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Level Crossing Profile Assessments

- Introducing NAPIER -

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Introduction

In 2004 there were two major incidents on level crossings. One resulted in the death of seven people [1] the other involved a train with around fifty children on board [2]. These incidents were deemed so 'significant' that they made the national press and led Dr Allan Sefton, HMRI Director of Rail Safety, to describe level crossings as posing the "greatest" potential rail risk [1].

Ever since the birth of the railways, where there has been the need for the rail infrastructure to pass at grade with the road network there has been the potential for accidents to occur. Sadly incidents, like those mentioned above, do occur on a very regular basis, and more often than not are due to user abuse – namely bad and illegal driving behaviour.

As part of the task of managing the safe use of level crossings, there is the HSE (Health & Safety Executive) Railway Safety Principles and Guidance Part 2 Section E: Guidance on Level Crossings [3]. Within this document there is the requirement, for certain types of level crossing, for all railway group organisations to check the level crossing profiles to set criteria (detailed below) and to assess the risk of "grounding" by road vehicles using the crossing. However, the HSE guidance does not detail how this is to be achieved.

There are also two Railway Group Standards regarding the specific requirements of level crossings, GI/RT7012 and GI/GN7612, which detail the holistic approach to a level crossing, including ensuring adequate ground clearance is provided across the road profile [9, 19].

Currently, there are no Railway Group Standards (including GI/RT7012 and GI/GN7612), Network Rail business process documents, or Highways Agency standards, which detail exactly how the level crossing road profile is to be checked. It is well known that level crossing profiles are to be checked in accordance with the 'Nairn's Profile' (described below), however there is a lack of information available regarding the correct detail, presentation, and assessment of a Nairn's profile. This has caused great concern over the years, for engineers carrying out track renewal, maintenance, or civil works within the vicinity of a level crossing.

This paper intends to highlight the current criteria for assessing road profiles over level crossings and to introduce a new level crossing profile evaluation process. This is NAPIER, the *Na*irn's *P*rof*i*le *E*valuation *R*eview, and is intended to aid engineers in determining, with regards to grounding, the suitability between

- A proposed vertical track alignment and existing approach road levels; or
- A proposed vertical approach road re-surfacing design and existing vertical track alignment; or
- A proposed new vertical track alignment and approach road re-surfacing design.

This paper will only be describing an evaluation process to assist with the appraisal of the suitability of the vertical road profile through an existing level crossing, to minimise the risk of grounding. It will not be discussing the suitability of level crossings, the construction of level crossings, recommendations for new level crossings or types of, or Network Rail's future policy regarding the use of level crossings.

When Does Grounding Occur?

Grounding occurs when the underside of a vehicle using a level crossing strikes the road surface of the crossing. This may result in either damage to the vehicle or, worst case, the vehicle becoming stuck on the level crossing, which could have fatal consequences.

Types of Level Crossing

There are two classification of level crossing: Active and Passive [7].

- Active level crossings provide the user with a visible and/or audible warning system (lights, siren, barriers, etc) to indicate when it is not safe to cross the infrastructure; and
- Passive level crossings provide the user with no visible and/or audible warning system – the crossing is dependant on the user's judgement on whether it is safe to cross the infrastructure.

On the UK rail network there are currently fourteen different types of level crossing: refer to Table One for details and classification into Active and Passive crossings. The NAPIER process can be applied to all types of level crossings.

Authorised pedestrian walkways for railway personnel and Road-Rail Access Points (RRAPs) are not classified as level crossings.

Level Crossing Incident Categorisation

Incidents at level crossings fall into four main categories:

I. Train strikes a pedestrian;
II. Train strikes vehicle;
III. Vehicle or train strikes the crossing equipment; and
IV. Level crossing misuse (near miss) or equipment failure.

The NAPIER process can be utilised on all types of crossing to aid in the mitigation of incidents that may occur within Incident Categories II and III; where there is a possibility of a vehicle grounding on the level crossing and, in worst case scenario, being struck by a train.

Level Crossing Statistics

Over the past eight years the following statistics have occurred [5].

- Over 7000 level crossings on the UK national rail network;
- Approximately 1500 level crossings are on public roads, used by an average of 1,718,000 vehicles traversing the rail infrastructure a year;
- An average of 10 fatalities per year at level crossings.
- An average of 3600 incidents at level crossings each year in the UK; and
- Category III accounts for approximately 10% of all incidents.

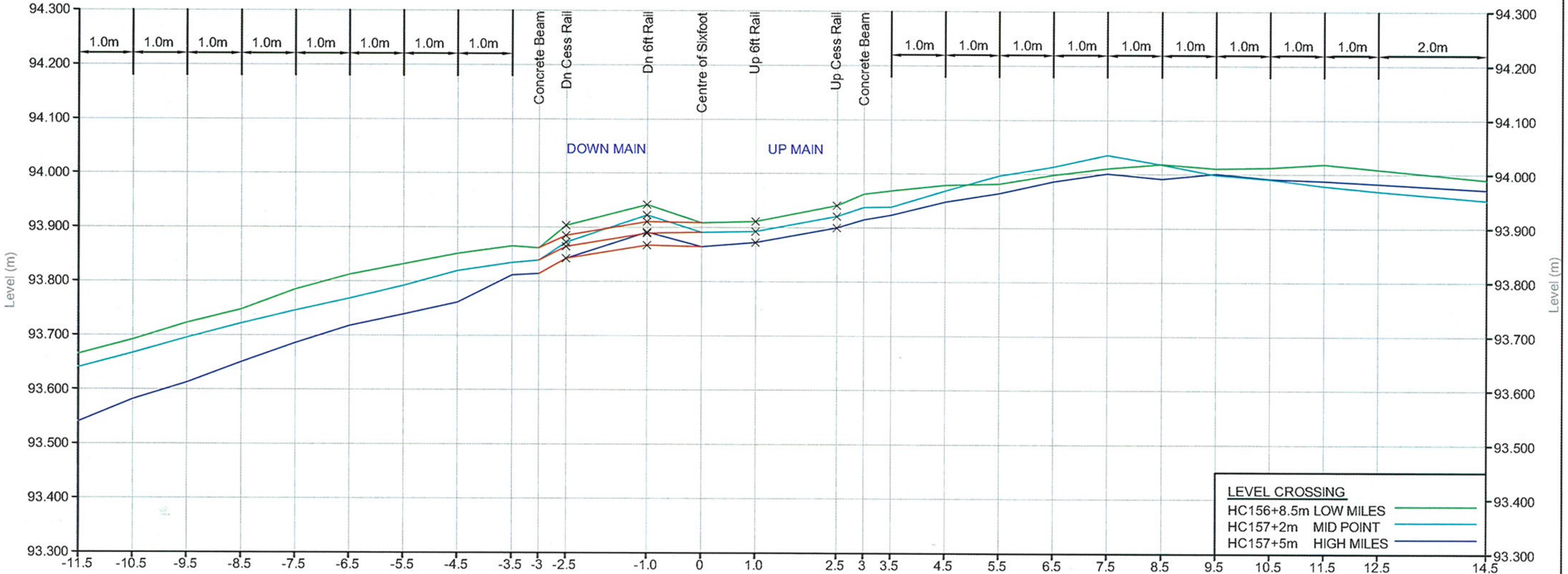
Table Two lists a selection of significant reported incidents at level crossings in 2008 – this list includes all known Incident Category I and II incidents, but not all Category III and IV incidents.

It appears that incidents in 2008 are mainly occurring on User-Worked Crossings (UWC) and Automatic Half Barrier (AHB) Crossings.

Passive level crossings are deemed to be inherently riskier by their very nature. However, statistics show – see Table Three (i) to (iv) – that this is not necessarily true in reality. Statistically over the past eight years there have been more fatal incidents on Active crossings than Passive.

Category II incidents occur most often on Automatic Open Crossing - Locally Monitored (AOCL) crossings; Category III incidents occur most often at Manual Controlled Barrier with Closed Circuit Television (MCB+CCTV) crossings.

Whist not accounting for all Category II and III incidents, grounding is still a significant risk; hence the HSE requirements for engineers to review the crossing profile, and NAPIER can be used to facilitate this review.



Horizontal Scale = 1:100,Vertical Scale = 1:10

Horizontal Scale = 1:100,Vertical Scale = 1:10

Existing Profile Design Profile Low Miles HC	93.666	93.692	93.723	93.748	93.785	93.812	93.832	93.851	93.865	93.862	93.903 93.885	93.942 93.910	93.909	93.911	93.941	93.962	93.969	93.979	93.982	93.999	94.011	94.019	94.011	94.013	94.019	94.009	93.990
Existing Profile Design Profile Mid Miles HC	93.641	93.667	93.696	93.722	93.746	93.768	93.792	93.819	93.834	93.839	93.872 93.864	93.923 93.889	93.891	93.893	93.921	93.938	93.939	93.969	93.997	94.014	94.036	94.018	93.999	93.991	93.978	93.969	93.952
Existing Profile Design Profile High Miles HC	93.540	93.582	93.613	93.651	93.686	93.718	93.739	93.761	93.811	93.814	93.842 93.842	93.891 93.867	93.864	93.872	93.900	93.915	93.924	93.948	93.964	93.986	94.001	93.992	94.001	93.992	93.988	93.983	93.971
Distance from Centre of Sixfoot	-11.500	-10.500	-9.500	-8.500	-7.500	-6.500	-5.500	-4.500	-3.500	-3.000	-2.500	-1.000	0.000	1.000	2.500	3.000	3.500	4.500	5.500	6.500	7.500	8.500	9.500	10.500	11.500	12.500	14.500

LEVEL CROSSING DOWN MAIN NAIRNS PROFILE REV. A01

Network Rail

TABLE ONE: LIST OF LEVEL CROSSING TYPES AND NUMBERS OF EACH TYPE [3, 9]

	TYPE OF CROSSING	ABBREVIATION	BRIEF DESCRIPTION	HSE REQUIRE ROAD PROFILE TO BE ASSESSED? *
ACTIVE	Manual Controlled Gate	MCG	Full road-width manually controlled gates, default position leaves gates open to predominant traffic-flow; operated by signaller, crossing keeper, or member of train crew	No
	Manual Controlled Barrier	MCB	Full road-width manually controlled barriers with audible warning, default position keeps barriers raised; operated by signaller, crossing keeper, or member of train crew	No
	Manual Controlled Barrier with Closed Circuit Television	MCB+CCTV	Full road-width manually controlled barriers with light and audible warning, default position keeps barriers raised; operated via CCTV by signaller	No
	Automatic Full Barrier	AFB	Full road-width barriers or gates with miniature stop lights, default position keeps barriers raised; operated automatically on approach from a train	Yes
	Automatic Half Barrier	AHB	Half road-width barriers, with light and audible warning, default position keeps barriers raised; operated automatically on approach from a train	Yes
	Automatic Barrier - Locally Monitored	ABCL	Half road-width barriers, with light and audible warning, default position keeps barriers raised; operated automatically on approach from a train - train driver is instructed by means of a light that the crossing is functioning correctly	Yes
	Automatic Open Crossing - Locally Monitored	AOCL	No barriers or gates, but with light and audible warnings, operated automatically on approach from a train - train driver is instructed by means of a light that the crossing is functioning correctly	Yes
	Automatic Open Crossing - Remotely Monitored	AOCR	No barriers or gates, but with light and audible warnings, operated automatically on approach from a train - equipment is monitored via the signaller at the nearest signal box	Yes
	User-Worked Crossing with Miniature Stop Lights	UWC+MSL	Full road-width barriers or gates with miniature stop lights; operation is linked to the signalling system, if a train is in the block the lights show either red or white	No
PASSIVE	User-Worked Crossing	UWC	This can be either gates, barriers or warning systems, requires user to observe approach of a train prior to use	No
	User-Worked Crossing with Telephone	UWC+T	This can be either gates, barriers, or warning systems, does provide telephone connection to local signaller for instruction on suitable time to use crossing	No
	Open Crossing (non-automatic)	OC	No barriers, gates, lights or warning system, requires users to observe approach of a train prior to use	Yes
	Bridleway Crossing	BC	Usually protected by gates for pedestrians, cycliss and equestrian users.	No
	Footpath Crossing	FC	Usually protected by gates or stiles, and occasionally Miniature Stop Lights, requires users to observe approach of a train prior to use - no road vehicle access	No

NOTES
* Requirement to assess the road profile is mandated in HSE Safety Principles and Guidance Part 2 Section E.

Recent Industry Response

Since 2004 Network Rail, in response to the large number of Category IV incidents, has taken an increased active approach to the management of level crossings on the UK national rail infrastructure. There has even been recent legal activity, giving Network Rail greater ownership for the overall control of safety on level crossings. In response, one of Network Rails initiatives has been an intensive advert campaign: "Don't Run the Risk" [6].

Network Rail, and its predecessor Railtrack, have actively been phasing out level crossings wherever possible, especially with regards to Passive crossings. During the West Coast Route Modernisation project almost all level crossings were replaced by a bridge structure.

After the fatal incident at Ufton Nervet, 6th November 2004, which claimed the lives of seven people, the Railway Safety and Standards Board, Director of Policy, Aidan Nelson, was quoted in the Guardian newspaper as saying "the best level crossing is a closed level crossing", thereby further increasing the drive to remove level crossings from the infrastructure [11].

However, it is extremely difficult to simply close any level crossing. Private crossings require approval from authorised users, footpath crossings require a suitable alternative route to be provided, usually in the form of a bridge, and public highway level crossings are often protected under current legislation [12]. Therefore, the onus is on Network Rail to mitigate risks associated with the four Incident Categories on any level crossing, including the risk of grounding. Sadly, however, as with the Ufton case, no mitigation can be implemented to take into account the act of suicide.

It is anticipated that the use of the NAPIER process could assist Network Rail in evaluating the risk of grounding associated with Incident Categories II and III.

Rail Industry Review of Level Crossings

The rail industry is mandated by the HSE to only check the road (Nairn's) profile of certain types of crossings – see Table One. This is because it is assumed that all other types of level crossing have a significantly reduced risk of a grounded vehicle causing an incident, principally because the level crossing is monitored in some way or the vehicle types that generally use the crossing should not pose a grounding risk.

There is currently no clearly defined procedure to use when reviewing a Nairn's profile to meet compliance with the measurement requirements of the HSE (see below), and engineers have resorted to several "tried and tested" methods, some including acetate cut-outs of vehicle shapes.

What is a Nairn's Profile?

The Nairn's Profile comes from a historic level crossing incident on a UWC at Nairn, in Scotland. The crossing was part of a farm track and on 4th May 1982 a derailment occurred when a train hit a grounded long wheel-based trailer which was being pulled by a tractor [18].

From this report the following was mandated - "A survey of all accommodation and occupation level crossings to be undertaken... to determine: the vertical profile over all crossings and their immediate approach" [4].

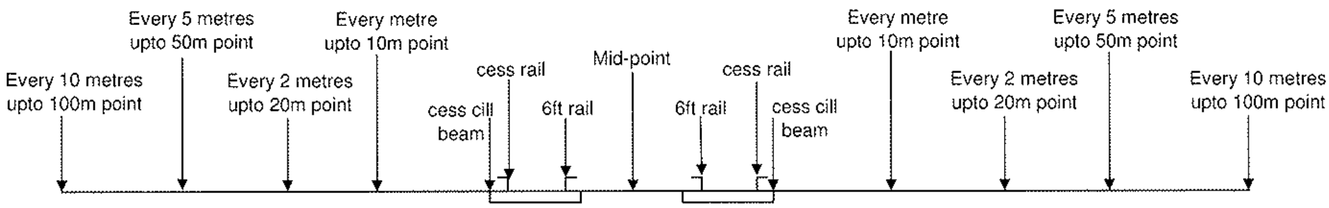
The graphical means by which the road profile is represented to an engineer is commonly referred to as the 'Nairn's Profile' [16].

TABLE TWO: Current List of Reported UK Level Crossing Incidents in 2008 * [1, 2, 7, 8]

LOCATION	CROSSING TYPE	DATE OF INCIDENT	HUMAN CONSEQUENCES
Broadley, Kent	FP	19/06/2008	1 fatality
Loover Barn, Kent	UWC+T	13/06/2008	No injury [1]
Pencoed Station, Mid Glamorgan, Wales	MCB (CCTV)	13/06/2008	1 fatality 1 near miss
Bardon Mill, Northumberland	UWC+T	03/06/2008	1 minor injury
Marston, Derbyshire	AHB	10/05/2008	1 fatality 2 minor injury 1 near miss
Kinbrace, Sutherland, Scotland	AOCL	16/04/2008	No injury [1]
Moor Lane, Staines, Surrey	FP	16/04/2008	1 fatality
Scopwick, Kirkby Green, Lincolnshire	MCG	09/04/2008	No injury [2]
Wokingham Waterloo Road, Berkshire	AHB	31/03/2008	1 fatality
Cullybacky, Ballymena, Northern Ireland	AHB	03/03/2008	1 injury [3]
Hythe Station, Colchester, Essex	MCB	27/02/2008	1 fatality 2 injury 1 near miss
Wraysholme, Flookburgh, Cumbria	AOCL	27/02/2008	4 minor injuries
Spondon, Derbyshire	MCB	15/02/2008	No injury [4]
Attleborough, Norfolk	FP	13/02/2008	1 fatality
West Lodge, Haltwhistle, Northumberland	UWC	22/01/2008	1 fatality
Hoylake, Wirral, Merseyside	UWC+T	21/01/2008	1 fatality
Whitemoss, nr Perth, Scotland	AHB	05/01/2008	1 minor injury

NOTES:
* This list is not conclusive, but is representative of known events in 2008 - many are still subject to legal investigations.
1. Vehicle struck by train
2. Train struck crossing barriers
3. Unconfirmed at time of going to print
4. Vehicle struck barrier

FIGURE TWO: Nairn's Profile Survey Data Points



NOTE: Figure shows typical 2-track section level crossing - mid-point dependant on number of tracks.

What does a Nairn's Profile Show?

Figure One shows an example Nairn's Profile. The Nairn's Profile should show a vertical cross section of the level crossing, including:

- 100m of existing road levels of both approach roads;
- All existing track (cess, six-foot, and ten-foot rails where applicable); and
- Proposed design levels of either track or roadway depending on nature of project.

Ideally a profile should be produced at regular intervals laterally across the crossing. As a minimum there should be three profiles produced for each level crossing; one for each carriageway edge (or 'channels') and one for the physical centre of the carriageway.

The survey data for the profile should be referenced from the centre point of the crossing, whether the track arrangement is 2-tracks, 3-tracks, or more. Figure Two shows the typical arrangements for survey data for a 2-track layout.

A Nairn's Profile does not show the construction of the level crossing or associated equipment.

Note: The half-chords shown on the NAPIER sheet is in relation to the track renewal half-chord system, which is an arbitrary longitudinal referencing method – any project specific referencing syst2em can be adopted. Half-chords should be referred to if more than one profile is taken laterally across a level crossing.

TABLE THREE: LEVEL CROSSING STATISTICS

(i): NUMBER OF CROSSING TYPES AND TRAFFIC VOLUMES PER TYPE PER DAY [3,7,10]

TYPE OF CROSSING	NUMBER OF CROSSING TYPE IN USE IN UK *	DAILY NUMBER OF VEHICLES	DAILY VEHICLE/TRAIN MOMENTS
MCG	259	600	33,600
MCB	242	1,445	108,375
MCB+CCTV	358	1,445	108,375
AHB	462	1,450	105,850
ABCL	45	1,000	41,000
AOCL	134	600	12,000
AOCR	1	600	12,000
UWC+MSL	155	22	1,100
UWC	1,979	7	350
UWC+T	1,617	7	350
OC	60	30	360
FC / BC	2,528	N/A	N/A
TOTAL	7,840	7,206	423,360

* Where two reports differ on number of type the lowest figure has been taken as correct.

(ii) AVERAGE NUMBER OF INCIDENTS PER CATEGORY PER YEAR [7]

INCIDENT CATEGORY	AVERAGE NUMBER OF INCIDENTS PER YEAR	EQUIVALENT NUMBER OF FATALITIES	INCIDENT/TOTAL PERCENTAGE
I	5	4	0.14%
II	20	2.8	0.56%
III	326	0.2	9.18%
IV	3,200	1.05	90.12%
TOTAL	3,551	8.05	

(iii): AVERAGE CATEGORY II AND III INCIDENTS PER CROSSING TYPE PER YEAR * [7]

TYPE OF CROSSING	CATEGORY II INCIDENTS	CATEGORY III INCIDENTS	TOTAL
MCG	0	28	28
MCB	0	51	51
MCB+CCTV	0	133	133
AHB	5	72	77
ABCL	0	6	6
AOCL	6	0	6
AOCR	0	3	3
UWC+MWL	1	6	7
UWC	2	10	12
UWC+T	4	16	20
OC	2	1	3
BC	-	-	- **
FC	-	-	- **
TOTAL	20	326	346

* Statistics do not specify whether vehicle involved in incident was grounded.
** No statistics available.

(iv): SUMMARY OF UK LEVEL CROSSING CATEGORY I AND II INCIDENTS IN LAST 8 YEARS * [2,4,5]

YEAR	NUMBER OF CATEGORY I and II INCIDENTS	NUMBER OF FATALITIES	MOST FREQUENT TYPE OF CROSSING INVOLVED ***
2008	17 **	9	UWC
2007	14	7	AOCL
2006	19	4	MCB
2005	16	13	-
2004	16	16	AOCL
2003	28	12	-
2002	23	20	AHB
2001	23	11	AOCL
TOTAL	156	92	

* This list is not conclusive, but is representative of known events between 2006-2008.
** Up to and including June 2008
*** No data available to interrogate for 2003 and 2005.

Requirements for Measurement of Level Crossing Profiles

There are two main sources of information regarding the requirements for measuring level crossing profiles; the HSE guidance book (primary source) and the Highway Authority regulations – details are given below.

HSE Guidance Book

The Railway Safety Principles and Guidance, Part 2 – Section E: Guidance on Level Crossings, section 14 details the HSE requirements for a compliant level crossing profile:

"The vertical profile over any vehicle crossing should have no sudden change of vertical curvature. The profile over an automatic half barrier crossing or user-worked crossing is critical to safety." Clause 184

"The profile over a automatic half barrier crossings should not cause a long, low vehicle... to become grounded and obstruct the railway." Clause 185

"It is the relationship of the wheelbase with the ground clearance of a road vehicle which is used to determine safe profiles." Clause 186

"The profile is measured in terms of the maximum permitted hump of 75mm anywhere on the road surface..." Clause 186

The guidance book then categories the vehicle wheelbase types required to be assessed over the crossing profile. Table 4, of the HSE guidance book, specifies the wheelbase lengths to be assessed as determined by the road and rail traffic density – refer to Table Four.

Table Four stipulates the need to check the level crossing profile for three wheelbase lengths: 8.5m, 9.75m, and 15.3m.

Table Four is based upon risk evaluation; the premise being that the variety of vehicle, and hence the chances of a larger vehicle using the crossing, is likely to increase if the number of vehicle and vehicle/train interaction is greater. However, this does not take into account the possibility of an "unusual" vehicle using the crossing at any time: this is why the Nairn's profile originated in the first place.

Highway Authority Regulations

The Highway Authority has a regulation concerned with the maximum "hump" allowed on a road surface. This is detailed within the Highway (Road Humps) Regulations 1990 [13].

There is currently no legislation governing the minimum clearance dimension between the underside of a vehicle and the road surface. An average car has an unloaded clearance dimension of between 120mm and 150mm – naturally, larger vehicles, for example 4x4s have a much greater dimension, sometimes up to 300mm.

However, when fully loaded this clearance dimension can reduce by up to 30mm in the average car.

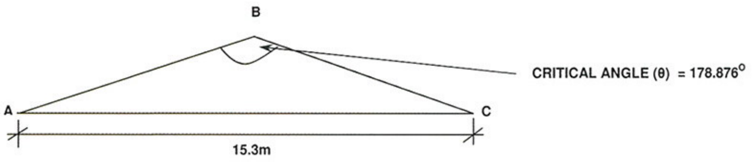
Luxury and sports cars, including funeral cars, have much smaller clearance dimensions: unloaded dimension – 100mm; loaded dimension – 75mm [14].

The dimensions stipulated for a road hump by the Highway (Road Humps) Regulations 1990 are [13]

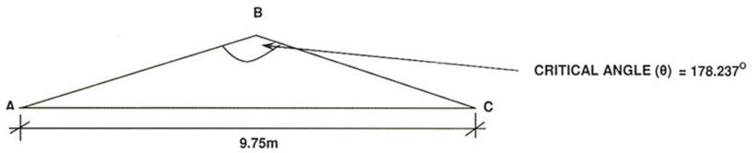
- The "hump" height is to between 50mm and 100mm – not exceeding 100mm; and
- The overall length of the hump to be no greater than 3.7m.

FIGURE THREE: Critical Angle and Z Level for Theoretical Ideal 75mm Hump

(i) Vehicle Category One - 15.3m Wheelbase



(ii) Vehicle Category Two - 9.75m Wheelbase



(iii) Vehicle Category Three - 8.5m Wheelbase

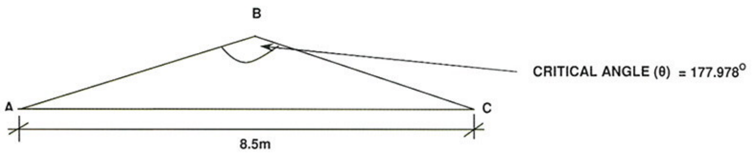


TABLE FOUR: HSE Measurement of Safe Profiles [3]

ACTUAL DAILY ROAD VEHICLE USER		DAILY TRAFFIC MOMENT	VEHICLE CATEGORY	THEORETICAL WHEELBASE LENGTH (metres)	THEORETICAL WHEELBASE LENGTH (feet)
more than 2000	OR	more than 80,000	1	15.3	50
2000 or less		80,000 or less	2	9.75	32
600 or less		25,000 or less	3	8.5	28

It is also recommended that the approaching and trailing gradients should be 1:10, and no steeper than 1:8 [15]. However, this applies more to a specific "hump" construction and not just poor road surface alignment. There is greater risk of a random "hump" occurring and that longer wheelbased vehicles will ground on the crossing.

Summary of "Hump" Requirements

Maximum "hump" dimension permitted on the level crossing road profile is [3, 17]

- HSE = max. 75mm
- Highway Authority = max. 100mm

What is the NAPIER Process?

The NAPIER process is an analytical aid to the evaluation of the Nairn's profile with regards to grounding, taking into account the criterion set out in the HSE guidance book, whilst taking a pragmatic approach in utilising the Highway Authority's maximum allowable road hump.

NAPIER is based on the critical angle (ɵ) and a theoretical offset level (Z), for the three wheelbase lengths, as calculated for a "hump" of 75mm of a triangle ABC; B being the "hump" apex. See Figure Three.

By comparing the actual measured angle against the critical angle, and the reciprocal vertical offsets, it is possible to determine whether the road profile is acceptable, and whether the reviewing engineer needs to make minor adjustments to either the track levels or the road surface could bring the road profile into compliance.

NAPIER simultaneously evaluates all HSE wheelbase lengths across the Nairn's profile, highlighting the vehicle category NAPIER result in the manner shown in Table Five. In other words, if the road profile over a given level crossing is acceptable (i.e. no road humps >75mm) then each vehicle category has a resultant A; hence the 8.5m wheelbase (Vehicle Category 3) will be given a resultant 3A, the 9.75m receives a 2A result, and so on. If a wheelbase fails then there are indicating categories to suggest whether remedial works are possible or whether a complete renewal/road surfacing project is required, which the reviewing engineer can then take account of in the overall appraisal of the level crossing profile.

How is the Nairn's Profile Used in NAPIER?

The level survey data, collected for the Nairn's profile, is inputted into the NAPIER spreadsheet. A macro is then run which carries out the analytical evaluation of the survey data in accordance with the HSE and Highway Authorities requirements. The results from the assessment are then presented in a tabulated form.

Ideally, there should be a minimum of three Nairn's profiles for each level crossing, and therefore three sets of results from the NAPIER process to be assessed in conjunction with each other – see Further Development of NAPIER.

NAPIER Result Interpretation

In theory a fully compliant level crossing is one which passes the evaluation for all three vehicle categories, and receives a 1A 2A 3A result; a level crossing that fails for all vehicle categories receives a 1C 2C 3C result; and all iterations therein.

Where a vehicle category has a number of different results, for instance over a number of "humps" the NAPIER resultant categories are a mix of A, B and C, then the worst case result will be quoted.

The HSE does not require every level crossing to be assessed for all three vehicle categories, and therefore all three results need not be reported. However, NAPIER will assess the Nairn's profile for all three vehicle categories regardless. It will be down to the assessing engineer to determine which is applicable.

TABLE FIVE: Vehicle Category Against NAPIER Resultant Category

VEHICLE CATEGORY	NAPIER CATEGORY A	NAPIER CATEGORY B	NAPIER CATEGORY C	
1	1A	1B	1C	NAPIER RESULT
2	2B	2B	2C	
3	3B	3B	3C	

<u>NAPIER Categories</u>

A - Pass

There appears to be no incident of a road hump exceeding 75mm

B - Fail with remedial woks

There appears to be at least one incident
a road hump exceeds 75mm but less than 100mm [1]

C - Fail

There appears to Pass
where a road hurr Fail with remedial woks

<u>NOTES</u>

1 Risk of grounding can be improved with either work to the track or the road surface.

FIGURE FOUR (i): Case Study #1 Nairn's Profile Extract

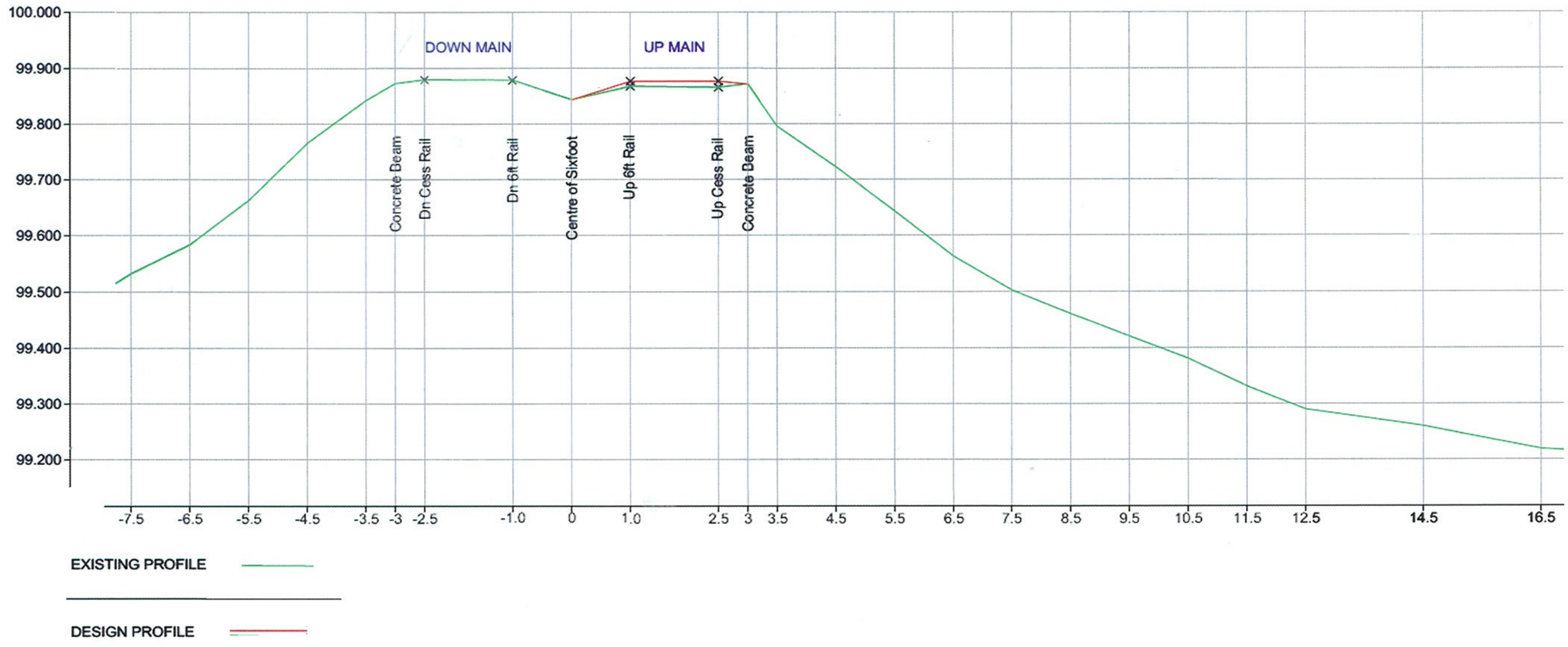


FIGURE FOUR: Case Study #1 NAPIER Assessment

NAPIER RESULT

Site: Case Study #1 Line: Down Main

PSR = 75 mph 120.70 kph

Drawing No.: case-study-1

Resultant NAPIER CATEGORY		
1C	2C	3C

8.5m Wheelbase (Vehicle Category 3)

Criteria:

= No Input Required

177.978° = Ideal θ Angle (75mm hump)

177.304° = Tolerance on Min. θ Angle (allowing for 100mm hump)

HALF-CHORD	DESIGN LEVELS			DESIGN DIMENSIONS				CRITICAL ANGLE	ITERATION CHECK		NAPIER
	A	B	C	Y_1	Y_2	X_1	X_2	(θ)	Z Level	B-Z Difference	CATEGORY
183773.0	99.843	99.876	99.46	1	7.5	0.033	0.416	174.935	99.798	0.078	B
183777.0	99.826	99.871	99.52	1	7.5	0.045	0.351	174.744	99.790	0.081	B
183781.0	99.833	99.868	99.505	1	7.5	0.035	0.363	175.225	99.794	0.074	A
183781.0	99.833	99.869	99.505	3.5	5	0.036	0.364	175.247	99.698	0.171	C
183773.0	99.467	99.879	99.843	2.5	6	0.412	0.036	170.298	99.578	0.301	C
183777.0	99.54	99.864	99.826	2.5	6	0.324	0.038	172.253	99.624	0.240	C
183781.0	99.61	99.855	99.833	2.5	6	0.245	0.022	174.193	99.676	0.179	C

COMMENT: *Urgent work required to road profile*

9.75m Wheelbase (Vehicle Category 2)

Criteria:

= No Input Required

= Distance C value to be used: No Input Required

178.237° = Ideal θ Angle (75mm hump)

177.649° = Tolerance on Min. θ Angle (allowing for 100mm hump)

HALF-CHORD	DESIGN LEVELS			DESIGN DIMENSIONS				CRITICAL ANGLE	ITERATION CHECK		NAPIER
	A	B	C	Y_1	Y_2	X_1	X_2	(θ)	Z Level	B-Z Difference	CATEGORY
183773.0	99.843	99.876	99.410	1	8.75	0.033	0.466	175.061	99.799	0.077	B
183777.0	99.826	99.871	99.477	1	8.75	0.045	0.3945	174.842	99.790	0.081	B
183781.0	99.833	99.868	99.424	1	8.75	0.035	0.444	175.091	99.791	0.077	B
183781.0	99.833	99.869	99.424	3.5	6.25	0.036	0.445	175.338	99.686	0.183	C
183773.0	99.467	99.879	99.410	2.5	7.25	0.412	0.469	166.940	99.452	0.427	C
183777.0	99.54	99.864	99.403	2.5	7.25	0.324	0.4615	168.973	99.505	0.359	C
183781.0	99.61	99.855	99.465	2.5	7.25	0.245	0.39	171.324	99.573	0.282	C

COMMENT: *Urgent work required to road profile*

15.3m Wheelbase (Vehicle Category 1)

Criteria:

= No Input Required

= Distance C value to be used: No Input Required

178.876° = Ideal θ Angle (75mm hump)

178.502° = Tolerance on Min. θ Angle (allowing for 100mm hump)

HALF-CHORD	DESIGN LEVELS			DESIGN DIMENSIONS				CRITICAL ANGLE	ITERATION CHECK		NAPIER
	A	B	C	Y_1	Y_2	X_1	X_2	(θ)	Z Level	B-Z Difference	CATEGORY
183773.0	99.843	99.876	99.232	1	14.3	0.033	0.64365	175.533	99.803	0.073	A
183777.0	99.826	99.871	99.235	1	14.3	0.045	0.6357	174.878	99.787	0.084	B
183781.0	99.833	99.868	99.230	1	14.3	0.035	0.6382	175.440	99.794	0.074	A
183781.0	99.833	99.869	99.230	3.5	11.8	0.036	0.6392	176.310	99.695	0.174	C
183773.0	99.467	99.879	99.287	2.5	12.8	0.412	0.5925	167.991	99.438	0.441	C
183777.0	99.54	99.864	99.265	2.5	12.8	0.324	0.59875	169.937	99.495	0.369	C
183781.0	99.61	99.855	99.295	2.5	12.8	0.245	0.56	171.898	99.559	0.298	C

COMMENT: *Urgent work required to road profile*

CORRECTION "Z" LEVEL FOR NAPIER CATEGORIES B AND C					COMMENTS:
Category	Half-Chord	New B Level	New Z	Lift / Lower	
8.5m Wheelbase	183773.0	99.873	0.075	-0.003	3mm lower required
	183777.0	99.865	0.075	-0.006	6mm lower required
	183781.0	99.773	0.075	-0.096	96mm lower required
	183773.0	99.653	0.075	-0.226	226mm lower required
	183777.0	99.699	0.075	-0.165	165mm lower required
	183781.0	99.751	0.075	-0.104	104mm lower required
9.75m Wheelbase	183773.0	99.874	0.075	-0.002	2mm lower required; 3mm lower for 8.5m wheelbase accommodates this
	183777.0	99.865	0.075	-0.006	6mm lower required; same as 8.5m wheelbase
	183781.0	99.866	0.075	-0.002	2mm lower required
	183781.0	99.761	0.075	-0.108	108mm lower requires
	183773.0	99.527	0.075	-0.352	352mm lower required
	183777.0	99.580	0.075	-0.284	284mm lower required
	183781.0	99.648	0.075	-0.207	207mm lower required
15.3m Wheelbase	183777.0	99.862	0.075	-0.009	9mm lower required
	183781.0	99.770	0.075	-0.099	99mm lower required
	183773.0	99.513	0.075	-0.366	366mm lower required
	183777.0	99.570	0.075	-0.294	294mm lower required
	183781.0	99.634	0.075	-0.221	221mm lower required

FIGURE FIVE (i): Case Study #2 Nairn's Profile Extract

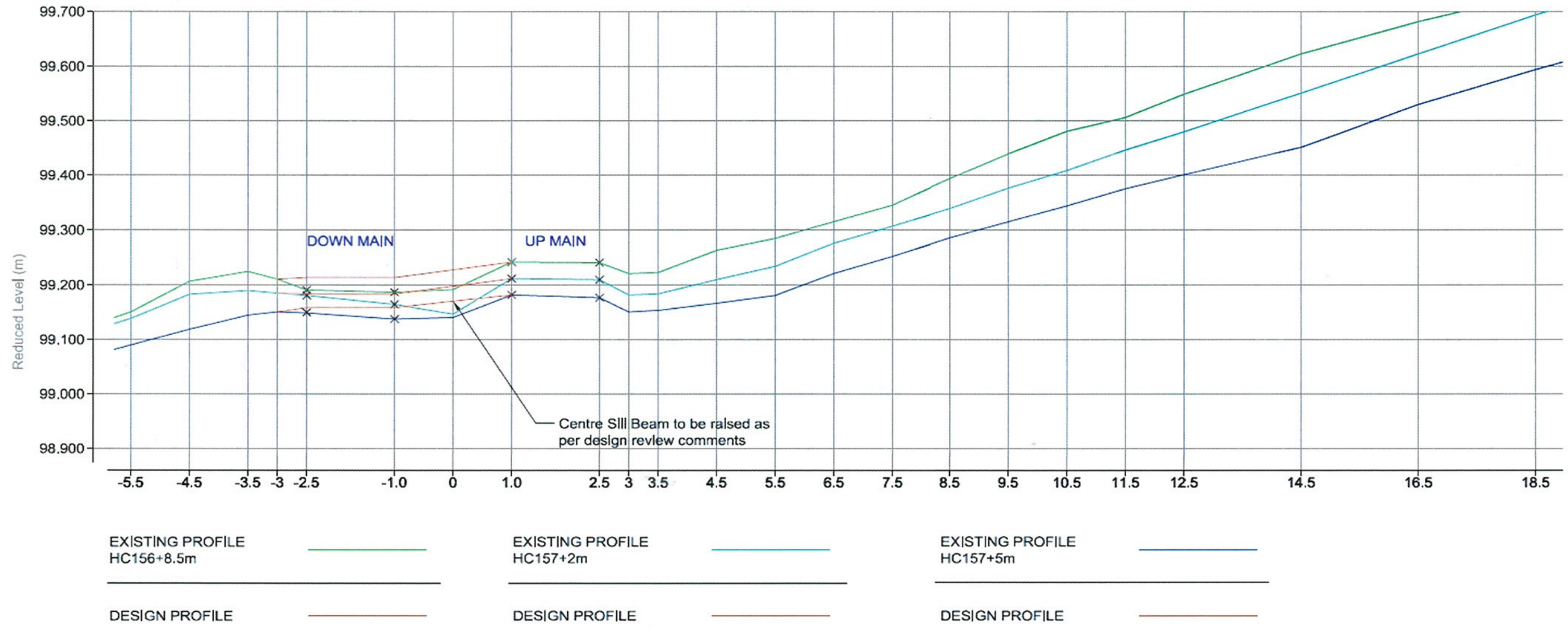


FIGURE FIVE (ii): Case Study #2 NAPIER Assessment

NAPIER RESULT

Site:	Case Study #2		Line:	Down Main	
PSR =	55	mph	88.51	kph	
Drawing No.:	case-study-2				

Resultant NAPIER CATEGORY		
1B	2B	3B

8.5m Wheelbase (Vehicle Category 3)

Criteria:

= No Input Required

177.978° = Ideal θ Angle (75mm hump)

177.304° = Tolerance on Min. θ Angle (allowing for 100mm hump)

HALF-CHORD	DESIGN LEVELS			DESIGN DIMENSIONS				CRITICAL ANGLE	ITERATION CHECK		NAPIER
	A	B	C	Y_1	Y_2	X_1	X_2	(θ)	Z Level	B-Z Difference	CATEGORY
158+8.5 LH	99.031	99.225	99.192	5	3.5	0.194	0.033	177.238	99.126	0.099	B
158+8.5 RH	99.192	99.242	99.394	1	7.5	0.05	0.152	178.299	99.216	0.026	A
157+2 LH	99.01	99.19	99.152	5	3.5	0.18	0.038	177.316	99.094	0.096	B
157+2 RH	99.152	99.147	99.339	1	7.5	0.005	0.192	181.753	99.174	0.027	A
157+5 LH	98.968	99.138	99.141	7.5	1	0.17	0.003	178.873	99.121	0.017	A
157+5 RH	99.138	99.182	99.286	1	7.5	0.044	0.104	178.275	99.155	0.027	A

COMMENT: *Risk of grounding sign required; two critical angles to be monitored.*

9.75m Wheelbase (Vehicle Category 2)

Criteria:

= No Input Required

= Distance C value to be used: No Input Required

178.237° = Ideal θ Angle (75mm hump)

177.649° = Tolerance on Min. θ Angle (allowing for 100mm hump)

HALF-CHORD	DESIGN LEVELS			DESIGN DIMENSIONS				CRITICAL ANGLE	ITERATION CHECK		NAPIER
	A	B	C	Y_1	Y_2	X_1	X_2	(θ)	Z Level	B-Z Difference	CATEGORY
158+8.5 LH	99.031	99.225	99.241	5	4.75	0.194	0.016	177.971	99.139	0.086	B
158+8.5 RH	99.192	99.242	99.450	1	8.75	0.05	0.2075	178.496	99.218	0.024	A
157+2 LH	99.01	99.19	99.212	5	4.75	0.18	0.022	178.204	99.114	0.076	B
157+2 RH	99.152	99.147	99.348	1	8.75	0.005	0.201	181.602	99.172	0.025	A
157+5 LH	98.968	99.138	99.181	7.5	2.25	0.17	0.043	179.796	99.132	0.006	A
157+5 RH	99.138	99.182	99.322	1	8.75	0.044	0.14	178.397	99.157	0.025	A

COMMENT: *Risk of grounding sign required; all critical angles to be monitored.*

15.3m Wheelbase (Vehicle Category 1)

Criteria:

= No Input Required

= Distance C value to be used: No Input Required

178.876° = Ideal θ Angle (75mm hump)

178.502° = Tolerance on Min. θ Angle (allowing for 100mm hump)

HALF-CHORD	DESIGN LEVELS			DESIGN DIMENSIONS				CRITICAL ANGLE	ITERATION CHECK		NAPIER
	A	B	C	Y_1	Y_2	X_1	X_2	(θ)	Z Level	B-Z Difference	CATEGORY
158+8.5 LH	99.031	99.225	99.324	5	10.3	0.194	0.099	178.329	99.127	0.098	B
158+8.5 RH	99.192	99.242	99.647	1	14.3	0.05	0.4046	178.758	99.222	0.020	A
157+2 LH	99.01	99.19	99.285	5	10.3	0.18	0.0953	178.468	99.100	0.090	B
157+2 RH	99.152	99.147	99.540	1	14.3	0.005	0.393	181.861	99.177	0.030	A
157+5 LH	98.968	99.138	99.230	7.5	7.8	0.17	0.092	179.377	99.096	0.042	A
157+5 RH	99.138	99.182	99.444	1	14.3	0.044	0.2615	178.528	99.158	0.024	A

COMMENT: *Risk of grounding sign required; four critical angles to be monitored.*

CORRECTION "Z" LEVEL FOR NAPIER CATEGORIES B AND C					COMMENTS:
Category	Half-Chord	New B Level	New Z	Lift / Lower	
8.5m Wheelbase	158+8.5 LH	99.201	0.075	-0.024	24mm lower of down cess required
	157+2 LH	99.169	0.075	-0.021	21mm lower of down cess required
9.75m Wheelbase	158+8.5 LH	99.214	0.075	-0.011	11mm lower required; 24mm lower for 8.5m wheelbase will correct this
	157+2 LH	99.189	0.075	-0.001	1mm lower required; 24mm lower for 8.5m wheelbase will correct this
15.3m Wheelbase	158+8.5 LH	99.202	0.075	-0.023	23mm lower required; 24mm lower for 8.5m wheelbase will correct this
	157+2 LH	99.175	0.075	-0.015	15mm lower required; 24mm lower for 8.5m wheelbase will correct this

FIGURE SIX (i): Case Study #3 Nairn's Profile Extract

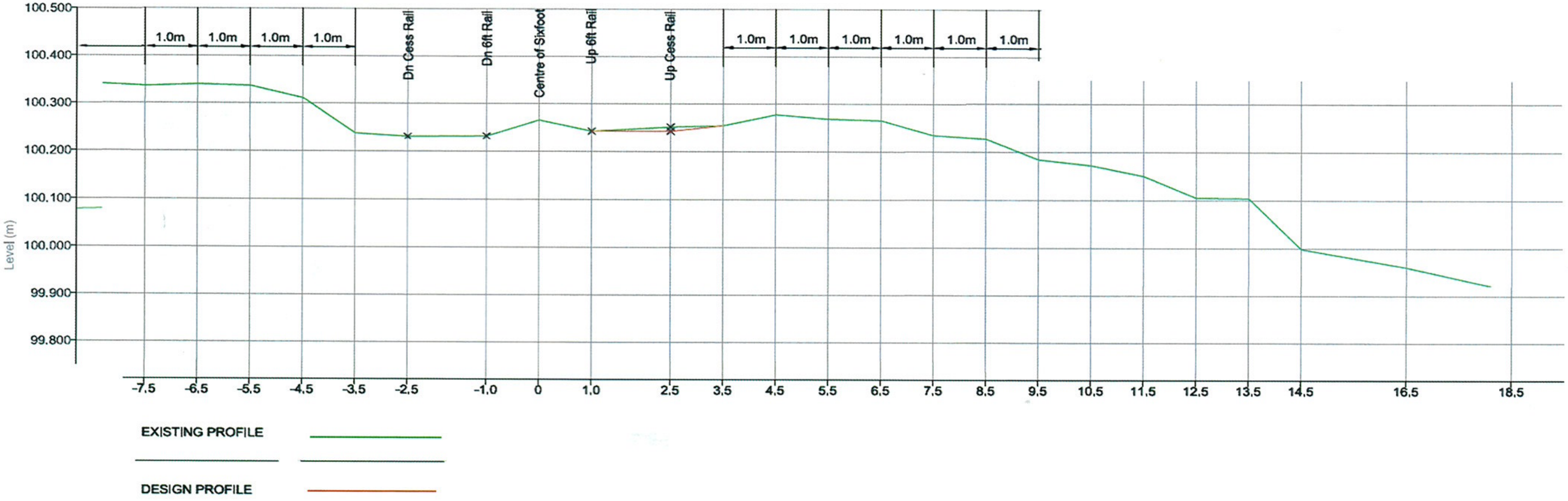


FIGURE SIX: Case Study #3 NAPIER Assessment

NAPIER RESULT

Site: Case Study #3 **Line:** Down Main
PSR = 60 mph 96.56 kph
Drawing No.: case-study-3

Resultant NAPIER CATEGORY		
1A	2A	3A

8.5m Wheelbase (Vehicle Category 3)

Criteria:

= No Input Required
177.978° = Ideal θ Angle (75mm hump)
177.304° = Tolerance on Min. θ Angle (allowing for 100mm hump)

HALF-CHORD	DESIGN LEVELS			DESIGN DIMENSIONS				CRITICAL ANGLE	ITERATION CHECK		NAPIER
	A	B	C	Y_1	Y_2	X_1	X_2	(θ)	Z Level	B-Z Difference	CATEGORY
36+0	100.31	100.337	100.233	5	3.5	0.027	0.104	177.989	100.265	0.072	A
36+0	100.337	100.233	100.261	5	3.5	0.104	0.028	181.650	100.292	0.059	A
36+7	100.25	100.28	100.219	6.5	2	0.03	0.061	177.989	100.226	0.054	A
36+7	100.28	100.219	100.237	2	6.5	0.061	0.018	181.906	100.270	0.051	A
37+4	100.239	100.291	100.215	6.5	2	0.052	0.076	177.365	100.221	0.070	A
37+4	100.291	100.215	100.244	2	6.5	0.076	0.029	182.432	100.280	0.065	A

COMMENT: *No issues.*

9.75m Wheelbase (Vehicle Category 2)

Criteria:

= No Input Required
= Distance C value to be used: No Input Required
178.237° = Ideal θ Angle (75mm hump)
177.649° = Tolerance on Min. θ Angle (allowing for 100mm hump)

HALF-CHORD	DESIGN LEVELS			DESIGN DIMENSIONS				CRITICAL ANGLE	ITERATION CHECK		NAPIER
	A	B	C	Y_1	Y_2	X_1	X_2	(θ)	Z Level	B-Z Difference	CATEGORY
36+0	100.31	100.337	100.226	5	4.75	0.027	0.111	178.352	100.267	0.070	A
36+0	100.337	100.233	100.248	5	4.75	0.104	0.015	181.373	100.291	0.058	A
36+7	100.25	100.28	100.225	6.5	3.25	0.03	0.055	178.766	100.233	0.047	A
36+7	100.28	100.219	100.242	2	7.75	0.061	0.023	181.917	100.272	0.053	A
37+4	100.239	100.291	100.215	6.5	3.25	0.052	0.076	178.202	100.223	0.068	A
37+4	100.291	100.215	100.242	2	7.75	0.076	0.027	182.376	100.281	0.066	A

COMMENT: *No issues.*

15.3m Wheelbase (Vehicle Category 1)

Criteria:

= No Input Required
= Distance C value to be used: No Input Required
178.876° = Ideal θ Angle (75mm hump)
178.502° = Tolerance on Min. θ Angle (allowing for 100mm hump)

HALF-CHORD	DESIGN LEVELS			DESIGN DIMENSIONS				CRITICAL ANGLE	ITERATION CHECK		NAPIER
	A	B	C	Y_1	Y_2	X_1	X_2	(θ)	Z Level	B-Z Difference	CATEGORY
36+0	100.31	100.337	100.242	5	10.3	0.027	0.095	179.162	100.288	0.049	A
36+0	100.337	100.233	100.249	5	10.3	0.104	0.016	181.281	100.308	0.075	A
36+7	100.25	100.28	100.24	6.5	8.8	0.03	0.04	179.475	100.246	0.034	A
36+7	100.28	100.219	100.16	2	13.3	0.061	0.059	181.493	100.264	0.045	A
37+4	100.239	100.291	100.249	6.5	8.8	0.052	0.042	179.268	100.243	0.048	A
37+4	100.291	100.215	100.138	2	13.3	0.076	0.077	181.844	100.271	0.056	A

COMMENT: *Non-compliant critical angle, but with acceptable "hump" value.*

Value Engineering

In order to assist the reviewing engineer to determine whether the level crossing being assessed is compliant, NAPIER can also provide an opportunity to determine the level of adjustment to the profile required to bring the area of non-compliance to within accepted values. If the level of adjustment is considered acceptable or achievable within the project, then the reviewing engineer can make the required adjustments to the proposed design, saving excessive re-work and possible rejection of submitted design. This feature is demonstrated within the case studies below.

Case Studies

In order to demonstrate how NAPIER works, there follow three case studies, taken from a selection of level crossings already assessed using NAPIER. The case studies used relate to track renewals work; however road re-surfacing projects would use the NAPIER process in exactly the same manner.

For the purposes of this paper, each level crossing has been assessed for all three vehicle categories; all three might not be applicable in accordance with the HSE guidance, it is the responsibility of the reviewing engineer to determine which vehicle categories are to be taken into account.

The identities of the level crossings used in the case studies have been removed.

Case Study 1

Refer to Figure Four (i) and Four (ii).
NAPIER Categories: 1C 2C 3C

This level crossing has a serious risk of grounding by any vehicle crossing it. It appears that half of the crossing has "humps" of less than 100mm, which could normally be catered for with the provision of "Risk of Grounding" signs. However, there are other areas within the crossing that pose a significant risk any vehicle striking the crossing and potentially grounding, with "humps" in excess of 100mm. This crossing should be categorised as a serious risk to the rail infrastructure and corrective work should be carried out as soon as possible.

It can clearly be seen that at all locations the critical angle is exceeded throughout the crossing. This means that any HSE categorised vehicle has the risk of being grounded.

This track renewal work is being carried out on the Up Main, and the designed tack level is the same as the Down Main. The issue arises out of the steep gradient of the Up Cess approach road. In order to make this profile compliant both tracks would require major re-levelling, with lowers of over 300mm. The reviewing engineer would need to consider this option in relation to the surrounding infrastructure and track alignment, or the possibility of carrying out road re-surfacing works to lift the levels of the approach roads.

For work to be carried out on the road surface, it is likely that an extended survey would be required to locate a suitable tie-in point for the new road profile.

The reviewing engineer should immediately notify the Territory Track Renewals Engineer and the Level Crossing Risk Control Coordinator.

Case Study 2

Refer to Figure Five (i) and Five (ii).
NAPIER Categories: 1B 2B 3B.

This level crossing falls within the "Risk of Grounding" type of crossing, common throughout the UK national rail network: in other words, there are areas that represent a "hump" of less than 100mm. Therefore, the overall risk associated with this crossing is not as significant as Case Study 1.

The work associated with this level crossing was being carried out to the Down Main. However, as illustrated the reason for the non-compliance is a "hump" in the road surface on the Down cess.

There are two possible solutions, which the reviewing engineer needs to consider: lift the Down Main track level to be co-planer with the Up Main or re-profile the Down Cess area, with a lower of 24mm.

It should be noted that the critical angle associated with the Up cess area, is still within an acceptable tolerance of the ideal angle, therefore if the Down Cess is lowered and the Up Main is tamped or lifted in any way, then it is likely that the road profile on that side of the crossing will also become non-compliant.

It would be prudent of the reviewing engineer to suggest to the Territory Track Renewals Engineer that any work to the Up Main should include a lowering scheme, along with the solution for the Down Cess non-compliance.

The local Level Crossing Risk Control Coordinator should also be notified of the reviewing engineer's findings.

Case Study 3

Refer to Figure Six (i) and Six (ii).
NAPIER Categories: 1B 2A 3A

This level crossing generally falls within the acceptable NAPIER categories; in all vehicle categories the "humps" are within the HSE requirement of 75mm.

For Vehicle Category 2 and 3 there are non-compliant critical angles. However, the "Z" level difference in all cases is less than 75mm, therefore there should be no issues with this "hump" – worst case would be to have to monitor this area of the level crossing profile to ensure there is no deterioration.

For this case study, the reviewing engineer should have no concerns with approving the proposed track design.

Advantages of Using the NAPIER Process

The advantages of using the NAPIER process are as follows.

- A quick turn around of results, after the level survey has been completed.
- Can be used on all types of crossing, including foot crossings.
- Provides the engineer with results in accordance with HSE and Highway Authority requirements.
- Survey tolerance accuracy.
- Can be used on track renewals, track maintenance and civils projects.
- Will indicate where "Risk of Grounding" signs are required, if not already mandated or prohibited – AHB crossings require these signs for Vehicle Categories 2 and 3, whilst risk of grounding for Vehicle Category 1 is prohibited on AHBs.
- Aids assurance that a compliant design has been submitted to the client.
- Could be used to monitor road profiles.

Future Development of NAPIER

It is anticipated that NAPIER will develop into a 3D evaluation model. This will then allow the parallel evaluation of several Nairn's profiles of a single level crossing to ensure complete compliance with the HSE and Highway's Authority road profile requirements and to comply with the requirement to assess the road profile with a view to the camber of the road surface [19].

There is further development anticipated for the NAPIER process to become incorporated into standard design packages (for example, MXRail or ClearRoute); thereby allowing designers greater ease in inputting the survey data and using the NAPIER process simultaneously with the track or road design to help reduce the requirement for re-work to be carried out.

NAPIER On-Line

A web-based version of the NAPIER process is currently being developed to act as assistance to reviewing engineers. This will be accessible to anyone via the internet. However, currently there are no plans to provide the level correction element of the process, detailed in the case studies above. The on-line version will provide a summary report of the NAPIER categories generated for a given Nairn's profile, inputted by the on-line user.

The web-based application should be available on-line in 2009. Please contact the author for further details.

Summary

The NAPIER process can be used on all types of crossing, including foot crossings, on track and civil projects. Once the survey for the Nairn's profile has been completed, it is a quick and simple process that can be used by engineers to assist them in determining the suitability of the road profile in question and to indicate a way forward to make the level crossing profile compliant.

Reviewing the NAPIER results will help the reviewing engineer in determine what course of action, if any, is required to either make the level crossing compliant or to help mitigate the grounding risks associated with that crossing.

NAPIER, in its conceptual state, has already been used to great success on the East Midlands area, where the proposed track design was either amended or civils works to the level crossing cill beams were proposed, which removed the risk of grounding issues for several level crossings in the area.

For further details regarding NAPIER please contact the author
david.brooks@corusgroup.com

A pdf version of this paper will be available from the author's website
www.authorandengineer.co.uk

Acknowledgements

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Book Review

The Transformation of St Pancras Station, by Alastair Lansley

240 pages, 250mm x 250mm, hardback
ISBN 978 1 85669 552 7
Published by Laurence King Publishing Ltd, 361 City Road, London, EC1V 1LR
Price £30.00

"The transformation of St Pancras is a triumph". This, the first sentence in the book, says it all. Admittedly when Sir Neil Cossons wrote this in his foreword he, wearing his hat as chairman of English Heritage, was looking from an architectural and cultural perspective on the creative reuse on a grand scale of an iconic structure. But within the pages of the book proper Alastair Lansley recounts much of the detail and context for the work involved between the start in 2001 and the official opening in November 2007. Lansley was chief architect and leader of the Rail Link Engineering architectural design team for the reconstruction of St Pancras station and for the international stations at Ebbsfleet and Stratford. A brief first chapter outlines the origins of the station and the adjacent hotel; anyone wanting to know more about this earlier period should look to Simon Bradley's book *St Pancras Station* (Profile Books, 2007). Ten further chapters explore various aspects of the story from the condition in which the station was inherited by Union Railways through the design and construction phases when the station was refurbished, remodelled and extended to meet its current purpose. The book concludes with a chapter describing the opening by Her Majesty the Queen.

The author is mindful at the outset to dedicate this book to the many hundreds of people who have contributed to the St Pancras International station project and he includes at the end of the book a list of all the companies who were involved. This was, in its time, one of the largest civil engineering projects in Europe.

Technical editor of this book was PWI member Bernard Gambrill. Anyone who has heard Bernard speak about the project or about the related works on the high speed railway to the Channel Tunnel will recognize his deft touch in teasing out and placing into context the crucial technical points. Seekers for arcane details about the new permanent way within the station will have to look elsewhere but there is a great deal in the book to intrigue the engineers amongst us. Chapter 6, *Transformation*, explains much about how the original train shed was refurbished and modified. It is something of a pity that this structure will probably remain known at the Barlow Train Shed. Not only does it, as Ted Hamer pointed out in his PWI Journal article (126/1, pp 13-16), owe as much to Rowland Ordish as it does to William Barlow but it now also owes a great deal to the design and construction skills of those involved in the past decade. There will also be wry smiles amongst many in the railway community with the account in this chapter of how drainage problems inherent in the original design, and either tinkered with or neglected by later generations, have only lately been identified and resolved.

A feature of the book is the lavish use of illustrations. Some of these photographs are quite spectacular. Those showing work in progress are particularly valuable in helping to explain how the construction was accomplished. Those in chapter 7, *21st Century Gothic*, in particular resonate with much that PWI past president Jim Cornell has recounted to section meetings about the work of the Railway Heritage Trust. This chapter also includes a succinct explanation of how the Grade 1 listed status of the original buildings was accommodated within the redevelopment work. Photographs also do justice to the *St Pancras Blue* colour scheme that many will be aware of and, if you look closely, also the rather less well known *Barlow Ordish Tartan*.

The book too is full of little surprises. It is useful to be reminded by the map on page 52 of just how many routes were proposed for the new high speed railway into St Pancras and on pages 222 to 225 of the vicissitudes of name changes and logos for the various participants. Similarly it is useful, else most of us would probably not notice, to have explained that the signage at St Pancras International has its own purposed designed typeface; skilfully deployed for the chapter headings in this book.

The development of St Pancras International is story that deserves to be told. This book tells the story well and is entirely worthy of a remarkable project.