Inquiry into the Derailment of a Freight Train at Cahir Viaduct on 7th October 2003

An Coimisiún Eatramhach Sábháilteachta Iarnróid

Interim Railway Safety Commission

(Cover image courtesy of Radio Teilifís Éireann)

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At approximately 06.00 hours on 7th October 2003 a laden Iarnród Éireann (IÉ) bulk cement train travelling between the Irish Cement plant at Castlemungret, near Limerick, and Waterford derailed as it passed over the viaduct across the river Suir at Cahir. After derailing the rear twelve wagons fell through the deck of the viaduct ending up in the river and on the river bank.

While nobody was injured as a result of the accident the deck of the viaduct was substantially destroyed and the rear twelve wagons damaged beyond repair. Irrespective of other consequential loss, the capital cost of this damage to railway infrastructure and rolling stock was in excess of €3 million. The EU Railway Safety Directive 2004/49/EC, classifies a 'serious accident' as, *inter alia*, one which results in 'extensive damage' i.e. €2 million or more.

On the 14/10/03 the then Minister for Transport, Seamus Brennan T.D., under the provisions of the Railway Regulation Act of 1871, appointed the Chief Railway Inspecting Officer of the Department of Transport's Interim Railway Safety Commission (IRSC) to conduct a Statutory Inquiry into the circumstances of the accident. The IRSC's Inquiry utilised documentary evidence provided by IÉ and by consultants that it engaged to assist in it's own internal inquiry into the accident, verbal evidence given in interview by various parties involved either directly or indirectly in the accident, and data obtained directly by the IRSC in its various site inspections.

Examination of the site and recovered debris, and interviews with individuals directly involved in the accident, did not confirm the cause of the derailment. Similarly the modelling of the viaduct and train dynamics conducted by IÉ's consultants failed to predict conclusively any derailment mode. The analysis therefore seeks to eliminate the factors that it could be said with a reasonable degree of certainty had not materially contributed to the accident, and to consider the factors that remain.

While it is not possible to state definitively what caused the accident, it appears that shortcomings in the timber deck structure of the viaduct and shortcomings in the associated inspection and maintenance regime were the most significant causal factors. If these had been fit for purpose it is unlikely that the accident would have occurred.

IÉ was addressing some of these shortcomings at the time of the accident, and has since introduced or proposes to introduce remedial measures. This report makes recommendations in relation to safety measures that are considered necessary in light of the accident, and gives indicative timeframes in each case for advising the IRSC of a remedial strategy and for the implementation of that strategy.

A copy of this report in draft form, excluding the conclusions and recommendations, was forwarded to all interviewees for comment. Two responses were received the content of which was taken into account in finalising the report.

It is important to acknowledge the cooperation of all parties in this Inquiry and of their commitment to identifying and addressing the cause of the accident.

2 Referencing Convention:

Throughout the report terms that are followed by a bracketed number are defined in the footnotes.

Distances along the railway are measured in a west-east direction, Limerick being the zero mile post and Waterford at approximately 121 km. Cahir, at 61.2 km is approximately half-way between Limerick Junction and Waterford and at the mid point of the Tipperary-Clonmel single track section.

IÉ utilises the historical railway convention of referencing train travel against track mileage. Trains can travel in either direction on the single line. If track mileage is increasing with travel the direction is referred to as Down and if decreasing as Up. Since mileage on the railway is recorded from Limerick to Waterford, which was the direction of travel of the train at the time of the accident, the train was travelling in the Down direction.

The rails and sides of the track are also referenced according to this convention. The left hand rail travelling in the Down direction is the Down rail and the left hand side of the track the Down side. Similarly the left hand rail travelling in the Up direction is the Up rail and that side of the track is the Up side (see Figure 1 below).

This convention will be used throughout this report.

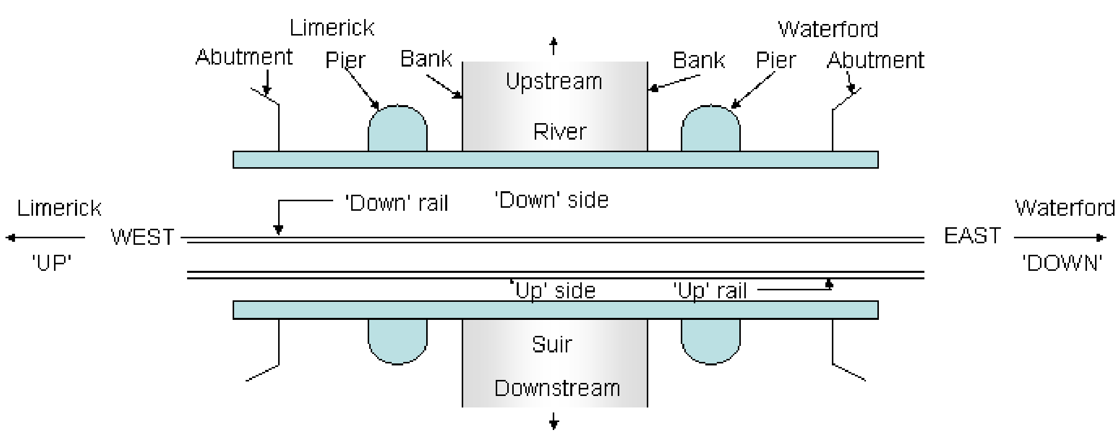

Figure 1 **Plan diagram of viaduct showing conventions used in the text**

The Viaduct is aligned approximately west-east relative to ascending mileage. The west bank of the river, abutment and pier of the Viaduct will be referred to as the Limerick bank, abutment and pier and similarly the east bank, pier and abutment as the Waterford bank, pier and abutment.

When transverse girders[1] and beams[2] are referred to in this report they are numbered sequentially, starting with transverse girder 1 at the Limerick abutment and finishing with transverse beam 95 at the Waterford abutment, with transverse girder 48 at mid-span. These are spaced at 915mm intervals, and provide a useful reference system for the location of other items on the deck of the Viaduct (Appendix 3).

IÉ gives all rail vehicles in its fleet a unique serial number. For the purposes of this report however reference to both locomotives and wagons will be on the basis of the position that they occupied in the train, the leading and following locomotives being locomotives 1 and 2 respectively and the 1st and subsequent wagons being wagons 1, 2 etc., the last wagon being 22. Full details of vehicle serial numbers, wagon loading, and wagon inspection and maintenance dates are given in Appendix 1.

Throughout this report metric units have been used. Where this has involved the conversion of imperial units quoted in documentary evidence the closest whole unit equivalent has been used. In no instance however is a variance from the exact equivalent imperial unit critical in the context of the report. Imperial units are quoted where pertinent.

Unless otherwise indicated, illustrations and diagrams were prepared by the IRSC.

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[1] Girder: An I-shaped beam fabricated from wrought iron and held together with rivets.
[2] Beam: An I-shaped iron or rolled-steel structural element, designed to sustain vertical loading forces.

3 The accident:

At approximately 06.00 hours on Tuesday 7th October 2003 a bulk cement train (the Train) travelling between Limerick and Waterford became derailed (the Derailment) as it crossed the viaduct that carries the railway over the river Suir (the River) at Cahir.

During the course of the accident the Train, which comprised two locomotives and twenty two laden cement wagons (the wagons), divided. The locomotives and the first ten wagons crossed the viaduct, coming to a stand with the rear of wagon 10 approximately 61m beyond the Viaduct. The remaining twelve wagons fell through the deck of the viaduct coming to rest in the river or on the Waterford bank (Figures 2 and 3).

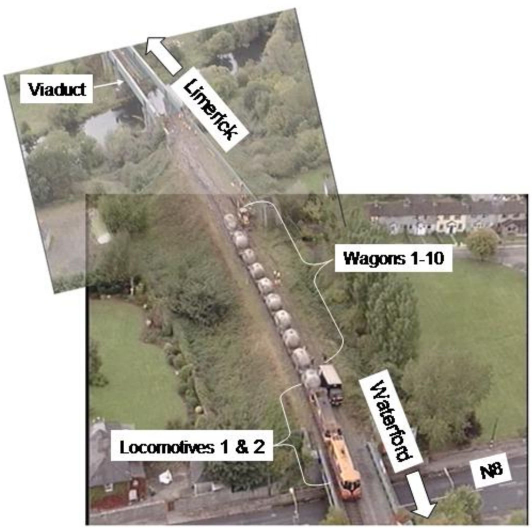

Figure 2 **Aerial shot of front of train (by courtesy of Radio Teilifís Éireann)**

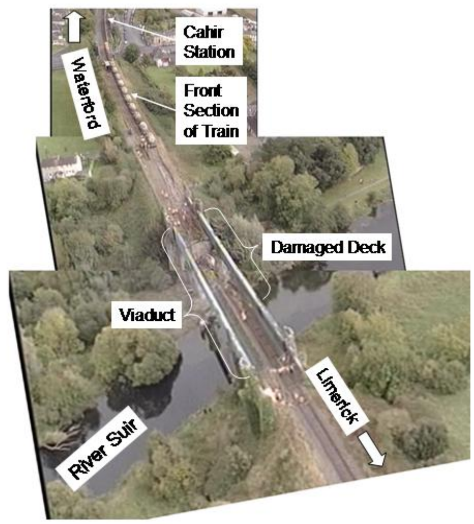

Figure 3 **Aerial shot of viaduct (by courtesy of Radio Teilifís Éireann)**

While no railway employee or other party was injured in the accident the rear twelve wagons of the Train were damaged beyond repair and the deck of the Viaduct required major reconstruction. The capital cost of this damage was in excess of €3 million. Following the accident the Limerick to Waterford railway remained closed until reconstruction work on the Viaduct was completed in September 2004.

The EU Railway Safety Directive 2004/49/EC defines accidents resulting in damage to rolling stock, the infrastructure or the environment of €2 million or more as serious accidents. The Directive when implemented will require that all serious railway accidents be investigated.

4 Background

4.1 The Railway:

The Limerick to Waterford railway is single track with intermediate double track loops at Limerick Junction, Tipperary, Clonmel and Carrick-on-Suir where trains may pass each other (Figure 5).

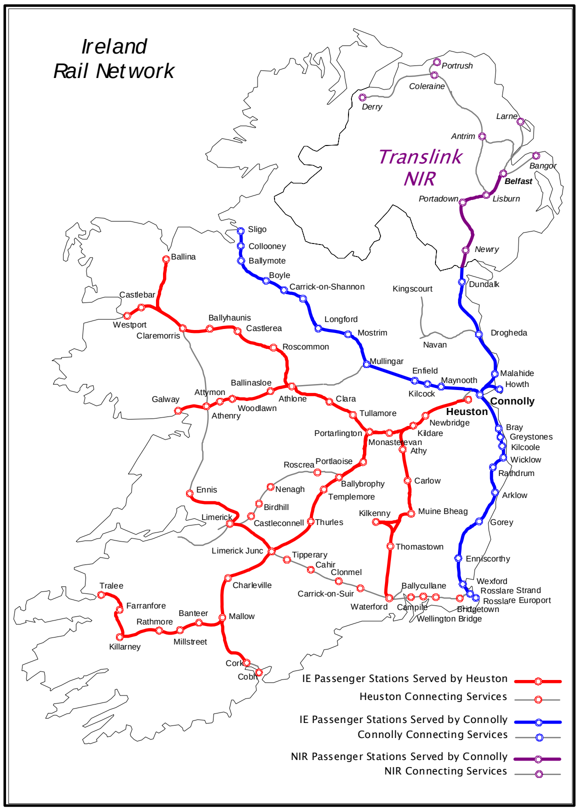

Figure 4 **Map of national rail network (by courtesy of Iarnród Éireann)**

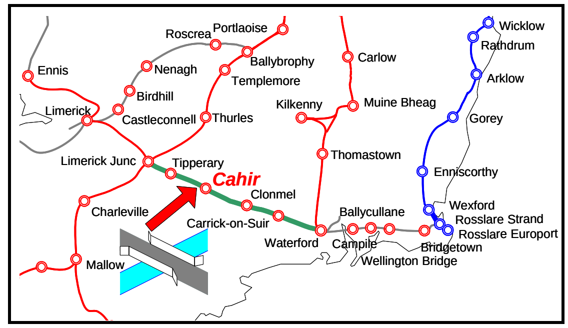

Figure 5 **Map showing location of viaduct (by courtesy of Iarnród Éireann)**

Movement of trains is controlled under the electric token block system. Single track sections between passing loops are protected by signals linked to a token machine in the controlling signal cabin. The issuing of a token by the signalman to a train driver allows a train to occupy a particular single track section of the railway. A token can only be removed from a machine if no other token for that particular line section is currently issued and if the points and signals for the route are correctly set. The route may only be re-set once the driver hands back the token to the controlling signalman at either end of the section and it is put back into a token machine.

The railway is relatively lightly trafficked. At the time of the accident there were only two passenger and two freight train movements scheduled in each direction on weekdays.

Seasonal beet traffic, which was in operation at the time, adds a further three possible train movements per day in each direction. Cement trains travel laden from west to east returning empty, while beet trains travel laden from east to west returning empty.

The maximum permitted speed for trains of two-axle bulk cement wagons on the IÉ system is 64 km/h. At the time of the accident, the permitted line speed at the Viaduct was also 64 km/h. Permanent speed restrictions apply at various locations on the railway due to localised track conditions. Temporary speed restrictions may also be imposed, again due to localised track conditions resultant on such as maintenance works. No local speed restriction was in force at the Viaduct. However, for some time prior to the accident a temporary speed restriction of 40 km/h had been in force over a 2.4 km section of track on the Limerick side of the Viaduct terminating 630m from the Viaduct. This speed restriction would have served to check the speed of trains approaching the Viaduct from the Limerick side, preventing them from reaching line speed at the Viaduct.

4.2 The Site:

The Viaduct is situated approximately 200m before Cahir station (the Station) in the direction of travel of the Train. Approaching the Viaduct from the west, the railway is on a left hand curve that terminates at the Limerick abutment of the Viaduct (Figure 6). Over the Viaduct the alignment is straight while beyond it and through the Station the railway is on a right hand curve.

From a point approximately 300m before of the Viaduct on the western side the railway is on embankment that increases gradually in height to approximately 15m at the Viaduct. Over the final 200m, the track is on a rising gradient of approximately 1:220. On the viaduct the track is nominally level and beyond it is again on an embankment as far as the Station with a falling grade of approximately 1:500.

Figure 6 **Viaduct from Limerick side**

200m before the Viaduct on the Limerick side a bridge carries the railway over the N24 Cahir to Tipperary road while approximately 150m beyond the Viaduct a bridge carries the railway over the N8 Cahir to Cashel road.

The land to either side of the railway on the Limerick side of the river is used for pasture with no provision for direct public access. Along the Waterford bank of the river there is a public footpath that commences at a car park approximately 200m south of the Viaduct, passes beneath the viaduct and continues northwards.

4.3 The Service:

IÉ train movements are scheduled in the Working Timetable which is periodically reviewed and republished. The 3rd June 2003 – 13th December 2003 edition of the Working Timetable [3] listed the Train identification as N504 and the movement as a 'path' that is to say provision is made in the schedule for a train movement but this may not necessarily be utilised.

The Train originated at the Irish Cement works at Castlemungret from where, after loading, it travelled the c. 5.5 km to Limerick Check signal cabin at the junction with the Limerick to Waterford railway. It was scheduled to subsequently depart Limerick Check at 03.35 hours passing through Cahir at 04.52 hours and arriving at Waterford at 06.06 hours, where the wagons would have been discharged.

[3] Working Timetable: An internal IÉdocument that lists all scheduled train movements and other operational data such as maximum permitted line speed, permanent speed restrictions and maximum speeds for particular types of rolling stock.

4.4 The Weather:

On the morning of the accident the weather was reported by those involved to be mild with a light rain falling. This is confirmed by Met Éireann data for the area which also indicates that it was cloudy and overcast with some outbreaks of rain or drizzle. The temperature was 11-12 ^{o}C, the mean wind speed was 16km/h from the north-east and visibility 3-6km though locally it may have been lower due to pockets of mist or fog.

Sunrise that morning in the Cahir area was at approximately 07.40 hours.

4.5 The Track:

Various rail types were in use on the track that comprises the railway. 50kg/m flat bottomed rail [4] was laid up to and over the Viaduct, and terminating about 53m beyond the Waterford abutment. This was manufactured in 1977 and initially laid on the more heavily trafficked Limerick to Limerick Junction section of the railway before being cascaded [5] to the Tipperary to Clonmel section in 1996. 87lb/yard (*43kg/m*) bullhead [6] rail was laid from that point and continued through Cahir Station.

On the approaches to the Viaduct the track is of traditional ballasted type with timber sleepers. On the ballasted track and the Viaduct the rails were seated on cast iron sole plates [7]. These support the rail and give it an inward inclination from the vertical of 1 in 20. On the Viaduct itself the rails and sole plates were connected to the way-beams[8] with wood-screws [9].

The track was laid in panels with rails joined by fishplates. For the 50kg/m rail the panel length was 36.6m. There were joints approximately 17m before the viaduct on each approach and on the Viaduct itself approximately 20m from each abutment.

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[4] Flat-bottomed rail: Rail with flat bottom-flange on which the rail is seated and by which, with the use of clips, screws or other fastenings, the rail is secured to the sleepers or other supporting system.
[5] Cascaded: The systematic re-laying of worn track from busy routes to routes with lower traffic demand profiles in terms of load, volume and speed.
[6] Bullhead rail: Older rail type with two wearing flanges designed to be inverted as one became worn but which must be seated in and supported by special chairs.
[7] Sole-plate: Cast-iron seating used in conjunction with flat bottomed rail and timber sleepers or way-beams. In addition to supporting the rail it also maintains its position relative to the securing bolts or screws and gives the rail an inward inclination.
[8] Way-beam: Long, heavy timber beam which runs longitudinally under the rail, giving it a continuous support platform.
[9] Wood-screw: Rail fastening used in conjunction with timber rail support systems that grips into the timber rather than being secured through it.

The track was canted [10] on the horizontal curves on both sides of the viaduct but not on the viaduct itself. To minimise the impact of jerk [11] as trains entered or left the horizontal curves both the radius and cant were introduced and dissipated gradually.

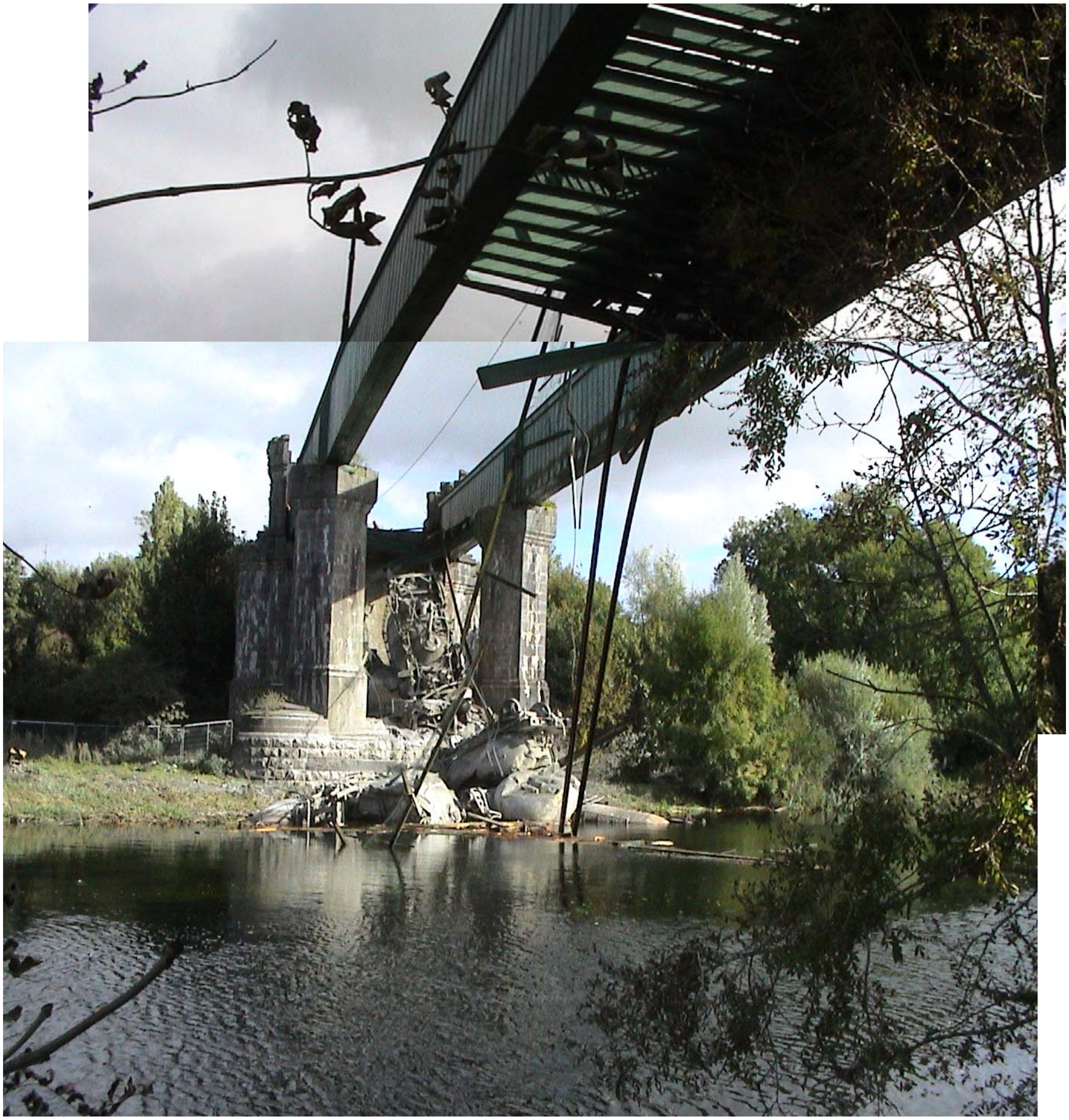

Figure 7 **Viaduct from Limerick bank, showing collapsed deck and wagons**

[10] Cant: Relative height of one rail above the other at any specific point on the track, with reference to the track gauge [21]. Typically applied artificially by raising of the outer rail above the inner rail on horizontal curves to counter the effect of centripetal force.
[11] Jerk: Rate of change of applied force on trains resultant on entering or leaving horizontal or vertically curved sections of track or variances in train speed.

4.6 The Viaduct:

The Viaduct, which was constructed in 1852, crosses the river at an oblique angle with the alignment of the abutments and piers being at approximately 60^{o} to the centre line of the deck.

It has three spans: a 15m approach span at each end between the abutment and a pier situated on the edge of the river bank, and a 46m main centre span over the river itself. The approximate height of the Viaduct deck over the river is 15m.

There are three principal constituent structural systems, the masonry piers and abutments, the primary deck spanning between the abutments and piers and the secondary deck on which the track was laid (see Figure 8).

The abutments and piers are constructed of cut limestone founded on limestone bedrock which outcrops on the Limerick side of the river. The piers each comprise a base plinth rising to approximately 3m over river level and supporting two separate columns centred under the main wrought iron box girders [12].

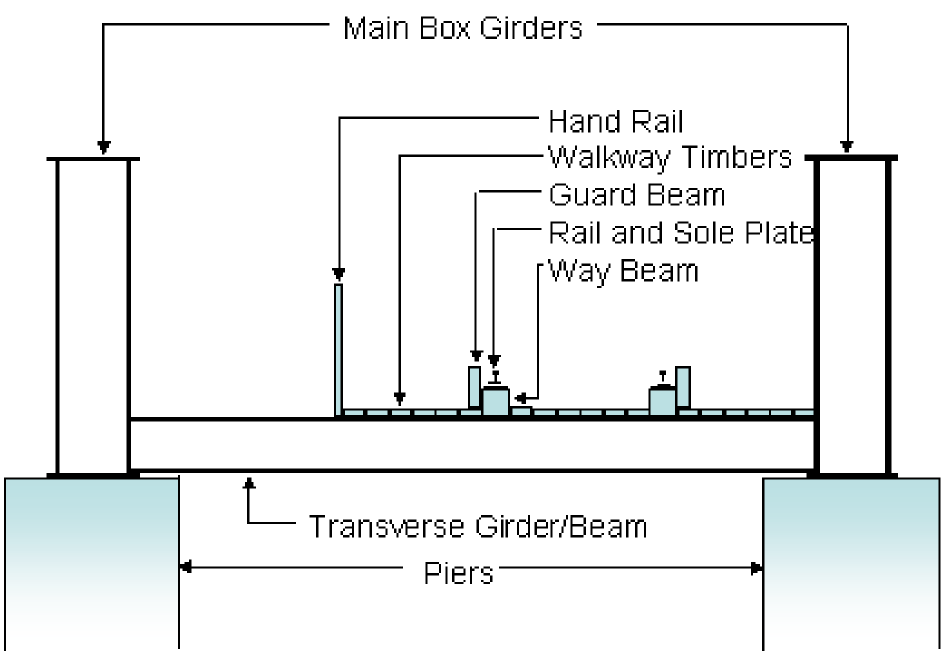

Figure 8 **Viaduct cross-section diagram**

[12] Box-girder: Girder where, in cross section, the constituent elements form a box.

Two element types comprised the primary deck, the main longitudinal support girders and the transverse girders. All were originally fabricated from plate and angle sections riveted together but a number of the transverse girders at the Waterford end of the Viaduct had been replaced with rolled mild steel beams after an accident in 1955.

The approximate dimensions of the main girders are 3500mm from top to bottom flange[13] and 750mm between webs[14]. At regular intervals along the girders there are internal diaphragms between the webs. The transverse girders and beams, of which there were 95, spanned between the main box girders spaced at 915mm centres. They were approximately 8075mm long, with the exception of those at the abutments at each end of the deck that were of various lengths to accommodate the oblique angle of the Viaduct. The wrought iron transverse girders had a flange width of 230mm and a depth of 483mm, and the steel beams a flange width of 190mm and depth of 610mm. The wrought-iron girders were riveted to the inner webs of the main beams with their bottom flanges immediately above those of the main girders, the whole assembly forming a trough through which the railway passes. The deeper mild steel beams were fitted to the main girders with their bottom flanges set slightly below those of the main girders.

The secondary timber deck structure was of way-beam type where the rails are carried on longitudinal timber beams instead of transverse sleepers (Figure 9). These way-beams were nominally 305mm wide and 305mm deep (12” x 12”) and ran continuously under each rail across the Viaduct. They were attached to the transverse girders/beams by bolts which in the case of the wrought iron girders passed through the top flange, and in the case of the steel beams had clips that gripped the outer edge of the top flange.

Outside each way-beam there was a timber guard-beam , nominally 152mm wide and 406mm deep (6” x 16”). The guard-beams were staggered longitudinally relative to the way-beams. Their apparent purpose was to provide derailment protection. At approximately 3000mm intervals, timber transoms kept the way-beams apart. Long steel tie-rods prevented the way-beams from spreading and, together with shorter tie-rods, were used to hold the guard-beams and way-beams together.

[13] Flange: The top or bottom of an I-shaped beam or girder.
[14] Web: The narrow portion of an I-shaped beam or girder.

Figure 9 **Way-beams over transverse girder 18**

Figure 10 **Flitch plate and top flange reinforcement plate at transverse girder 20**

At every second way-beam joint there were pairs of steel flitch plates [15] that were the same depth as the way-beams to which they were bolted on either side (Figure 10). The plates were approximately 2060mm long and spanned three transverse girders to which they were riveted. They were mounted at longitudinal intervals of 11.7m in staggered fashion, reflecting the probable original length and layout of the way-beams. The flitch plates helped to provide lateral, longitudinal and rotational fixity to the way-beams and, along with the staggered guard-beams they provided longitudinal continuity.

The Viaduct was designed to accommodate two sets of railway tracks but carried only one set which was offset to the Up side of the deck centreline. Approximately mid-way between the Down way-beam and Down main box girder there was a hand rail. Between this and the Up main box girder any remaining areas were fully decked out with 76mm (3”) timbers providing walkways on both sides of the track. With the exception of the transverse girders the space between the hand rail and Down main box girder was void.

4.7 The Train:

The Train involved in the Derailment comprised two locomotives and twenty-two purpose-built bulk cement wagons.

[15] Flitch plate: Steel plate typically applied to the side of a timber structural member of provide added strength. In the case of the Viaduct theses plates also located and secured the way-beams.

Figure 11 **20 tonne two-axle cement wagon**

The wagons were twin axle type having a net weight of c.11 tonnes, a 20 tonne capacity and 15.5 tonne axle load. They were designed and built by IÉ at its Inchicore works between 1967 and 1972 and based on the British Rail Mk I freight wagon. The basic configuration is a 12mm plate steel torpedo shaped vessel mounted on a rigid under-frame fabricated from various steel sections carried on two fixed axles at 3.65m centres (Figure 11). The overall wagon length from buffer to buffer is 7.17m. Suspension is of leaf-spring type. Train operated vacuum brakes apply on one diagonally opposite wheel of each axle. Lever operated manual parking brakes apply on all four wheels. In both instances braking is by cast iron shoes acting on the running surface of the wheel and operated though cranks and levers. The wagons are coupled by shackles between hooks on the end buffer-beams [16].

Two General Motors' diesel-electric locomotives were hauling the Train, a class 121 leading that had been in service since 1961 followed by a class 181 that entered service in 1966. Both locomotives have two twin-axle bogies, their respective axle loads being 16 and 17 tonnes. Both locomotive types are equipped with train radios and have Hasler recorders [17] fitted.

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[16] Buffer-beam: Main transverse structural element at each end of a wagon sun-frame on which the buffers and coupler are mounted.

[17] Hasler recorder: Proprietary analogue device, similar to a road vehicle tachograph, that record train speed over approximately the last kilometre travelled as radial displacement from a central point. Train braking can also be inferred from the trace.

5 Events immediately prior to and post derailment:

5.1 The Journey:

The Train departed Limerick Check at 03.38 hours, 3 minutes after the scheduled time. It was subsequently held at Tipperary to allow it to cross [18] with a westbound beet train and did not enter the Tipperary-Clonmel section until 05.18 hours. At the time of the accident the Train was running approximately 1 hour behind schedule.

Other than being delayed and experiencing some locomotive wheel-slip, which would not be unexpected given the weather conditions, the driver of the Train (the Driver) indicated that the journey prior to the derailment was uneventful. He was conscious of the change in resonance as the Train moved from ballasted track onto the Viaduct deck but was aware of no unusual movement or sound until the train brakes applied automatically as the locomotives were leaving the Viaduct. He described the braking as 'quick' but not 'sudden' and indicated that the Train came to a stand with the locomotive 1 on the bridge over the N8 Cahir to Cashel road. The Driver believed that this happened shortly before 06.00 hours.

5.2 Response:

When the Train came to a stand the Driver applied the locomotive brake. Because it was dark and raining he was unable to effectively see anything from the cab and it was only when he walked back along the train that he realised that it was derailed. He then tried to use the train radio to advise the situation but was unable to make any contact because the Train was in a "black spot" [19]. He then used a telephone on the platform at the Station and contacted the gatekeeper at Nicholastown level crossing, which is approximately 8km east of the Station, explaining that there had been a derailment. The Driver asked the gatekeeper to notify the signalman in Clonmel and to ask him to call him (*the Driver*) on his (*the Driver's*) mobile.

At this time the Driver believed that only one wagon was derailed. It was not until he again walked back along the Train, at which time the signalman at Clonmel had telephoned him, that it became apparent that only the first ten wagons remained attached to the locomotives and that the remaining twelve had fallen through the deck of the Viaduct.

[18] To Cross: Operational procedure where, on a single track railway, a trains travelling in opposite directions pass each other at a double track section of railway at the end of a single line block section.
[19] Black spot: A location on the railway where, due to local topographic conditions, there is no train radio reception.

The table below outlines the times of various subsequent accident response events.

Time	Event
06.10-06.15	Time at which Clonmel signalman estimates that he advised both Waterford station and the IÉ District Inspector of the situation.
06.15	Central Traffic Control (CTC) Connolly records indicate that the Limerick Maintenance Foreman advised that the Train had derailed and was missing wagons
06.16	CTC records indicated that the CTC regulator confirmed in a return telephone call to the Driver that he was aware that the Train had derailed and was missing wagons.
06.18-06.25	CTC regulator advised various IÉ engineering and management personnel of the derailment but was not at this point aware of the collapse of the Viaduct.
06.26	Tipperary signal cabin records indicated that the Signalman was advised of the derailment by the gatekeeper at Nicholastown. It is understood that he then called the Driver on his (*the Driver's*) mobile phone and that the Driver asked him to contact the Gardaí which he did.
06.45	The Divisional Engineer was the first IÉ manager to arrive on site.
07.00	Time that the Driver estimates that two Gardaí arrived on site and, at their request, he subsequently accompanied them to the bank below the Viaduct on the Waterford side of the river. Following inspection the Gardaí undertook to contact the Environmental Protection Agency
08.00	Time when the Driver estimates that he returned to his locomotive at which point various other IÉ personnel had arrived on site. The IRSC was advised of the accident through IÉ's Safety Department.
08.00-09.30	Various IÉ and other personnel arrived on site including Tipperary County Council's Chief Chemist and the Superintendent of Cahir Garda Síochána.
09.45	District Manager Limerick convened a site meeting of IÉ personnel and subsequently contacted various other agencies including the local Conservation Ranger, Fisheries Board, Environmental Protection Agency and Civil Defence.
13.15	IRSC inspectors arrive on site.

Table 1 Table showing times of accident response events

The site was cordoned off and all public and media personnel excluded. Civil Defence personnel initially took responsibility for securing the Waterford river bank below the Viaduct to prevent public access along the footpath. IÉ subsequently engaged a private company to provide 24 hour security in this area and at both ends of the viaduct commencing on the evening of the day of the accident.

5.3 Examination, Recovery and Testing:

Immediately following the accident IÉ conducted detailed measured and photographic surveys of the site. These included an underwater survey to, in so far as was practicable, locate and identify accident debris that had fallen into river and to examine those parts of the cement wagons that were under water to ascertain what if any pollution potential existed.

Subsequent recovery focussed initially on making safe the damaged Viaduct deck and removal of the cement wagons from the river and river bank to minimise any ongoing risk of pollution. When this work was completed all remaining loose debris identified in the river, along with that from elsewhere on the site, was removed and stored for further examination.

IÉ conducted a structural assessment of the damaged Viaduct to ascertain its immediate integrity and the potential for reconstruction as opposed to replacement. On completion of site examination wagons 1-4, still laden, were taken to IÉ's East Wall depot where they were tested under simulated track twist to determine the degree of redistribution of load that would have occurred between wheels.

On behalf of IÉ, independent consultants also examined the site and conducted a load test on the intact section of the Viaduct. Data from this and the wagon test along with other information was input by the consultants to a proprietary computer model to assess any potential for derailment.

The IRSC conducted inspections and surveys at the site on the day of the accident and on a number of subsequent occasions. It also engaged its own independent experts to carry out a structural assessment of the main Viaduct structure. In addition to its own data and the reports of its consultants, the results of surveys, examinations and tests conducted or commissioned by IÉ were made available to the IRSC for use in conducting its Inquiry.

6 Inspection and Maintenance

6.1 The Track:

The track section including the Viaduct was walked by a Patrol Ganger on Mondays, Wednesdays and Fridays to carry out routine gauge checks and look for track and general infrastructure defects. On the remaining two weekdays the Patrol Ganger carried out minor repairs. The Patrol Ganger's report sheets were submitted to the Permanent Way [20] Inspector who prioritised any necessary maintenance works and also accompanied the Patrol Ganger on a bi-monthly inspection.

The Divisional Engineer accompanied by the Permanent Way Inspector would travel the line in an inspection car approximately every two months having previously identified locations of concern from various report and survey data. A walking inspection would be carried out including measurements of gauge [21] and cant at these locations and at major features such as the Viaduct. On the Viaduct itself the condition of timbers and fastenings would be assessed as well as the overall condition of the structure, although this was not part of IÉ's standardised viaduct inspection and maintenance regime. The most recent Divisional Engineer's inspection prior to the accident was on 28/08/03.

Periodically the track was surveyed by IÉ's EM50 track recording vehicle that measures various parameters including cant, gauge and twist [22]. At the request of the Divisional Engineer an EM50 run had been scheduled for 29/09/03 but this did not take place until five days later, 04/10/03, three days before the accident. The Divisional Engineer received a copy of the EM50 data print-out on 06/10/03 and having identified and prioritised defects of concern, had planned to inspect these during an inspection car run on 08/10/03, the day after the accident.

A new patrolling standard with associated reporting and signing-off arrangements had been in course of development for approximately two years prior to the accident but implementation only commenced, as pre-scheduled, approximately one month after the accident.

[20] Permanent Way: Collectively the ballast, track, signalling, structures etc. that comprise the railway.
[21] Gauge: The distance between rails measured between the inner faces of the top flange on straight track. on the IÉ network 1602 mm.
[22] Twist: The variance in cant [10] measured at two points a fixed reference distance apart.

6.2 The Viaduct:

6.2.1 Inspection Standards:

IÉ classifies structures like the Viaduct, as it existed at the time of the accident, as open-deck girder bridges. Guidance on the inspection of this and other types of bridge on the IÉ system is contained in Technical Information Sheet MW41, which is part of the Maintenance of (the permanent) Way Handbook. In relation to the process of inspection, MW41 specifies:

- a requirement for biennial inspection which is the responsibility of the Divisional Engineer,
- that for "thorough" inspection, arrangements should be made to access all parts of the structure requiring examination including specifically the removal of timber decking and advertising boards where necessary, and
- that to access high structures the use of hydraulically operated platforms should be considered as necessary.

In relation to inspection records, MW41 also specifies:

- a requirement that record cards be kept detailing the defects found in each inspection,
- that the principle of marking by exception should be adopted i.e. that lack of specific reference to a component will be taken as an indication that it is in good condition, and
- that defects should be ranked from 1 to 3, 1 being a serious defect requiring "immediate reference by telephone or letter to the Chief Civil Engineer or to the Structural Engineer".

For various bridge types, MW41 also gives a basic description of structural configuration and lists the main defects to be looked out for in inspections. For open-deck girder bridges like the Viaduct eight main defects are listed, all associated with the primary iron/steel deck structure. While no specific reference is made to potential defects to be looked for in inspecting the masonry elements of this type of bridge some of the guidance given in relation to common defects found on "masonry, brick and concrete arches" is relevant. However, no reference is made to potential defects in the secondary timber deck structure, either in this section or elsewhere in MW41.

MW41 concludes by stating that the inspection frequency set out in the document is "binding" throughout the whole IÉ system and re-emphasises that the periodic inspection of bridges is a "prime charge" on Divisional Offices.

In instances where Divisional inspections identify serious structural defects, it is the practice to seek expert structural engineering assistance in relation to conducting a more detailed assessment and in the design and specification of whatever remedial works are required. Typically this assistance is provided by IÉ's central structural engineering department.

6.2.2 Divisional Inspection Cards:

The Divisional bridge inspection card relating to the Viaduct subdivides the three structural systems into their principal component parts. For the masonry system these are the abutments, piers and columns, wing walls, parapets and copings; for the primary deck structure the main box girders and transverse girders/beams and in relation to the secondary timber deck structure the walkways, packs [23] and transoms and the way-beams and fastenings. The condition of each component is rated across a 3 point scale and any remedial works required are listed along with salient comments.

6.2.3 Inspections Pre-accident:

The most recent inspections prior to the accident were on 28/09/99 and 09/07/02. The 28/09/99 inspection identified the need for various repair and maintenance works to the abutments and piers and that some of the secondary deck walkway timbers were rotten. The Viaduct was assessed as being "OK from top" in the 09/07/02 inspection "but requires further inspection".

Independent consultants inspected the Viaduct in January 2001 and recommended that non-slip metal decking be installed on top of the walkway timbers. This work was done soon afterwards.

6.2.4 Inspections Post-accident:

Following the derailment IÉ's Structural Engineer carried out a detailed survey of the masonry and primary iron/steel Viaduct systems and concluded that at the time of the derailment both were capable of adequately sustaining operational loads and that their design and condition were not causal factors in the accident. The IRSC's own consultants shared this view.

[23] Packs: In the particular context of this Viaduct, material inserted between the top of the transverse girders and the underside of way-beams to provide an even seating adjacent to reinforcing plates.

6.2.5 Structural Drawings:

There are two sets of historical drawings of the Viaduct. The first dates from 1911 and details two proposed arrangements for re-timbering though there is no evidence of either having been implemented.

The second set of drawings details repairs carried out to the Viaduct following a similar accident in 1955 when a run-away beet train crashed though the Waterford end of the Viaduct deck.

At the time of the accident there were no contemporary drawings of the Viaduct either showing the general structural arrangement or details of any component parts, apart from a 1982 sketch showing a cross-section of the guard-beam arrangement.

6.2.6 Maintenance

Repair and maintenance works have not been comprehensively recorded and only limited details are available.

Following the 1955 accident, 18 of the original 95 wrought iron transverse girders were replaced with mild steel beams having approximately the same dimensions. Other than the use of mild steel as opposed to wrought iron the only material structural change at this time was to clip the way-beams to the outer edges of the upper flanges of the new beams rather than bolting them through.

Corrosion of the ironwork has necessitated various lesser repairs principally involving the fixing of reinforcing plates or straps to the webs and flanges of the wrought iron transverse girders (see section 4.5, figures 9 and 10). In 1973, reinforcing plates were fixed to the top flanges of eleven transverse girders, the bottom flange of one transverse girder and two main box girders connections. Detailed examination by the Divisional Engineer and Bridge Gang Foreman in 1995 identified further corrosion damage requiring repairs to the webs of 46 transverse girders and the bottom flanges of a further 5. The dates of prior repairs are not known.

The bridge iron and steelwork was painted in 1996 following the 1995 repairs, and again in 2002.

The Divisional Engineer had identified four way-beams under the Up rail along with corresponding guard-beams requiring replacement due to deterioration. Three of these, located adjacent to each other and approximately centrally on the main span of the

Viaduct, were replaced on the Sunday immediately prior to the accident along with their associated guard-beams. The remaining way-beam, Way-beam 6, and its associated guard-beam located on the Limerick side span adjacent to the pier, was scheduled for replacement the week after the accident. Prior to this work other timbers had been replaced, with six new way-beams and guard-beams installed in April 1996 and others in 1991, 1988 and 1986.

6.2.7 Maintenance Standards:

Other than in relation to the procurement of replacement timbers there were no written or diagrammatic standards or specifications regarding:

- tolerances for preparatory work and machining of way-beams and guard-beams,
- their relative positioning on the deck and to each other, or
- the number and location of securing bolts and tie-rods.

Training in relation to both the inspection of the Viaduct and the carrying out of maintenance and renewal works was not standardised. Instruction was provided on the job with skills and knowledge being passed on informally from more to less experienced team members.

6.3 The Train:

As with all IÉ rolling stock the wagons are subject to a planned preventative examination and maintenance programme that is principally time based and is fully prescribed and documented. Four examination streams apply to the cement wagons.

- At six-monthly intervals all component parts such as wheels, axles, springs and brake gear are checked and refurbished or replaced as necessary,
- At two-yearly intervals the axles are ultrasonically tested,
- Again at two-yearly intervals, but not necessarily at the same time as ultrasonic testing, the cement vessels and associated equipment are checked, and
- General repair, which effectively involves a complete strip-down of the wagon and replacement of major components such as wheels, is mileage based but typically occurs every four years.

In all instances examination results and details of works carried out are recorded and for each exam stream an advance notice is automatically generated when 90% of the inter-examination time from the last scheduled date has elapsed. Independent of this programme all trains are routinely inspected by Train Examiners at marshalling locations including Limerick cement factory. Internal compliance auditing procedures are also in place.

Records indicate that, at the time of the accident, all 22 wagons were compliant with the 6-monthly examination requirements and 17 had undergone general repair within the previous four years. Five wagons were however outside this period with respect to general repair. This was because they had been assessed as not yet requiring such repair rather than reflecting a failure in the maintenance regime.

7 Analysis

7.1 Derailment Sequence:

The extent of the damage sustained by the track and Viaduct structure in the Derailment meant that there was little evidence on which to assess the sequence of the Derailment. A number of salient facts are however known:

- All axles of the locomotives, both axles of wagon 1 and the leading axle of wagon 2 remained on the rails following the accident.
- On the front section of the Train, that came to a stand on the Waterford side of the Viaduct, the rear axle of wagon 2 and all axles of wagons 3 to 7 derailed to the Up side while wagons 8-10 derailed inside the gauge [24] .
- At the first point where derailment damage was evident this was inside the gauge of both rails suggesting that at some stage in the derailment sufficient gauge spread [25] occurred to permit both wheels of one or more axles to drop within the gauge.
- There was no clear evidence of wheel climb on either rail.
- At Way-beam 10 between transverse girders 28 and 31 there was a cluster of drop-off marks [26] to the outside of the Up rail, indicating that at a number of wheels had in fact climbed the rail in advance of this location.
- The way-beams and guard-beams on the Up rail that had been installed on the Sunday immediately prior to the derailment were recovered largely intact. A number of sole plates and wood-screws remained in place and on the screws located outside the gauge there were marks consistent with their having been struck by one or more wheel flanges. While there was also evidence of wheel damage to the inner face of the associated guard-beams there was no damage on the upper face.
- Damage to the Up side way-beams and guard-beams was much less substantial than damage to the Down way-beams and guard-beams (Figures 12 and 13).

[24] Inside the gauge: Between the running rails.
[25] Gauge spread: Increase in gauge, may be static or dynamic occurring under train load.
[26] Drop-off marks: Marks on the rail cause by wheels which, after climbing the rail and crossing the rail head, drop outside the gauge.

Figure 12 **View of collapsed deck from Limerick side of Viaduct**

Figure 13 **Detail of Down side after debris was removed**

- On the upper flanges of the transverse girders and beams in the area of the collapsed deck there was varying amounts of damage indicative of their having been struck by one or more wheel flanges. On the fully-collapsed transverse girders these marks tended to be clustered approximately 300mm outside the gauge on the Down rail and, correspondingly, 300mm inside the gauge on the Up rail. Over approximately the last 15m of the deck approaching the Waterford abutment there was a gradual shift in the clustering of the wheel-flange strike marks of approximately 100mm to the Down side.
- Wagon 11 came to rest on top of wagons 12 and 13, with wagons 14 and 15 adjacent at the bottom of the Waterford abutment and wagons 18 to 20 against the plinth of the Waterford pier (see figure 7).

Taking all evidence into consideration it appears that initial derailment occurred to the Up side somewhere between the point at which there was the first evidence of derailment and the cluster of drop-off marks on the Up rail.

Since leading axles of wagons and bogies are more likely to derail than trailing axles, the first axle to derail was probably the leading axle of wagon 3 with the resultant applied force then derailing the trailing axle of wagon 2. Complete derailment of wagon 3 would then have initiated progressive derailment of following axles.

The Derailment was initially contained with the derailed Up side wheels running between the Up rail and its associated guard-beam. Correspondingly, the Down side wheels would have dropped inside the gauge running on the sole plates and on top of the Down way- beams.

As the passage of successive wheels increasingly damaged the Down way-beams they appear to have lost their structural integrity and capacity to support the wheels. The resultant force on the Up wheels caused by this loss of Down wheel support would then have broken the initial mode of derailment, causing instead the remaining Up wheels to derail inside the gauge. This almost certainly occurred after wagon 7 and probably between wagons 11 and 13.

With the destruction of the Down way-beams, the Down wheels began to run directly on the top flanges of the transverse girders, imparting, as they dropped into and were pulled out of the space between successive girders, both vertical and horizontal impact forces to the top flanges of the girders. Compared to contemporary mild steel beams, which are produced under highly controlled conditions, the wrought iron girders have significantly less capacity to resist such loads, by virtue of their metallurgical properties and their relatively light cross-section.

Initially, one transverse girder would have failed, followed, as increased loads were imposed on adjacent girders, by others. This progressive failure of the transverse girders would have occurred both forwards and backwards.

As the overall integrity of the track and viaduct deck was lost, gauge spread, and with it the derailment, may have progressed backwards from the point of initial derailment with the last axles of the train being dragged down between the rails.

The increasing drag caused by the progressively derailing train and the collapsing deck of the Viaduct would eventually have caused the failure of the coupler between wagons 10 and 11, causing, with the rupture of the brake pipe, the train brake to apply. There is no clear evidence to indicate the location of the train when this happened, but the divide probably occurred when wagon 10 was at or around the Waterford abutment.

7.2 Cause of derailment:

Examination of the site and recovered debris, and interviews with individuals directly involved in the accident, gave no clear indication of the cause of the derailment. Similarly, the modelling of the Viaduct and Train dynamics conducted by IÉ's consultants failed to conclusively predict any derailment mode.

Given the foregoing, in analysing the accident it is appropriate to eliminate those factors that are unlikely to have been the cause, and concentrate on the more likely factors.

7.2.1 Speed:

The history of occurrence of related accidents and incidents on the line, and with the particular rolling stock involved, suggest that the maximum permitted line and Train speeds were robust.

The Hasler recorders fitted to both Locomotives measure speed as a function of wheel diameter and speed of rotation. Because the diameter varies with wheel wear, the output from the Hasler requires calibration in order to determine the actual speed of the locomotive. After the accident, the Hasler recorder discs from both locomotives were removed by IÉ for calibration and analysis. This indicated that the traces from the two Locomotives were in agreement, and that, when approaching the Viaduct, the Train was travelling at approximately 69 km/h. This is 5 km/h in excess of the permitted maximum speed. It would be expected that such speed variances could occur from time to time, and that allowance would have been made for this when setting speed limits.

In this context excessive Train speed, although significant, is not considered to have been a primary causal factor.

7.2.2 Malicious act;

The Viaduct represents a potential pedestrian crossing point of the river Suir, the closest alternative crossing points being a road bridge 400m downstream in Cahir town centre and the N8 road bridge which is over 2km upstream. There are, however, no significant attractors that give rise to a strong trespass desire line over the Viaduct and, while IÉ acknowledges that occasional trespass does occur, there is no history of this being malicious. This is supported by there having been no significant trespass indicators in the area, such as graffiti or accumulations of drink containers.

The previous train to cross the Viaduct, a beet train that passed through Cahir at approximately 04.55 hours on the morning of the accident, did so without incident, the driver having seen no trespassers in the area and having noted nothing unusual. Had any malicious act occurred, this would therefore almost certainly have been subsequent to the passage of the beet train, which would have been in the early hours of the morning when it was still dark.

Any obstacle placed on the track, or damage done to the track, would have been encountered first by the leading locomotive of the Train but there was no damage or other evidence to indicate that either had happened. Neither was any indicative debris found on the Viaduct or recovered from the river.

It is unlikely therefore that the derailment was the result of a malicious act.

7.2.3 Catastrophic failure of the viaduct;

There is no evidence to indicate that failure of either of the two principal structural Viaduct systems, i.e., the masonry abutments and piers and the primary iron/steel deck structure, caused the derailment.

All damage was consistent with impact loading from derailed wagons as opposed to failure under normal working load.

7.2.4 Viaduct deflection:

The main box girders were continuous over the three spans of the Viaduct. Under the imposed load of passing trains, they would have been subject to varying degrees of deflection depending on the position of the train and its axle loads. The greatest deflection would have occurred at the centre point of the Up main box girder because, due to the track being offset to the Up side of the deck, this girder would carry proportionately more of the train load.

Similarly, because the track was offset, the transverse girders and beams were not loaded centrally. The resultant deflection under the Down rail, being closer to the centre of the deck, would therefore have been greater than that under the Up rail.

The magnitude of, and relative variance in, these deflections under various imposed train loads would have been small in the context of such track parameters as level, cant and twist and the potential therefore for influencing the derailment would have been insignificant.

7.2.5 Viaduct resonance:

It is highly unlikely that viaduct resonance was a factor in the derailment.

Under certain loading conditions, some structures can resonate and, in extreme cases, this resonance may increase under sustained loading to the point where structural damage and even collapse occurs. Long slender structures are particularly susceptible to the phenomenon. If present in a rail bridge, such resonance could increase the potential for derailment.

With a height to width to length ratio of approximately 1 to 2.7 to 13.1 the main span of the viaduct is not particularly slender and the shorter side spans are less so. Additionally, the nature of the overall construction with its various longitudinal and transverse metal and timber elements would tend to dampen any resonance that might occur.

7.2.6 Train stability in operation:

While it is almost certain that the derailment was initiated by wheel climb [27] rather than track failure there is nothing to indicate that any defect in the Train contributed in a significant way to this event.

IÉ operates bulk cement trains over a number of other routes in addition to that between Castlemungret and Waterford. In addition to the twin axle wagons involved in the accident, newer bogie type wagons with a 50 tonne capacity and 16 tonne axle load are also used.

Class 121 and 181 locomotives and twin axle cement wagons have been in continuous use since their initial introduction to service in the 1960's. Of the original 150 wagons of this type that were commissioned, 137 remained in service at the time of the accident. On average, each wagon travels approximately 65,000 km annually. IÉ's wider freight wagon fleet includes a further 500 wagons of similar design and age. Like the cement wagons, most were purpose built to carry specific types of freight such as pallet cement, gypsum and sugar beet but all are of similar configuration and have approximately the same un-laden and laden weights and axle loads.

[27] Wheel climb: Situation where, as the wheel rises from its normal running position, wheel/rail contact transfers from the running surface of the wheel to the flange in the ultimate state leading to derailment.

Railway industry experience of wagons of this type is that they are more prone to derailment than freight or passenger vehicles with bogies. The fixed axle and rigid frame construction makes them particularly sensitive to track twist increasing the likelihood of wheel unloading [28] and consequent wheel climb.

Under IÉ operation, the safety performance of twin-axle cement wagons has however been good. While there have been derailments at low speed in yards, due principally to poor track conditions, IRSC records for the last ten years indicate only one previous derailment of a laden cement train on a running line. This also occurred on the Limerick to Waterford line but near Bansha, approximately 13km on the Limerick side of Cahir. On that occasion a temporary speed restriction was in force at the site, due to ongoing track renewal works, and IÉ's internal investigation judged failure to observe the speed restriction to be the primary cause of that accident.

The locomotives and first ten wagons of the Train were inspected on site immediately after the accident. While there was varying degrees of damage to the derailed wagons, principally to the brake gear but also to the buffers on wagon 7 and axle guards on others, none had sustained major structural damage. The indications were that, with the exception of some very minor non safety-critical faults, all of the damage was sustained in the derailment and that prior to this the Train was fully serviceable.

Following on-site examination after the accident, wagons 1-4 were taken to IÉ's East Wall yard, where each axle was weighed on level track and then checked for the degree of load transfer occurring under simulated track twist. This would indicate the presence of any deficiency, principally in wagon suspension or load distribution, which might make a particular wheel more susceptible to wheel climb.

The standard that IÉ uses when balancing wagon suspension requires that when one wheel is lowered 24.4mm, simulating a twist of 1:150, the wheel continues to carry at least 25% of the total axle load. No wheels failed this test and salient results, with those for a further test conducted to the limit of the test rig, are tabulated below in Table 2.

[28] Wheel unloading: Reduction in loading on a wheel as a result of vehicle dynamics or track irregularities which may be a precursor to wheel climb.

Simulated twist	**1:150** (test standard)	**1:73** (test rig limit)
Loading Condition	**% of total vehicle axle load**	
IÉ test standard	25.0	n/a
Minimum for 16 wheels tested	29.5	18.7
Average for 16 wheels tested	33.0	22.7
Up wheel of leading axle of wagon 3 (believed to be first to derail)	35.8	25.7

Table 2 Table showing results of simulated wagon test for track twist

Measurements taken after the accident indicated that, while wheel wear had occurred, this was not excessive and the wheel profiles were within IÉ maintenance tolerances. The wear had however reduced wheel conicity [29], increasing the potential for hunting [30] and flange contact [31] with the gauge face [32] of the rail and therefore also for wheel climb.

7.2.7 The Secondary Deck:

The potential for the secondary deck to have initiated the derailment is significant, and this is discussed in detail in Section 7.3.

[29] Wheel conicity: Inward inclination of the rail and wheel running surfaces designed to create restoring forces that centre the train on straight track.
[30] Hunting: Tendency for a vehicle to swing from side to side.
[31] Flange contact: Situation during wheel climb where wheel contact transfers from the normal wheel/rail running surfaces to the wheel flange and gauge face of the rail.
[32] Gauge faces: The inner faces of the rails between which gauge is measured.

7.3 Assessment of the Secondary Deck of the Viaduct

Two factors make assessment of the secondary deck structure difficult. Firstly, there were no drawings or structural standards in place at the time of the accident, although some historical drawings were available and used for comparative purposes. Secondly, the section of deck where it can reasonably be assumed that the derailment commenced was disturbed in the accident.

However, since the whole Viaduct deck was subject to the same inspection and maintenance regime the condition of the approximately 40% that remained intact following the derailment may be taken as indicative of that of the remainder that was destroyed. For illustrative purposes, a sketch plan view of the intact portion of the deck is shown in Appendix 3, figure 34.

The potential for the secondary deck to have initiated the derailment is treated under the following headings:

- Type and Condition of timbers;
- Dilution of standards;
- Complexity;
- Inspection and Maintenance;
- Replacement of the way-beams;
- Derailment containment;
- Way-beam 6.

Figure 14 **View of secondary deck, looking back toward point of original derailment**

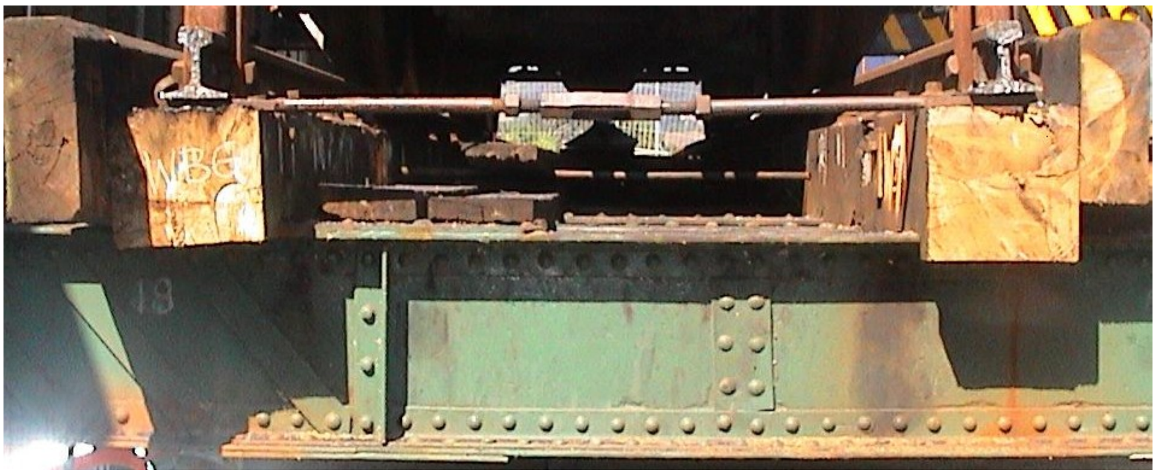


Figure 15 **View of secondary deck at transverse girder 18, with way-beam 6 at left**

7.3.1 Type and Condition of timbers:

No systematic record of the replacement of the various component timbers was kept and therefore, with the exception the recently replaced way-beams and guard-beams, it is not possible to say how long each had been in service. Inspection indicated a considerable variation in their type, age and condition. Independent of the mix of hard and soft woods utilised, their differing ages and degrees of deterioration would have resulted in variation in the structural properties along the Viaduct deck.

Figure 16 **Rail mounted on way-beam 6, with adjacent guard-beam 6 in poor condition**

7.3.2 Dilution of standards:

In so far as any standard existed for the construction of the secondary timber deck the historical drawings can be taken as indicative of same. These show the size, number and location of the various timber components and of the various metal ties and fastenings. Drawings dating from 1911 showed proposals for more substantial re-timbering of the secondary deck, though there are no indications of these having been adopted.

Inspection of the intact section of the deck and of recovered materials indicated an apparent degradation of this indicative standard and its application over the life of the Viaduct. This had probably been a gradual process resultant, in the absence of formal standards, on the adoption of a policy of like-for-like replacement. It is considered likely that such an approach would have lead to quality being compromised rather than enhanced, with the omission of a component or relaxation of a tolerance on a particular occasion becoming the standard template for subsequent replacement.

On the Viaduct this was evidenced by a general lack of consistency in the secondary deck structure in that:

- there was considerable variation in the length of way-beams and guard-beams and the nature and relative location of the joints between them, with the length of way-beams currently being provided being nominally half as long as the 11.9m (39') beams proposed in the 1911 drawings;
- some of the washers on the ends of the tie-rods that held the way-beam and guard-beam assembly together were in excess of 100mm square, while others were little more than the size of a standard engineering washer for that diameter rod (Figure 17);
- there was considerable variation in the depth and quality of notching in the underside of the various way-beams;
- in some cases the guard-beams were seated on top of walkway timbers and in other cases they were not, and
- some tie-rods appeared to have been omitted, as evidenced by the lack of drilling of way-beams to match corresponding holes in the flitch plates.

Figure 17 **Guard-beam showing tie-bar and washer.**

The configuration of the timbers, as indicated in a drawing of the Viaduct prepared after the accident by the Divisional Engineers, differs from that shown in the historical drawings in that the guard-beam is shown seated directly on the transverse girders as opposed to top of the walkway timbers: the same configuration was also indicated on a sketch prepared in 1982 (Figure 31 in Appendix 2).

7.3.3 Complexity

Actions taken subsequent to construction have served to complicate the relatively simple original design of the secondary deck. In that design, it would appear that the way-beams were intended to sit directly on top of the transverse girders without any requirement for notching. To facilitate this, the rivets in the upper flange were inserted from below, leaving the top face of the upper flange relatively flat.

When the top flanges of some of the transverse girders were reinforced with plates, these were secured to the upper face and the rivets inserted from the top. Not only, therefore, did the plates themselves break the continuity of the level seating of the way-beams, but the domed rivet heads exacerbated this situation.

Figure 18 **Old guard-beam abutting new guard-beam on Up side: way-beam behind has deep notching at its base**

On the Up side, some of the reinforcing plates on top of the transverse girders commenced half-way across the way-beam seating, (see section 4.5, figures 9 and 10). This meant that those way-beams, in addition to requiring notching to accommodate the reinforcing plate and its rivets, also required packing [33] to create a level seating across their whole width.

[33] Packing or Packs [23]

It seems unlikely that, in carrying out this reinforcing, there was a full appreciation of the impact on the way-beams, both in terms of the increased difficulty in installing them effectively and their increased vulnerability to decay resultant on notching.

In some instances, way-beams appeared to have been notched over transverse girders the top flanges of which had not been reinforced. When and why this more extensive practice of notching developed is not clear. If, at the time of construction of the bridge, there had been variance in the level of the tops of the transverse girders, it is likely that this would have been minor, requiring only minimal notching of some way-beams to compensate. On the intact portion of the deck however both Up and Down way-beams were notched over all the transverse girders, in some instances to a depth of 90mm which is approximately 30% of the overall depth of the beam (see figure 18).

Figure 19 **Down guard-beam and decking arrangement**

Figure 20 **Up guard-beam and decking arrangement**

As illustrated by the 1911 drawing, it was clearly intended that the 75mm walkway timbers would extend under the guard-beams and support them. On the section of deck that remained intact after the accident this was the case for the Down guard-beams only (see figure 19).

The walkway timbers did not extend under the Up guard-beams which were either seated directly on top of the transverse girders or supported only by the lateral bolts securing them to the associated guard-beams (see figure 20). In the case of way-beam 6 for example, the guard-beam was 25mm above the transverse girder 18 (Figure 21). Any guard-beam mounted in this way would not only have failed to help counter any rotational force applied to the way-beam through the rail by a train but also would have acted with this force.

Figure 21 **Up guard-beam suspended over transverse girder 18, at way-beam 6**

7.3.4 Inspection and Maintenance:

To be effective, an inspection and maintenance regime needs to be both planned and preventative. Timely identification and rectification of deterioration ensures that components and systems are fit for purpose at all times and that failures and accidents are prevented. In the case of the regime in place on the Viaduct at the time of the accident, there appear to be been shortcomings in both inspection and maintenance.

While there was a basic planned structure to inspections in terms of frequency, content and guidance, this did not reflect the magnitude of the various risks arising from the use of the Viaduct. The fact that the bridge deck was incapable of sustaining the load of an uncontained derailment was recognised. However, the fact of the way-beams and guard-beams being therefore, arguably, the most safety critical elements of the structure was not reflected in the inspection and maintenance regime. While some guidance was given in MW41 on the potential defects to be looked for while conducting inspections of the masonry and iron/steel bridge systems, none was available in relation to the more perishable timber elements.

The structural assessment of the Viaduct conducted by IÉ found that the masonry and iron/steel structural systems had been fit for purpose at the time of the accident. This view appears to be robust. Inspection of the intact section and of recovered debris suggests that this cannot be said for the secondary timber deck. This was particularly so in two areas, i.e., derailment containment, and the condition of way-beam 6 that had been scheduled for replacement the week after the accident.

There is no indication that the “further inspection” recommended in the findings of the inspection of the Viaduct on 09/07/2002 ever took place. By inference, it was envisaged that this would include concealed or inaccessible parts of the structure. Had this happened, some of the deficiencies in the secondary timber deck structure may have been identified sooner and remedial action taken.

7.3.5 Replacement of way-beams:

The replacement of three way-beams and their associated guard-beams only two days previously was significant in structural terms and, if not carried out satisfactorily, undoubtedly had potential to cause derailment.

Preparatory work on the new way-beams had been carried out in advance of installation. In the absence of standards or drawings, the work was carried out by simply replacing like with like. This involved cutting notches in what would be the underside of the way-beams to accommodate the wrought iron transverse girders on which they would sit. The way-beams that were to be replaced were used as templates for the preparatory work on the new beams, with the depth of the various notches in a specific way-beam being measured from a reference line on the side of its counterpart old way-beam. The work was carried out by the Limerick Junction Bridge Maintenance Gang under the direction of the Bridge Foreman.

The replacement work was carried out under a track possession [34] by two work gangs, namely the Bridge Gang and the Permanent Way Gang.

The Bridge Gang was responsible for the removal of the old way-beams and guard-beams. It was also responsible for further preparatory work on the replacement way-beams involving secondary notching to accommodate the rivet heads in the top flange of the transverse girders, for the boring of holes to take the way-beam and sole plate securing bolts and screws and for their final installation.

It was the task of the Permanent Way Gang to remove the rails and fixings prior to replacement of the beams and to replace them once the new beams were in place. In practice, the two gangs worked as a single team. The work was completed within the period of the possession which was listed for the day in IÉ's Weekly Circular [35] No. 3056 between 07.00 hours and 17.00 hours on 5th October and, following final inspection, the line was reopened to traffic.

[34] Track possession: Temporary cessation of train movements on a track, typically to facilitate maintenance and development works.
[35] Weekly Circular: A publication that lists operational information such as temporary speed restrictions, maintenance works, etc.

Notwithstanding the lack of standardisation, both gangs had a full understanding of the work involved in replacing the way-beams and how it was to be carried out. This included an appreciation of the safety criticality of the work and particularly of the necessary quality of workmanship. In this context, the view expressed by both teams that their work was completed satisfactorily and were fit for purpose when returned to service appears robust. This is supported by the fact that the replacement way-beams and associated guard-beams appear to have contained the derailment and that 14 trains, some of similar type and loading to that involved in the Derailment, had crossed the Viaduct without incident subsequent to completion of the works.

7.3.6 Derailment containment:

It seems that that the Viaduct guard-beams were there to either deflect or to contain the wheels in the event of a derailment, although exactly which of these was to be achieved is not clear from available documentary evidence. The rapid escalation of the derailment, resulting in the disproportionate collapse of the Viaduct deck, suggests that the containment or guarding arrangement was inadequate. Given the safety criticality, the guarding arrangement should have been adequately specified and maintained.

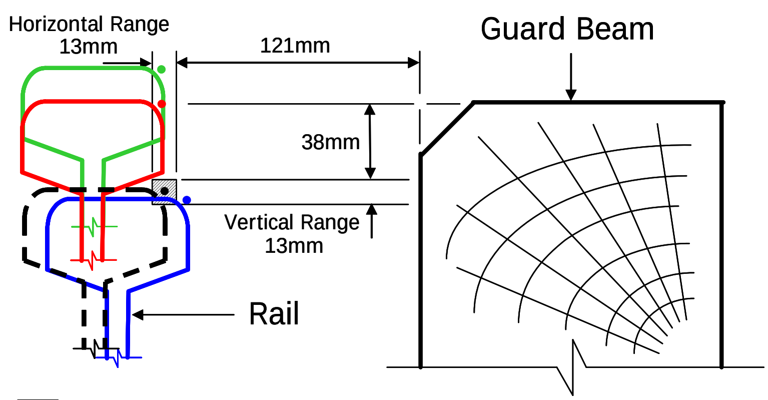
Available Viaduct drawings are consistent in showing way-beam and guard-beam dimensions as nominally 305mm x 305mm and 406mm x 152mm respectively and the depth of the walkway timbers as 76mm. When seated on top of the walkway timber, as indicated in drawings dating from 1911, 1955 and 2003 (Appendix 2, figures 29, 30 and 32), the top of the guard-beam would have been 177mm above the top of the way-beam and 48mm above the rail.

The only available drawing relating specifically to provision of derailment protection on the Viaduct is a 1982 IÉ sketch (Appendix 2, Figure 31). This indicates the required height of the top of the guard-beam over the top of the rail to be in the range 38mm-51mm (1½”-2”) and the gap between its inner face of the guard-beam and the outer face of the rail head in the range 120mm-133mm (4¾-5¼”). In the sketch, no beam or timber dimensions are given and the guard-beam is erroneously called a way-beam. The 1982 sketch shows the guard-beam seated directly on the transverse girder rather than on top of the walkway timber. In showing an arrangement that contradicted previous drawings, this apparent error may have introduced confusion.

The drawing of the secondary deck prepared by IÉ in 2004 (Appendix 2, figure 32 is not compliant with the derailment protection requirements shown in its 1982 sketch and shows the rail-head higher than the top of the guard-beam. As in the 1982 sketch, the guard beam is also shown seated directly on top of the transverse girder rather than on top of the walkway timber.

The rail type shown in the 1956 drawings is 85lb/yard flat bottomed which has a height of 129mm. In this case, if the rail had been mounted directly and centrally on top of the way-beam as shown in the 1982 IÉ sketch, its position relative to the guard-beam would have been within vertical tolerance limits but 4mm tighter than the horizontal tolerance.

The 50kg/m rail installed on the Viaduct in 1996 was mounted on sole plates, giving it a rail-head height of approximately 179mm above the top of the way-beam. This raised the rail height by 50mm, leaving the guard-beam 2mm below the top of the rail rather than the required 38mm to 51mm above the rail. With the sole plate mounted centrally on the way-beam, and allowing for the 1:20 inward inclination of the rail, the horizontal guard-beam gap would have been within the required tolerance range.



Acceptable range of rail-head position based on 1982 IE sketch

Optimum rail-head position based on 1982 IE sketch

85lb/yard rail-head position based on 1956 IE drawing

50kg/m rail-head position as installed on viaduct in 1996

Maximum rail-head height over top of guard beam measure post derailment

Figure 22: Sketch showing acceptable range, expected position and actual position of rail-head, relative to Up guard beam

Following the accident, the height of the rail-head relative to the top of the guard-beam was measured at the Up side over the intact section of the deck. At all points, the top of the guard-beam was less than the indicated minimum height of 38mm over the rail-head. Over the last 12m of rail that was undisturbed in the accident the guard-beam was found to be as much as 56mm lower than the indicated minimum height, i.e., 18mm below the rail-head.

At some point, a practice had developed of forming an approximately 20mm chamfer along the upper edge of the guard-beams, though the reason for this is not clear. In contrast, historical drawings show a sharp edge on these corners.

There were undoubtedly safety benefits in the installation of the heavier section, longer length, 50kg/m rail in 1996, but there is no evidence of guarding arrangements having been reviewed at this time. Inconsistencies in related documents and practice indicate a lack of clarity regarding how the guarding arrangement was intended to work in practice, and a lack of appreciation of the need to maintain its effectiveness.

Figure 23 **Outward tilt of way-beam 6**

Figure 24 **Height of rail above guard-beam at Way-beam 6**

7.3.7 Condition of way-beam 6:

The condition of way-beam 6, which was the last remaining of the four scheduled for replacement and was not materially damaged or displaced by the derailment, requires particular consideration. This way-beam was 5.45 metres long, and extended from transverse girder no. 15 to no. 21 on the Up side. Transverse girder no. 24 was located approximately three metres (9’) beyond the end of way-beam no. 6: the IÉ consultants’ report indicates that the track prior to this point did not appear to have been badly disturbed.

Based on site inspections, the following observations were made in relation to way-beam no. 6:

a) It was clear from cursory inspection that the inner face was out of verticality and consequently the upper surface was off-level (Figure 23). The beam was surveyed on a number of occasions the results indicating that there was an outward slope on the top of the beam of approximately 1:15.5. This meant that the effect of the inclined sole-plate seating was negated and the rail had an outward inclination of approximately 1:70 rather than an inward inclination of 1:20.
b) When this beam was lifted it was noted that there were 12mm reinforcing plates riveted to the upper faces of the supporting transverse girders and that these extended across the inner half of the way-beam seating. However, in contrast with way-beam 8, there were no supporting packing plates over the outer half of the seating to ensure that the way-beam was both level and prevented from rotating outwards (Figure 26 illustrates).
c) The static gauge varied between 1615mm and 1623mm as compared with the standard for straight track of 1602mm.
d) Over the length of the way-beam the top of the guard-beam was on average 6mm lower than the top of the rail rather than being in the prescribed range 38-51mm above it (Figure 24 illustrates).
e) The IRSC surveyed the way-beam on three occasions. Between these surveys rail vehicles were brought onto the intact section of Viaduct deck both as part of the process of making the site safe and secure and of the load test conducted by IÉ’s consultants. There were variances in both the gauge and the measured inclination of the top of the way-beam between surveys indicating that rotational movement about its longitudinal axis had occurred. This would have resulted from the movement of rail vehicles onto the deck.
f) There was an indication of further widening of gauge occurring that was proportionate to load. Measured gauge increased progressively from the unloaded state, through that of the EM50 track recording vehicle that has a 9 tonne axle load, to

the post accident load test by IÉ's consultants where the axle load was approximately 16 tonnes.

g) Significant vertical elongation was noticed in a hole drilled through the way-beam to accommodate a tie-rod suggesting that rotational movement had been occurring for some time prior to the accident (Figure 25). In addition, and in contrast with the adjacent way-beams 4 and 8, the four vertical bolts securing this way-beam to the transverse girders were all loose, with in excess of 25mm of the bolt shank visible between the bolt-head and the underside of the girder top flange (Figure 26).

Figure 25 **Tie-rod hole elongation on way-beam 6, between transverse girder 15 & 16**

Figure 26 **End of Way-beam 6 at transverse girder 21**

h) IÉ's post accident survey data indicated significant track cant of about 1:68 in the area of way-beam 6, with the Up rail-head as much as 23.5mm lower than the Down rail-head. While data from two such surveys show the same pattern of cant over the intact deck there are variances in the values, again indicating that track movement had occurred between the surveys.

i) The impact of the adverse gauge and cant was illustrated during the load test in that the flange of the Up-side wheel of one axle seated over way-beam 6 was hard against the gauge-face of the rail while the outer edge of the corresponding Down-side wheel was located approximately centrally over the rail-head (Figure 27).

j) An approximately 600mm x 200mm x 50mm section of the outer underside of the way-beam between transverse girders 16 and 17 came away easily under hand pressure (Figure 28).

Figure 27 **Opposite wheels of test train axle at Way-beams 6 and 7 respectively**

Figure 28 **Badly deteriorated timber removed from underside of way-beam 6**

k) Although, in accordance with the configuration indicated in historical drawings, the associated guard-beam appears to have been attached to way-beam 6 at such a level as to allow it to sit on top of the walkway timbers it did not in fact do so. It is not clear how this situation came about but as a result the guard-beam, being unsupported from below, imposed an additional outward rotational load on the way-beam rather than helping to support it (section 7.3.3, Figure 21).

l) The flitch plates were located to accommodate the 11.9m (39') way-beams shown in the 1911 drawings. Way-beam no. 6 was only half the length so flitch plate restraint, which would have helped to counteract rotational forces, was only available at one end rather than at both ends of the way-beam.

Although way-beam 6 was scheduled for replacement, this should have been done before it reached the undoubtedly unserviceable condition that it was in at the time of the accident.

7.3.8 Possible derailment mechanism:

While, relative to the position of the drop-off marks on the Up rail, way-beam 6 is located in an area where the derailment might reasonably have been expected to have commenced, it is not possible to say for sure whether the condition of way-beam 6 was solely or partly responsible for initiation of the derailment.

The adverse lateral rotation of this way-beam under load would suggest that load may have contributed to the critical state that led to derailment. The propensity of the wagons to roll laterally would also be more pronounced in laden wagons.

IÉ’s consultants considered that two track-related factors may have been primarily responsible for initiating wheel climb and derailment. They demonstrated through dynamic modelling that the presence of cyclic cant [36] would have contributed to lateral roll. They also concluded that the significant gauge narrowing between the defective track, as evidenced by way-beam 6, and the new way-beams that had been installed to correct gauge two days before the accident, would have generated significant lateral forces.

In addition to the gauge narrowing on the approach to the new way-beams, there would also appear to have been a step change in the resilience of these two sections of track: the defective way-beam structure giving a much softer ride than the much tighter structure in the area of the new way-beams. If this was the case then there may only have been significant risk of derailment after these works were completed.

Static measurements showed significant cant of about 1:70 at way-beam no 6. This would have encouraged the wheels to ride close to the lower (right-hand) rail. This, combined with the worn wheel profiles on the wagons, indicates that wagons would have tended to run in flange contact with the lower rail. The outward rotation of the same way-beam by about 1:15.5 had lessened the angle between the wheel flange and the inner face of the lower rail, making conditions more favourable to the initiation of wheel climb.

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[36] Cyclic cant: repetitive rise and fall in the track cant [10] value while travelling along the railway.

7.4 Risk to life:

It appears unlikely that a catastrophic failure or event caused the accident and it is likely that the Derailment was initiated by a combination of factors reaching criticality. Some of these factors such as the combination of vertical and horizontal loads imposed by the Train should have been adequately sustained by that track had it been fully fit-for-purpose.

The combination of factors that caused the Derailment may have occurred previously but without reaching criticality, and trains crossing the Viaduct may have been at risk of derailment for some time prior to the accident. Almost certainly there was significant risk to some of the fifteen trains that crossed the Viaduct after maintenance works were completed on the Sunday prior to the accident Although this included two passenger trains, the advanced computer modelling conducted by IÉ's consultants indicated that the performance of passenger vehicles is generally far better than that of the wagons that made up the derailed freight train. This indicates that the risk of derailment of a passenger train would have been significantly lower than the risk to a freight train.

Seven of the fifteen trains passed over the Viaduct during daylight hours, when there would have been a greater likelihood of members of the public using the riverside path beneath the Viaduct and of their being at risk had a derailment occurred that similarly led to the collapse of the Viaduct.

7.5 EM50:

The data output from the EM50 track recording vehicle was not critical in terms of the causal analysis of this accident. Given however the importance of the effective operation of the machine in the context of IÉ's overall track monitoring programme two particular facts that emerged during the course of the wider accident investigation are significant. Throughout the IÉ system mileposts are marked along the trackside as well as the intermediate ¼, ½, ¾ mile locations. During the course of the survey run the operator of the EM50 uses the event recorder [37] to indicate the location of these mileposts so that the output data can be subsequently correlated with features on the ground.

In analysing the EM50 output trace for the run between Waterford and Limerick on the Saturday prior to the accident the Divisional Engineer found that the indicated mileage

[37] Event recorder: Mechanism for manually marking specific events (locations) on the graphical output of measuring equipment, in this instance the EM50 track recording vehicle.

was incorrect relative to other recorded parameters such as cant and curvature. This was due to the event recorder not having been operational on the day of the survey.

Similarly, in their analysis of data associated with their modelling of the dynamic interaction of the Train and track, IÉ's consultants found inconsistencies in the relationship between recorded gauge and cant. To fully synchronise the output it was necessary to advance the cant record by 22m relative to the gauge record.

Comparison of EM50 cant measurements with those of manual post accident surveys also suggested that under certain conditions the EM50 was under-measuring cant by approximately 50%. The IRSC also noted very significant and variable longitudinal offset between the graphic and numeric outputs of the same data stream.

8 Conclusions:

The weather, malicious act, catastrophic failure of the viaduct, structural performance of the masonry and iron/steel elements of the Viaduct and the standard of workmanship in the recent replacement of way-beams and guard-beams can all be ruled out as having caused or materially contributed to the accident. The train speed may have contributed to the extent of revealing a critical fault in the track, but it can be ruled out as a cause.

The response to the accident by all agencies involved was both timely and effective including procedures for the protection of the public and the environment.

Examination of the Train following the accident identified no safety critical faults. Similarly, tests conducted on wagons 1-4, one of which almost certainly was the first to derail, indicated that components that might significantly contribute to derailment potential were all within operational maintenance tolerances. The construction of the cement wagons made them more sensitive to track irregularities than bogie wagons, but laden cement wagons rarely derail.

Before arriving at the Viaduct, the Train had successfully passed through a number of locations where the ballast track was in poor condition. However, failure to maintain track parameters is more critical on way-beam structures, which are more rigid and less forgiving than ballast track.

Significant evidence was lost as a result of the extensive damage sustained by the Viaduct in the accident. However, on the basis of available evidence it is possible to say with reasonable certainty that of the various factors than combined to cause the derailment, the safety critical shortcomings in the Viaduct secondary deck timber structure and its associated inspection and maintenance regime were principally responsible for the accident. These included the absence of:

- consistent design detail for what was arguably the most safety critical part of the Viaduct,
- a fully specified and risk based inspection regime,
- adequate standards and specifications for maintenance works,
- adequate training of staff involved in inspection and maintenance and
- effective provision for derailment containment.

In publishing its 1998 Review of Railway Safety in Ireland, the consultants International Risk Management Services (IRMS) highlighted the risks associated with the absence of fully developed and promulgated standards and specifications and the reliance on un-documented local procedures and solutions. Despite good progress in addressing other aspects in the management of IÉ's infrastructure, it would appear that in this context significant deficiencies remained. If appropriate standards and specifications had existed at the time of the accident and had been rigorously applied in relation to the design, inspection and maintenance of the Viaduct it is unlikely that the Derailment would have occurred.

8.1 Safety Criticality:

There was an appreciation among IÉ staff, from senior engineering management to ground level operatives, of the principal risks associated with the operation of trains over the Viaduct. This was not however translated into an inspection and maintenance regime or into standards and guidance that reflected the safety criticality of the Viaduct as a whole or of its various structural elements.

The responsibility for, and extent of, all railway works should be adequately defined. In relation to any specific task, what is to be done, and why and how it will be done should be clearly understood by all involved.

<u>Recommendation 1</u>
IE should conduct a review of its safety management system to identify all areas where design, inspection and maintenance procedures are not fully developed and documented, and should establish a programme to develop and implement the necessary specifications and standards prioritised on the basis of safety risk.

The content and structure of each specification or standard should reflect the safety criticality of the various elements of the associated procedure or physical asset.

(Review 6 months, Establish programme within 24 months)

Since its construction various modifications had been made to the Viaduct deck. Whether or not the adverse safety impacts of some of these modifications were fully appreciated is not clear. For all structures, new and old, the reasons for adopting a particular design must be clearly understood as should the reasons for, and implications of, making any modification to that design.

<u>Recommendation 2</u>
For remaining way-beam structures IÉ should review all available drawings and design documentation to identify, in so far as is practicable, variances from the original designs, and ensure that any safety implications are fully understood and that associated safety risks are reduced to as low as reasonably practicable.

(Review 3 months, Mitigation programme completed 24 months)

8.2 Derailment protection:

The magnitude of the accident was disproportionate to the failure(s) that caused the initial derailment. If the guard-beams had been able to effectively contain the Derailment the damage would have been restricted to the track, way-beam and guard-beam structure. It is not possible to say whether this would have been the case had the guard-beams been robust and in compliance with original design over the whole Viaduct. However, although the Up guard-beams that had been installed the previous Sunday survived, the opposite Down way-beams were progressively destroyed by the derailed train.

The reconstructed Viaduct deck incorporates guarding arrangements that reflect modern industry practice and is designed to support the load of a derailed train. There are however a number of other major way-beam structures on the IÉ system. The guarding arrangements employed on these structures vary considerably and in one instance no guards are installed.

<u>Recommendation 3</u>
IE should review the derailment containment arrangements on its various structures and make whatever modifications might be required to ensure that they are fit for purpose and capable of preventing disproportionate failure.

(Review 3 months, Modification programme completed 12 months)

Following the accident, IÉ implemented measures to control risk on structures similar to the Viaduct including speed restrictions and detailed inspection. While in force such interim measures require constant monitoring and review.

Recommendation 4
In parallel with, and pending implementation of Recommendations 2 and 3, IÉ should periodically review and amend as necessary the safety measures implemented at structures similar to the Viaduct to ensure that operational safety risk is reduced to as low as reasonably practicable.

(Review 3 months ongoing)

8.3 Training Needs Analysis

Learning on the job is part of the overall process on ensuring that individuals are equipped with the knowledge and skills required to carry out their work effectively. However, this needs to be supported by an appropriate process of formal training and assessment that ensures adequacy and commonality of such knowledge and skills throughout the organisation. The acquisition, maintenance and application of these skills must be measurable.

These issues were also highlighted in 1998 by IRMS who recommended that a training needs analysis be conducted and that appropriate training plans be put in place for all management and supervisory staff.

Recommendation 5
The training needs analysis conducted by IÉ on foot of the IRMS recommendation should be reviewed and, as necessary extended to include all staff involved in safety critical work. Where necessary new training plans should be introduced or existing plans modified or enhanced

(Review 6 months, Implementation programme completed 24 months).

8.4 Track Monitoring

It is essential that robust condition and performance data is available to underpin effective asset management. In relation to the track, such data was not available to IÉ at the time of the accident.

Recommendation 6
IÉ should implement a strategy that ensures that its ongoing track monitoring requirements are effectively met, particularly in the short term pending upgrading of the EM50 track recording vehicle.

(Review 3 months, Implementation 6 months).

8.5 EM50

The EM50 track recording vehicle is IÉ's principal means of ascertaining track condition. It was purchased in 1973 and the onboard monitoring equipment was refurbished in 1993. Though not directly related to the accident, its performance when the line was surveyed three days prior to the Derailment fell significantly short of what would be expected of contemporary equipment and technology of this type.

The consultants engaged by IÉ to assist it in conducting its internal investigation of the accident identified a number of problems with, and limitations of, the track recording vehicle, including very significant longitudinal offset between the gauge and cant channels and lack of consistent accuracy of cant channel measurement. The IRSC noted very significant and variable longitudinal offset between the graphic and numeric outputs of the same data stream.

IÉ has recognised that the EM50 track recording vehicle has significant shortcomings and accordingly has made provision for its upgrading in the proposed Railway Safety Programme 2004-2008. A wide variety of options are available for the active recording of track condition and it is important that these are fully assessed in the context of EM50 upgrading.

Recommendation 7
In developing a strategy for upgrading the EM50 track recording vehicle IÉ should ensure that all available technologies for monitoring track condition are fully assessed and the specified functionality reflects the best combination of available technologies.

(Assessment 3 months, Strategy 6 months).

8.6 Asset management:

Maintenance of comprehensive life-cycle records, from construction/procurement through operation and decommissioning, are a necessary part of a robust asset management system. IÉ has established a computerised data-base for bridge inspection and maintenance and is in the course of establishing a comprehensive Infrastructure Asset Management System. Data from both will be input to a system risk model that has been developed to underpin the Railway Safety Programme.

To be fully effective, these and other allied systems need to capture relevant data and to generate appropriate and timely outputs that are available to those who have immediate responsibility of the asset or have ownership of the risk. Closure of the feedback loop is particularly important so that all concerned both have confidence in the system, and have evidence that issues are being effectively dealt with.

Recommendation 8
IÉ should review, and amend as necessary, its asset management systems to ensure that data is pertinent, comprehensive, concise and accessible and provides evidence that all outstanding issues are appropriately actioned and closed out.

(Review 3 months, Amendment programme completed 12 months).

Implementing change, such as the development of data management systems on the scale currently being undertaken by IÉ, itself introduces risk. It is essential that during this interim period comprehensive and up-to-date infrastructure asset inspection and maintenance records are maintained and relevant data is effectively promulgated to those with related responsibilities.

Recommendation 9
IÉ should ensure that, pending full implementation and validation of new data management systems including those currently in course of development, comprehensive and up-to-date records of infrastructure asset inspection and maintenance are maintained and that relevant data is effectively promulgated to inspectors, maintainers and managers.
(Review and implementation 3 months)

8.7 Internal auditing:

An effective programme of internal auditing is essential to ensure that specifications, standards and procedures are fully and effectively implemented in all areas of operation.

> ***Recommendation 10***
> ***Provision is being made in the proposed Railway Safety Programme 2004-2008, for the establishment of internal IÉ auditing procedures. As with the overall safety development programme, IÉ should ensure that the introduction of these procedures is risk based with auditing introduced first in those areas presenting the greatest safety risk.***
>
> ***(Review 3 months, Risk based audit programme commenced 6 months)***

8.8 Speed Restriction and Monitoring:

The performance history of two-axle bulk cement wagons operating for 35 years on the IÉ network suggests that the general speed restriction of 64 km/h on these vehicles is robust. Nevertheless, computer modelling of the circumstances of the Derailment by the IÉ consultants indicated that under certain track conditions these wagons may display unstable running characteristics at and above that speed. It is advisable that further work would be done to establish the limits of stability of these vehicles within the context of wagon and track maintenance parameters, and to review the maximum permitted speed on that basis.

> ***Recommendation 11***
> ***IÉ should review the performance characteristics of two-axle bulk cement wagons within the context of their wagon and track maintenance limits, to determine the extent to which these maintenance limits and maximum permitted speeds are mutually compatible and to propose practical solutions if necessary.***
>
> ***(Review 3 months).***

At the time of the accident the Train was travelling slightly in excess of the permitted maximum speed but although this may have been significant it is not believed to be the primary cause of the accident.

The Driver failed to observe the 40 km/h speed restriction that terminated 630m before the Viaduct. This is similarly not considered to have been a primary cause, but in that instance Train speed was, in a safety context, significantly in excess of the permitted maximum speed.

Rules and regulations are established for sound operational and safety reasons and adherence to them is at the core of a developing and maintaining a positive organisational safety culture.

Train speed is significant in relation to both the potential for and impact of derailment. In this regard, the establishment of and adherence to appropriate maximum train speed limits for rolling stock and track is particularly safety critical. It is therefore important that effective monitoring arrangements are in place.

Recommendation 12
IÉ should review and amend as necessary its arrangements for monitoring adherence to both permanent and temporary maximum train speed limits, through a combination of line-side measurement, interrogation of in-cab recorded data and spot-checks of sectional running times of trains in service, to ensure that they are appropriate in the context of current driving practice.

(Review 3 months, Necessary amendments introduced 6 months).

The functionality of the Hasler recorders fitted to older IÉ locomotives like class 121 and 181 that were hauling the Train is limited. It falls significantly short of that provided by current related technology in the context of causal analysis of accidents and the monitoring of train speed . In contrast, IÉ's most recent class 201 locomotives and its diesel and electric multiple units are fitted with Teloc data-loggers that capture a wider range of functions over a longer timeframe. While this includes all the core safety functions, the data-loggers are designed as diagnostic tools and cannot be readily interrogated in the context of day-to-day safety monitoring.

The IRSC Report of the Inquiry into the Level Crossing Collision that occurred at Kiltoom Level Crossing on 16.02.01, recommended that the technology that IÉ now employs for in-cab data logging should be fitted to older classes of locomotive. This was that in the context of providing the facility to analyse train data when a journey is complete. IÉ is currently implementing this recommendation.

<u>Recommendation 13</u>
The functionality of the Teloc equipment currently in use by IÉ should be assessed, and modified as necessary, to ensure that it provides the level of access to data necessary for effective day-to-day safety management.

(Review 3 months, Necessary modifications implemented 24 months).

8.9 Driver Communications:

An effective means of communications between drivers of trains and the controlling signalman is essential, particularly under degraded operation or in an accident situation. The driver indicated that in reporting the accident he was unable to make use of the train radio as the Train was in a reception “black spot”. Though the time lost in resorting to other means of communication was not critical, had anyone been injured as a result of the accident it might well have been so.

<u>Recommendation 15</u>
IÉ should review its existing communications systems and take whatever action is necessary to ensure that on all parts of their system train drivers are provided with an effective means of communicating with the controlling signalman.

(Review 3 months, Necessary change implemented 24 months).

Appendix 1: Wagon details

CAHIR DERAILMENT, 07/10/03 Train vehicle location. Registration, weight and examination details						
Vehicle	Number		Weight (tonnes)	Examination		
	Train Location	IE Registration		6 Month	2 year ultrasonic	General Repair
Locomotive	1					
	2					
wagon	1	25163	30.44	12/09/03	19/12/01	19/12/01
	2	25198	30.58	03/10/03	15/04/03	15/04/03
	3	25091	30.72	05/09/03	26/03/02	26/02/98
	4	25137	30.44	06/10/03	01/04/03	01/04/03
	5	25120	30.68	04/07/03	18/04/03	09/02/01
	6	25051	30.54	04/07/03	04/03/03	04/03/03
	7	25178	30.78	25/04/03	25/04/03	26/03/99
	8	25155	30.56	02/05/03	02/05/03	02/05/03
	9	25138	30.56	04/04/03	04/04/03	04/04/03
	10	25156	30.58	09/05/03	09/05/03	21/05/99
	11	25110	30.64	11/07/03	09/11/01	09/11/01
	12	25107	30.54	26/09/03	22/11/02	22/11/02
	13	25084	30.74	16/05/03	16/05/03	01/04/98
	14	25060	30.56	06/05/03	06/05/03	06/05/03
	15	26185	30.64	16/05/03	16/05/03	13/07/01
	16	25153	30.50	19/09/03	19/04/02	19/04/02
	17	25114	30.64	22/08/03	05/07/02	05/07/02
	18	25055	30.54	22/08/03	15/01/01	26/07/02
	19	25075	30.66	23/05/03	23/05/03	23/05/03
	20	25157	30.56	23/05/03	23/05/03	23/05/03
	21	25083	30.70	29/08/03	02/11/01	02/11/01
	22	25173	31.22	29/08/03	11/07/03	01/04/98

(red)	Denotes examinations outside prescribed period
(orange)	Denotes condition assessed deferral of examinations

Table 3 Table of train consist, vehicle registration, weight and exam details

Appendix 2: Cross-section drawings

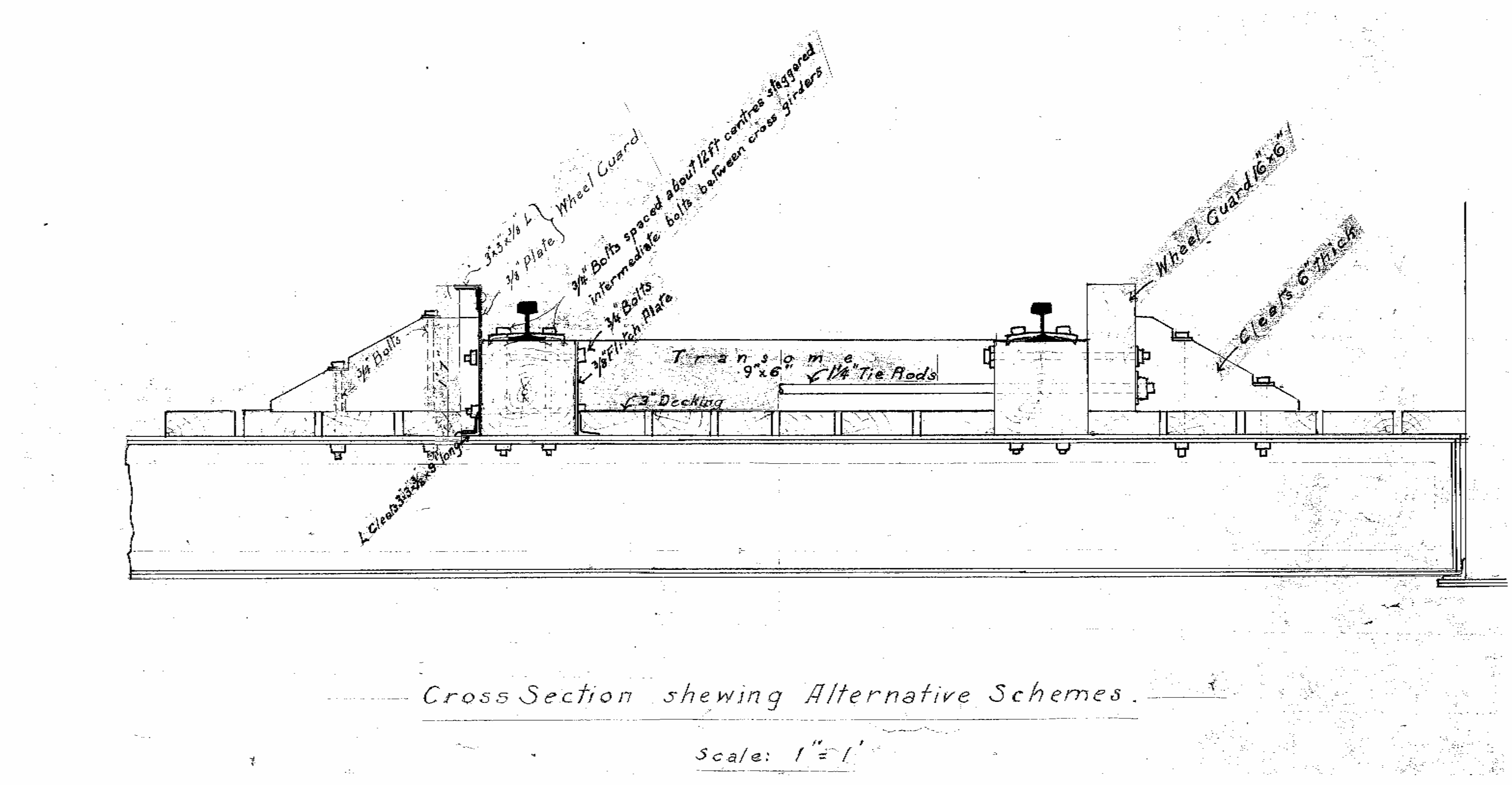


Figure 29 **Cross-section showing alternative schemes for re-timbering (GS&WR,1911)**

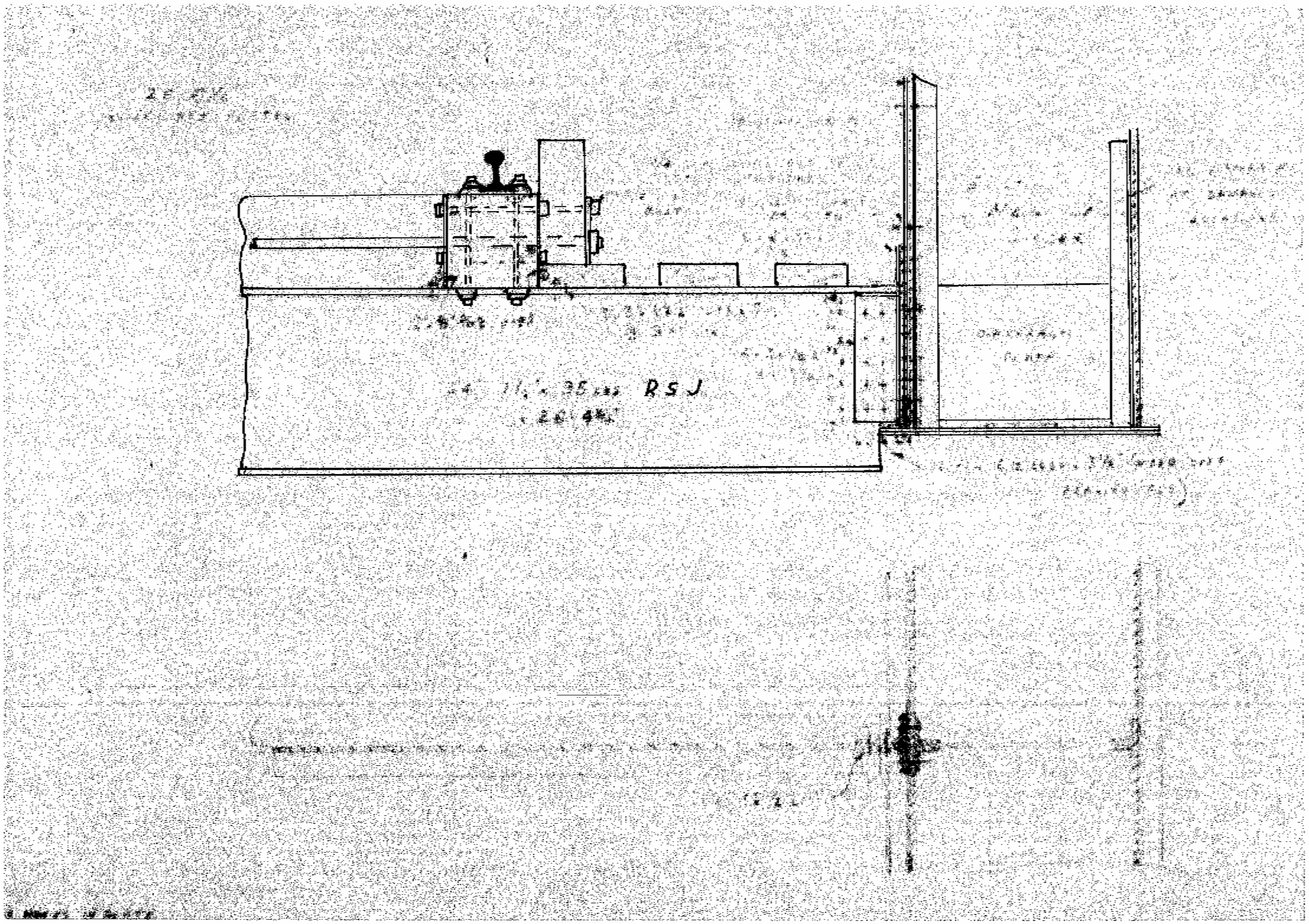


Figure 30 **Detail of new transverse beam arrangement (GSR, 1955)**

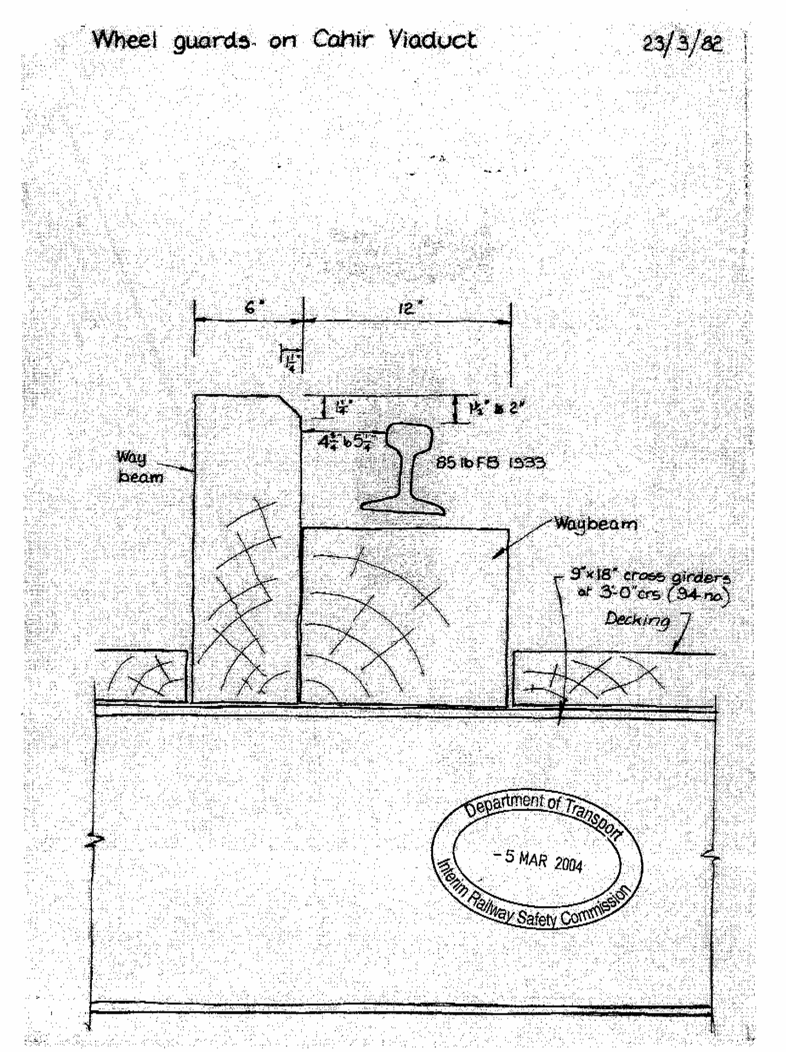


Figure 31 **Cross-section detail of wheel guards (CIÉ Chief Civil Engineers, 1982)**

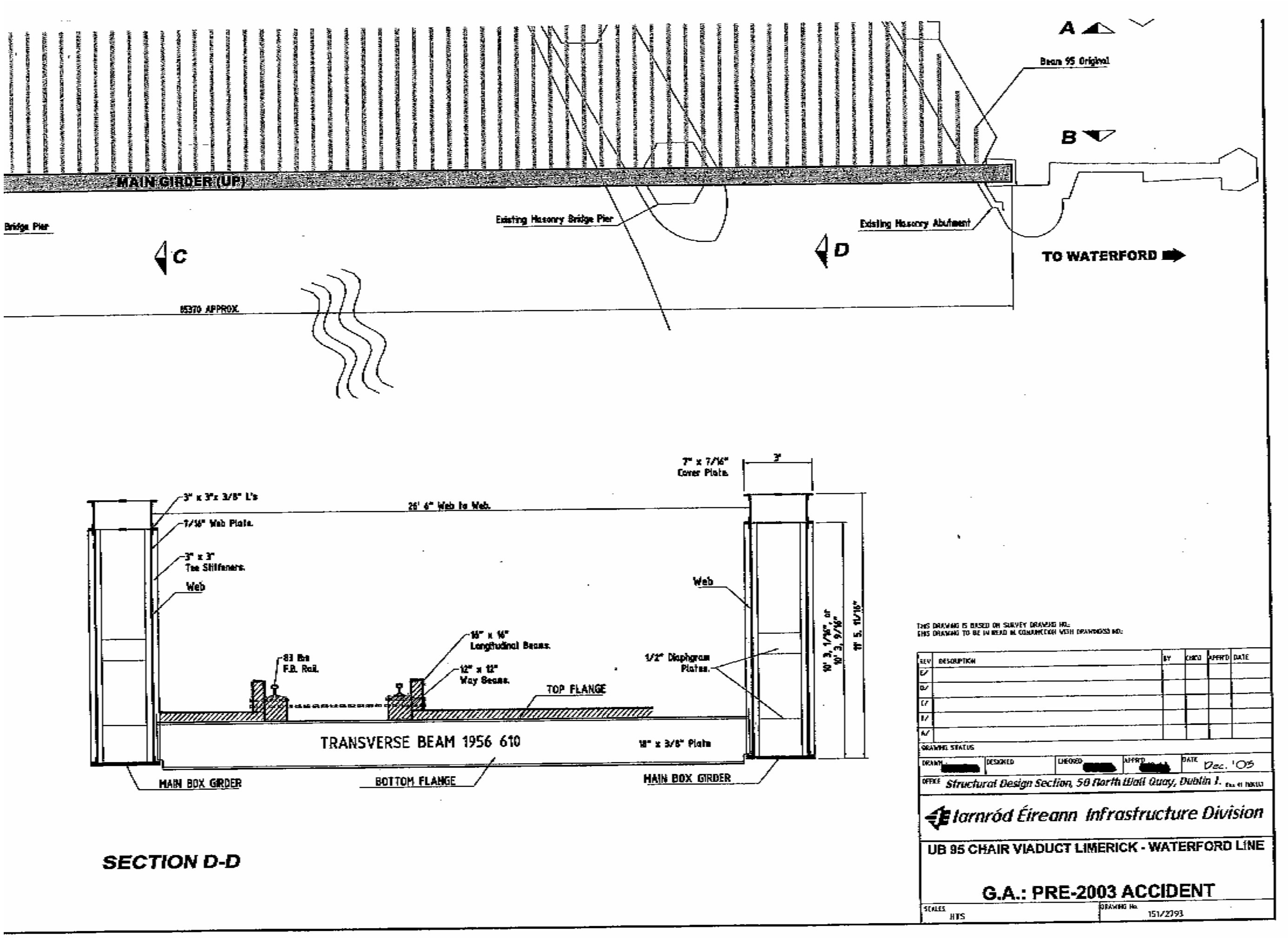


Figure 32 **Cross-section of structure pre-2003 accident (IÉ Structural Design, 2003)**

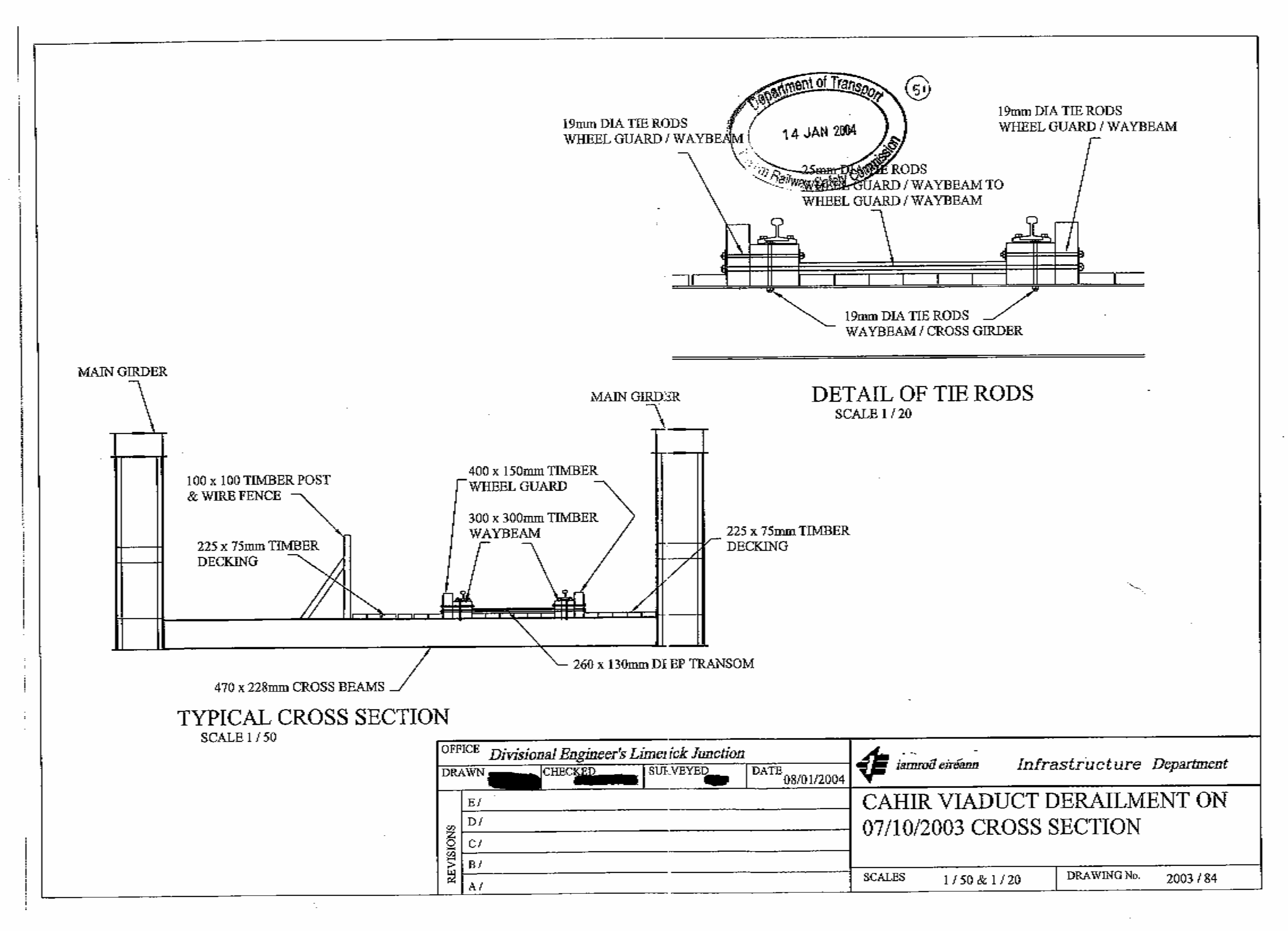
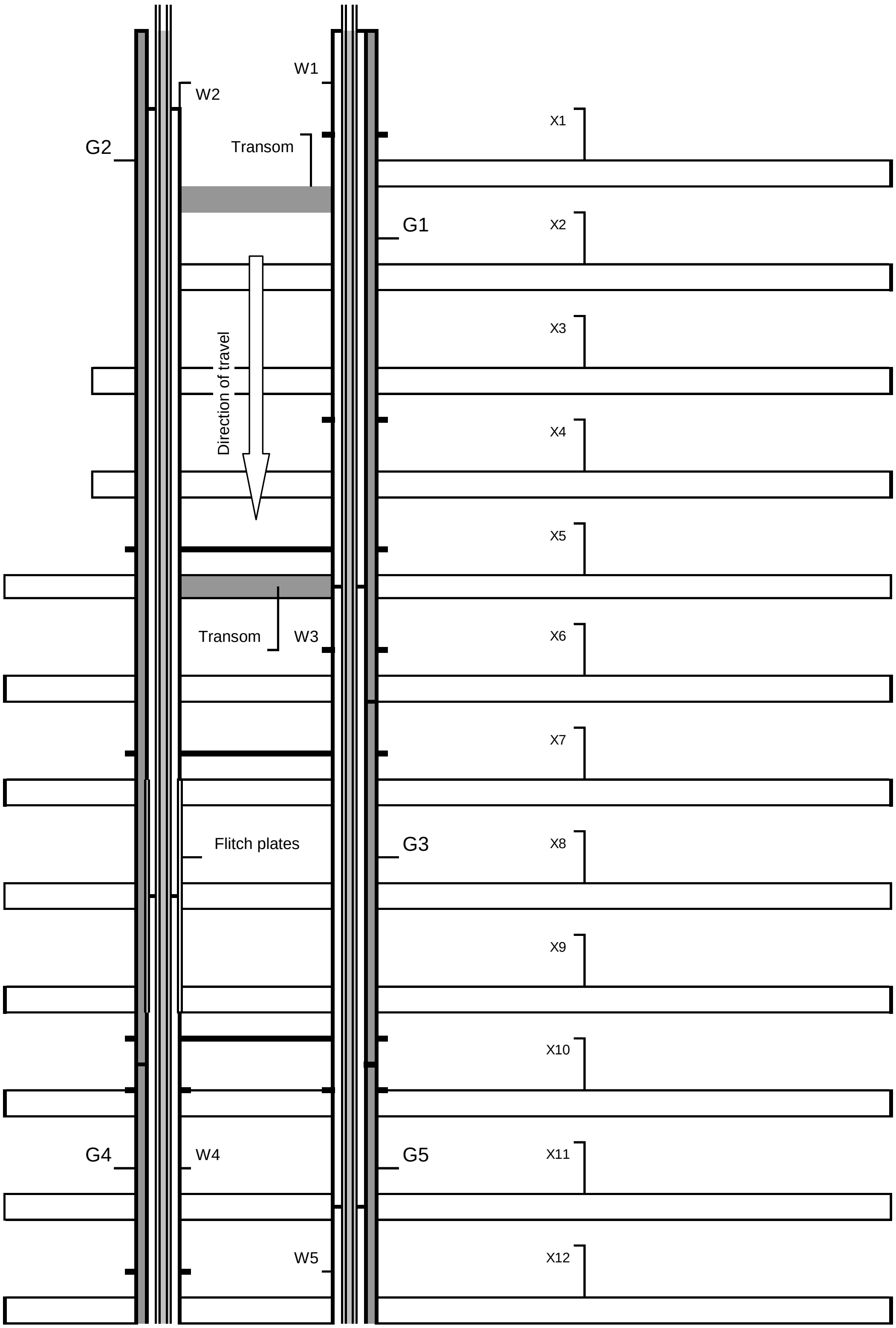
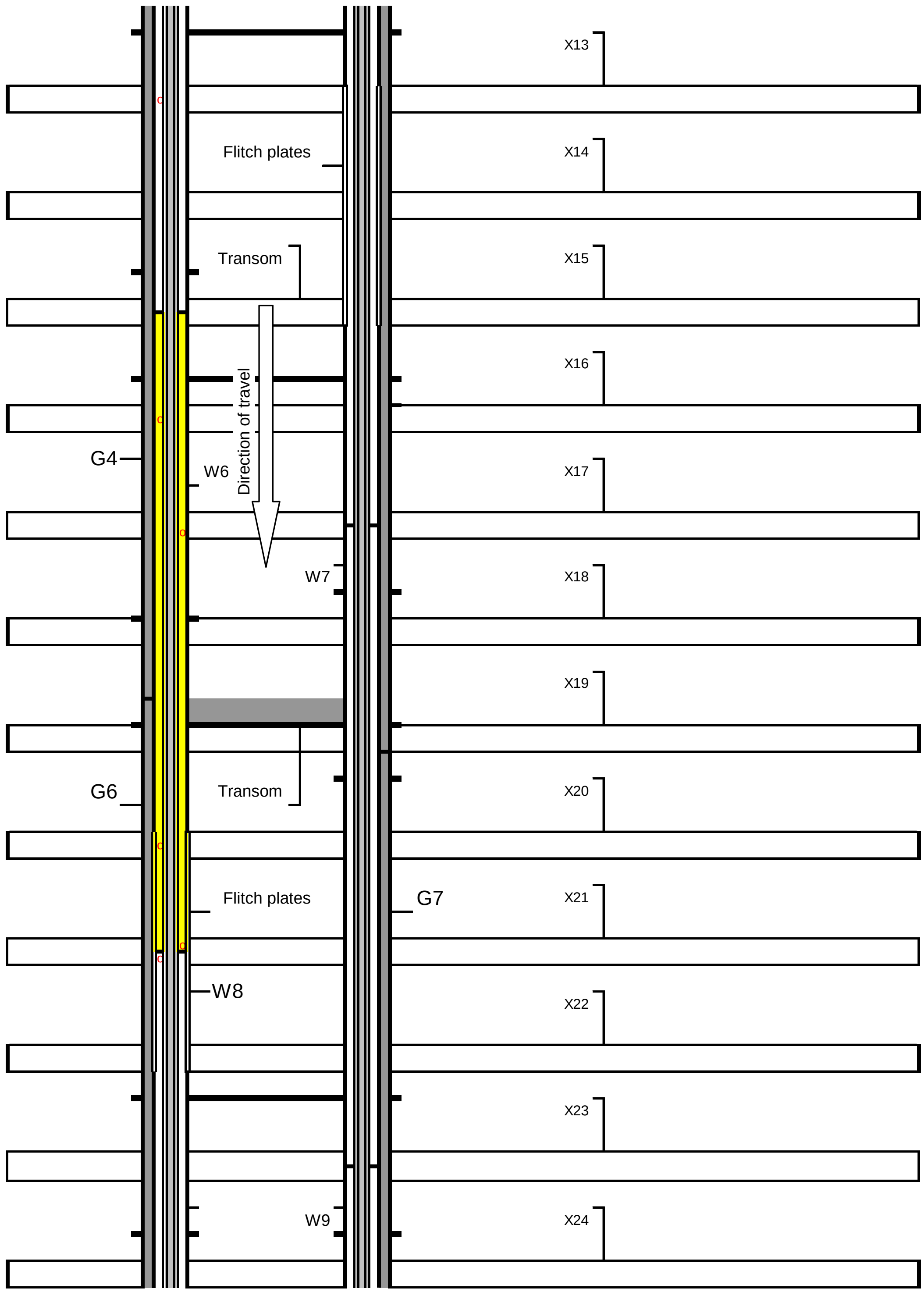


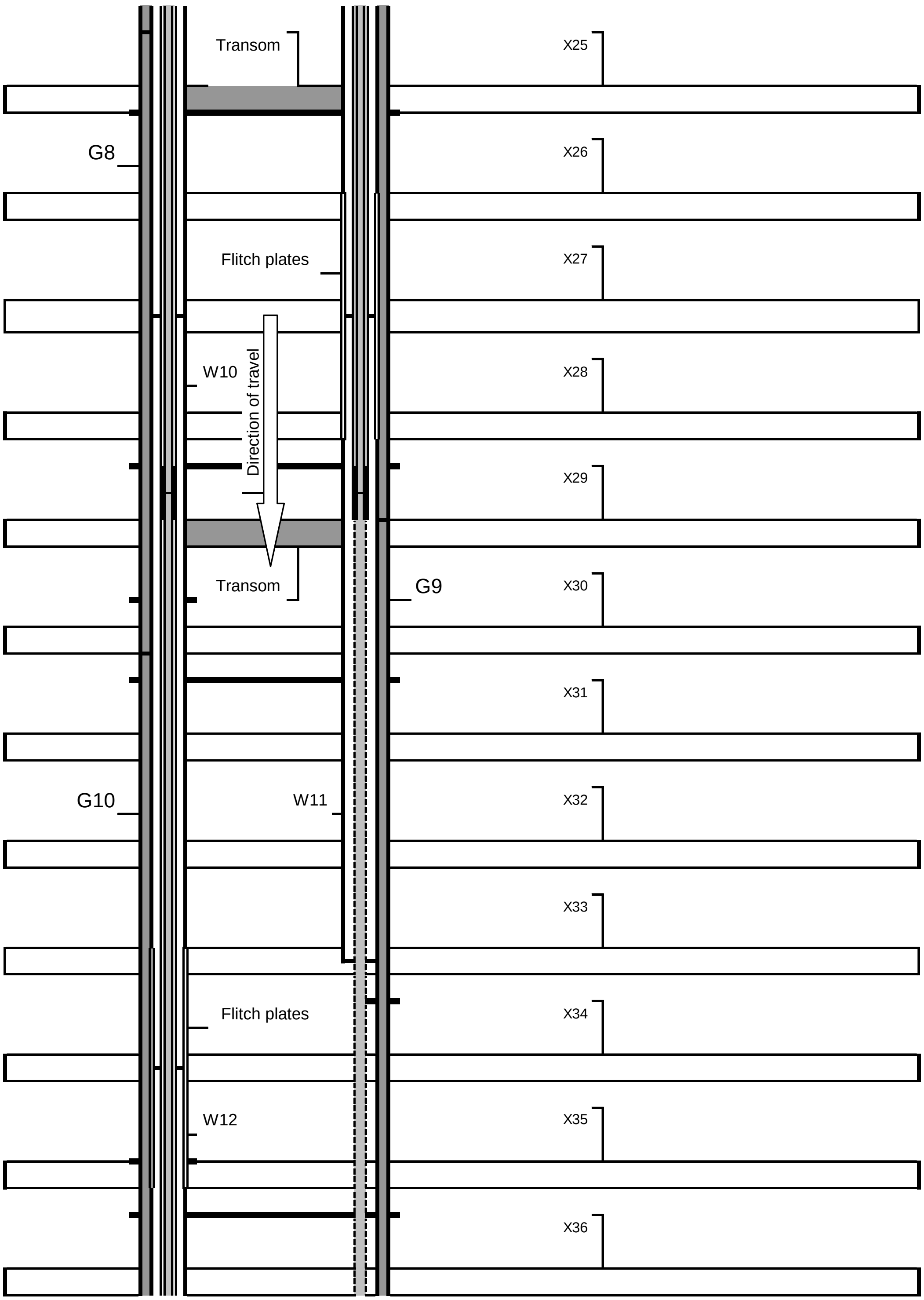
Figure 33 **Cross-section of structure on 07/10/2003 (IÉ Divisional Engineers, 2004)**

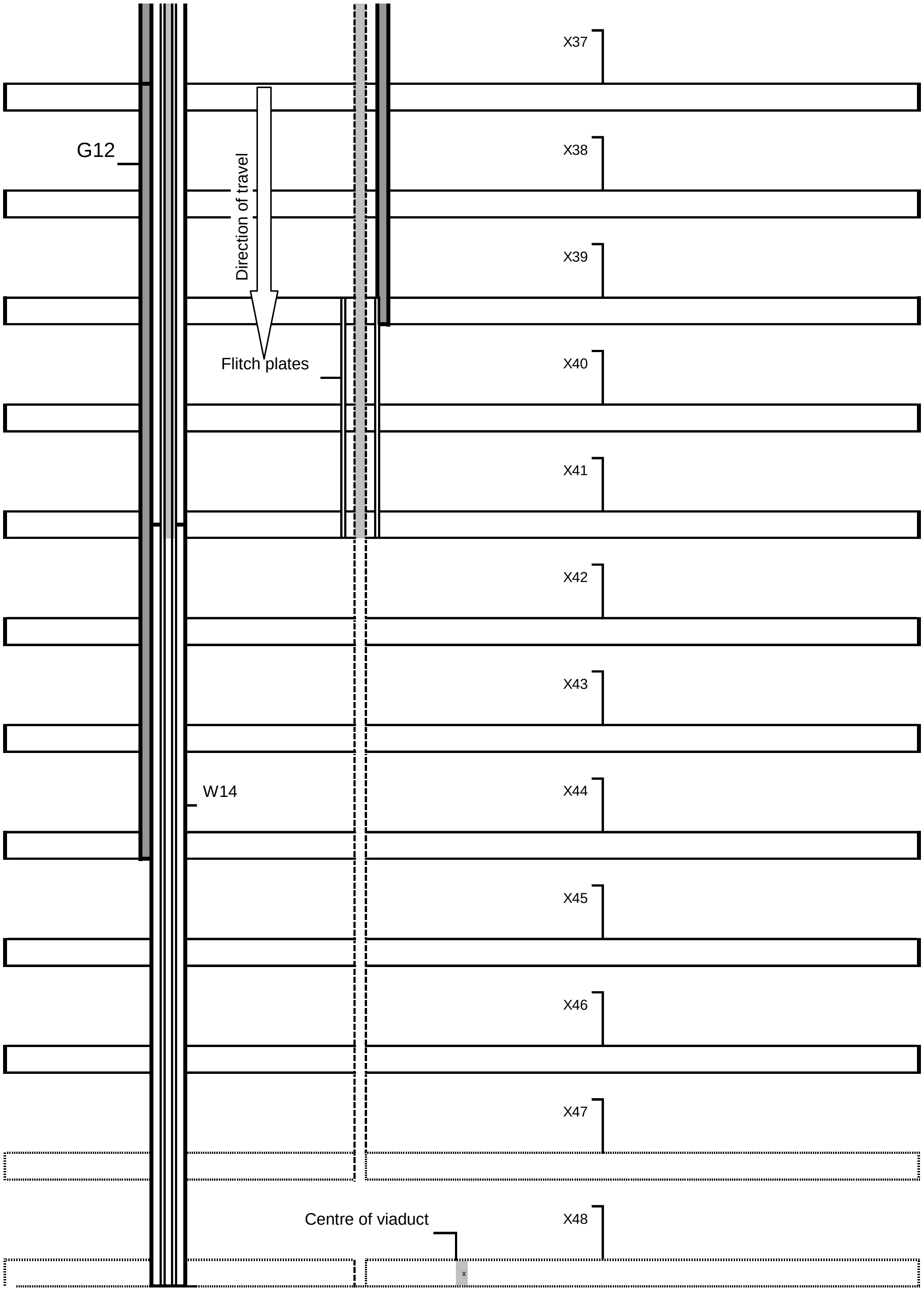
Appendix 3: Plan diagram of intact bridge deck

Figure 34 **Plan diagram of intact bridge deck**




X13
Flitch plates
X14
Transom
X15
X16
Direction of travel
G4
W6
X17
W7
X18
X19
G6
Transom
X20
Flitch plates
G7
X21
W8
X22
X23
W9
X24


Transom
X25
G8
X26
Flitch plates
X27
W10
Direction of travel
X28
X29
Transom
G9
X30
X31
G10
W11
X32
X33
Flitch plates
X34
W12
X35
X36


X37
X38
G12
Direction of travel
X39
Flitch plates
X40
X41
X42
X43
W14
X44
X45
X46
X47
Centre of viaduct
X48