximum engineering stress. In tension, that may be sustained without fracture.
Track circuit block	A signalling system that uses track circuits to confirm the absence of trains in order to control the movement of trains.
Underlying cause	Cause relating to skills, procedures and maintenance.
Up direction	The line on which trains normally travel towards Limerick.

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