The Resilience of Vision-Based Technology for Trackbed Monitoring

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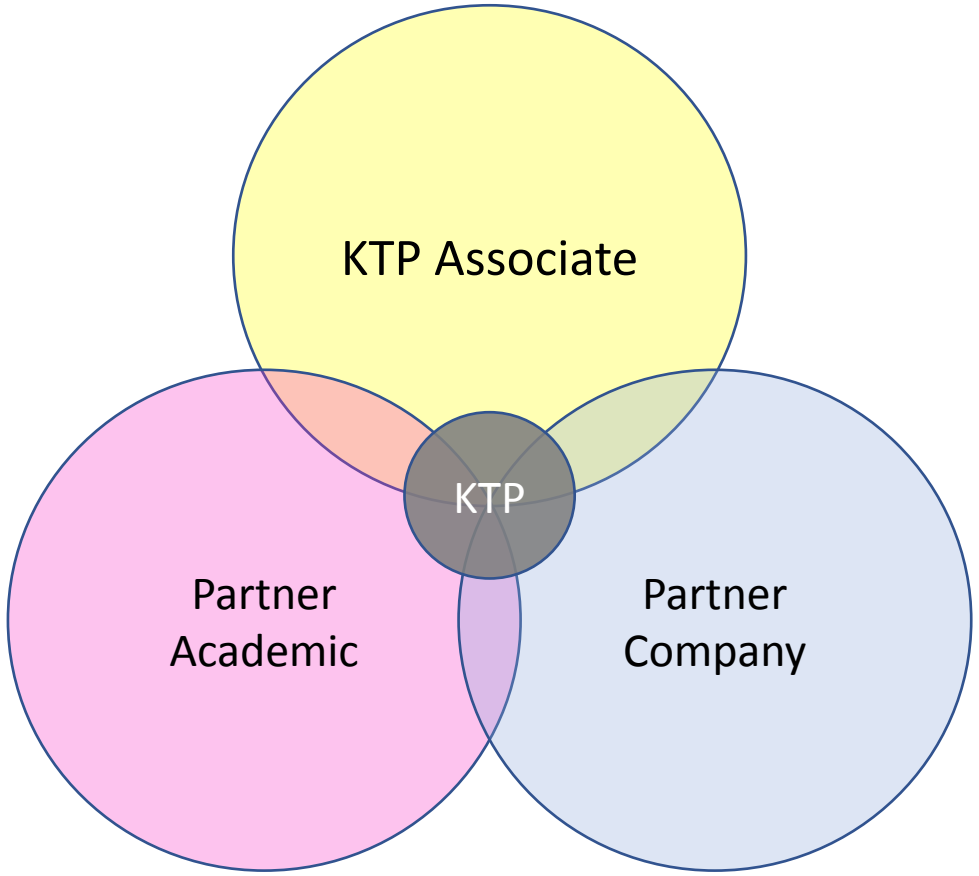

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Van Elle Holdings plc, the **UK's** largest ground engineering contractor

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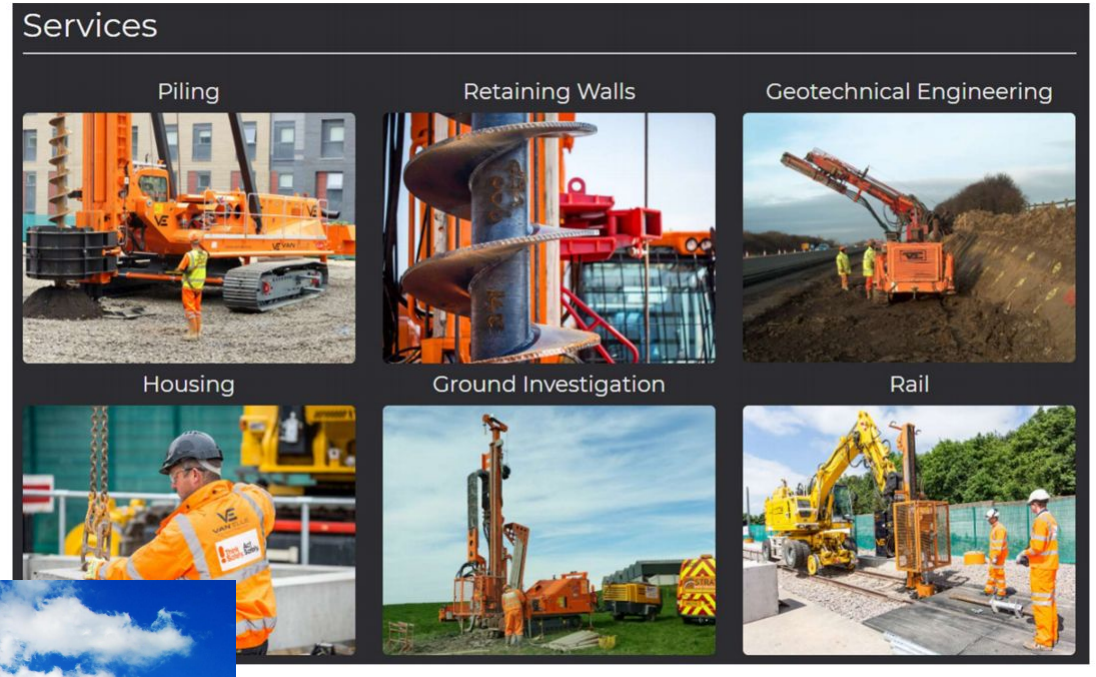
Van Elle Group:

One of the UK's leading piling contractors

- **UK's Largest Ground Engineering Contractor**
- **Specific Rail Division**
- **Network Rail Principle Contractor**
- **Ground Investigation Capability**
- **In House Transport Fleet**

- **In house Van Elle Training and Assessments** established in 2017, has been set up to service both internal and external training needs



VE deliver training in the following areas:

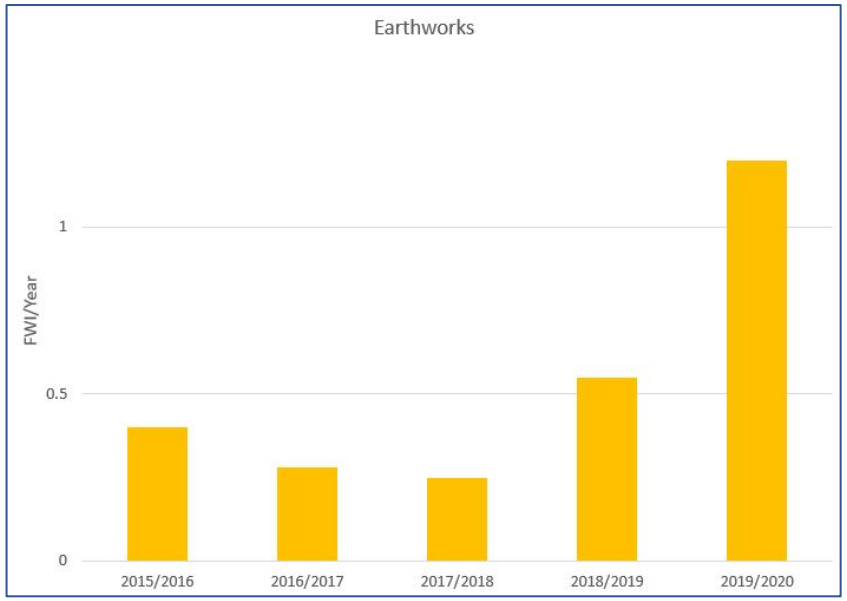
- PLANT
- CIVILS
- CONSTRUCTION EQUIPMENT
- SITE SAFETY
- VOCATIONAL QUALIFICATIONS
- BESPOKE TRAINING COURSES

Railway track failure

Britain's National Rail networks are one of the safest railways in Europe (ORR, 2020a), However:
every year accidents are occurring on a section of track due to a number of landslides and other geotechnical failures.

- Earthworks contribution to train accident risk as measured by the PIM* from 2015/16 to 2019/20. The predicted Earthworks risk, (from 2015/16 to 2019/20) varies from approximately 0.25 to 1.25 Fatality Weighted Index (FWI) per annum.

*A Precursor Indicator Model (PIM) has been developed by the Rail Safety and Standards Board (RSSB) as a quantified risk model for understanding train accident risk.



Earthworks contribution to train accident risk (source: A Review of Earthworks Management 2020, Network Rail)

The problem in the railway systems

- **Track subgrade failure**

Railway track bed failure induced by:

- Poor track geometry due to subgrade failure.
- Critical velocity sites – failure due to repetitive cyclic loading of soil.

Not always easy to spot by observation.

Which Result in……..

- Increased maintenance costs
- Temporary Speed Restrictions (TSR).
- Reduced utilisation of track
- Reduced line speed

- and consequential and **costly train delays**

Rapid rate of geometry deterioration as a result of low track stiffness
(source: A Guide to Track bed Micro Piling, 2017)

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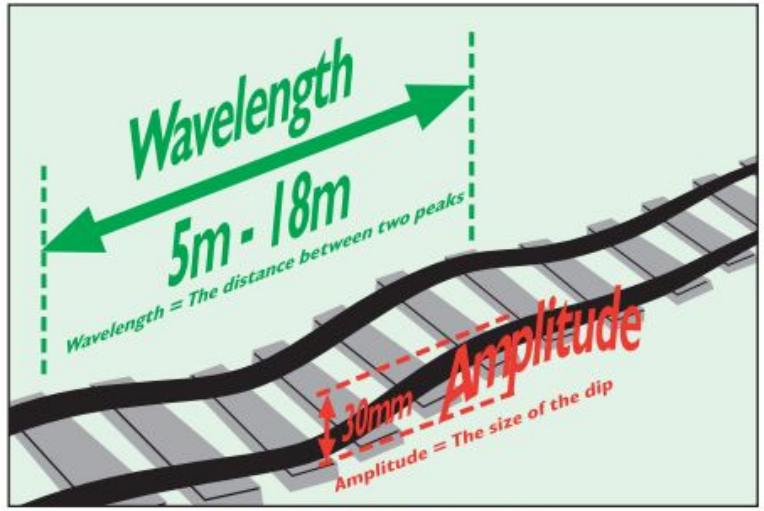
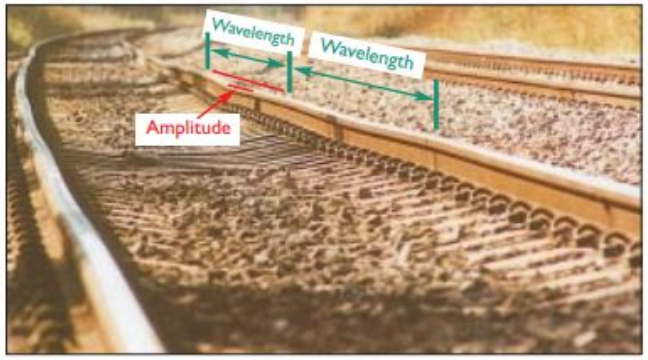
The Problem



Wavelength and amplitude of cyclic top faults



Photograph of cyclic top site

Home » News

NEWS

Network Rail fined £733,000 over freight train derailment

20 March 2018

Network Rail Infrastructure has been fined £733,000 after its track maintenance team failed to carry out repair work that would have prevented a train derailing near Gloucester.

R
AIB

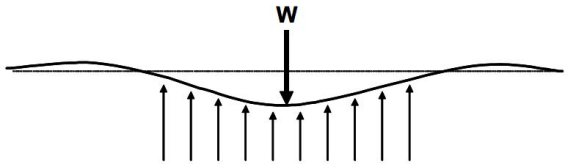
The incident happened at around 8.15pm on 15 October 2013, about 6.4 km south west of Gloucester station on the railway line from Newport via Lydney.

The Direct Rail Services-operated freight train was travelling at 111 kph when the rear wheelset of the last wagon derailed on track that had regularly spaced dips in both rails.

The track defect, known as cyclic top, had formed due to water flowing underneath the track and was the immediate cause of the derailment, the Rail Accident Investigation Branch (RAIB) found. This was accentuated by inadequate drainage.

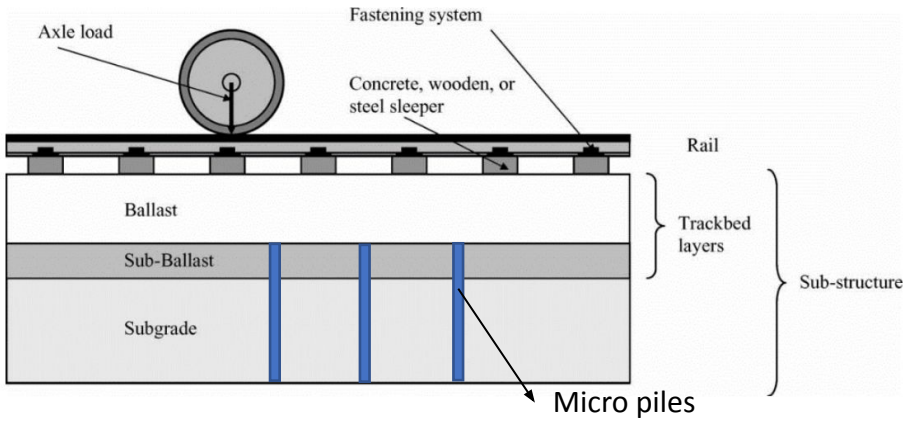
Track stiffness

- **Track stiffness** is used to assess the trackbed condition, which is defined as the **amount of force required to deflect the track vertically**, and its values depend on the effective stiffness's of all the individual elements of the track system combined; including ballast, rail, fastenings, sleepers and subgrade.



Rail deflection under load for beam-on-elastic-foundation theory

- In areas of soft subgrade, **micro piles** can offer a solution to these types of problems without the requirement to remove the track.



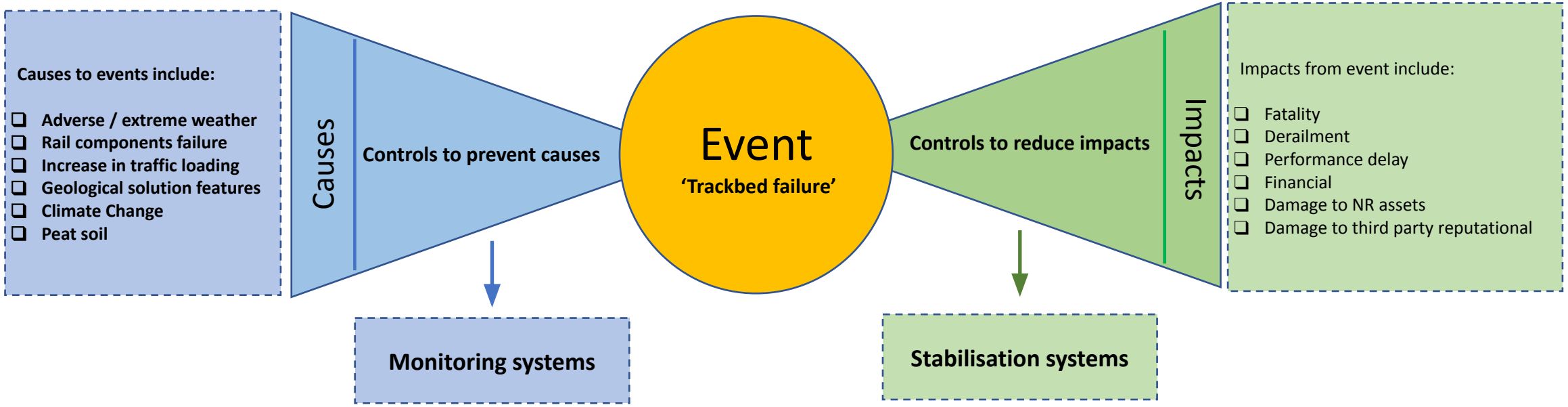
Ballasted rail track typical section (source: Glendinning et al. 2009)

Installation of Screw piles (source: Van Elle ltd.)

Project aim

- To optimise **micro-piling systems** installed into **rail track beds** that will **improve train stability** using:

- an accurate **non-contact measurement** collection methods and
- geotechnical design models (i.e. **numerical analysis**)

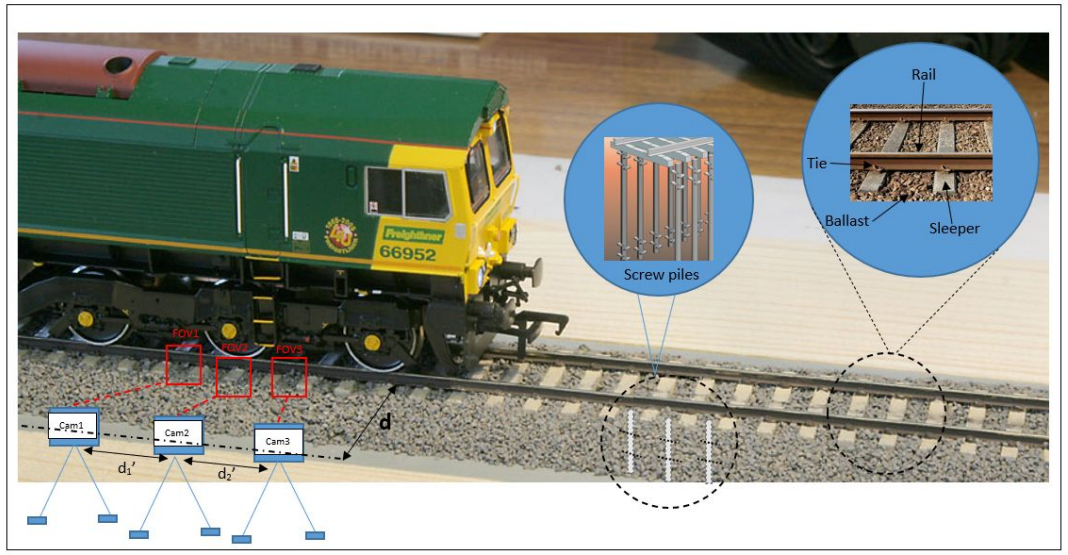


Trackbed monitoring and stabilization systems

- **Vision-Based monitoring (VBM):** an accurate **non-contact measurement** collection method to measure trackbed deflection

- N**umerical analysis** (i.e. FEM): to simulate trackbed stabilisation systems (i.e. micro piling)

measuring and modelling rail track beds and optimising **micro-piling systems** installed into **track beds** that will improve train stability.



Trackbed monitoring, and stabilisation systems

VBM

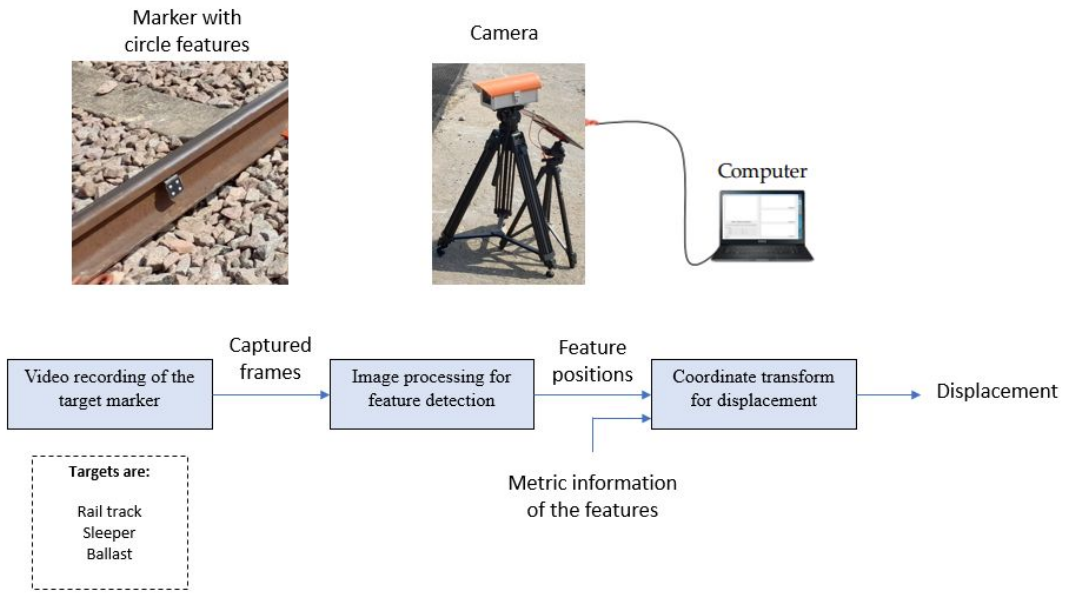
Vision-Based monitoring (VBM) technology:

VB technique is generally composed of image acquisition device (cameras or frame grabber boards), computer, and an image processing software. In this application, a high-speed camera is used to record the video that is post-processed using video-processing code custom-developed in MATLAB.

VBM

A target-based VB system was used for tracking artificial targets using standard high-speed camera, equipped with lens to achieve resolution to a small fraction of a pixel.

- Algorithm in MATLAB
- Signal processing (filter the noise, smooth the graph)

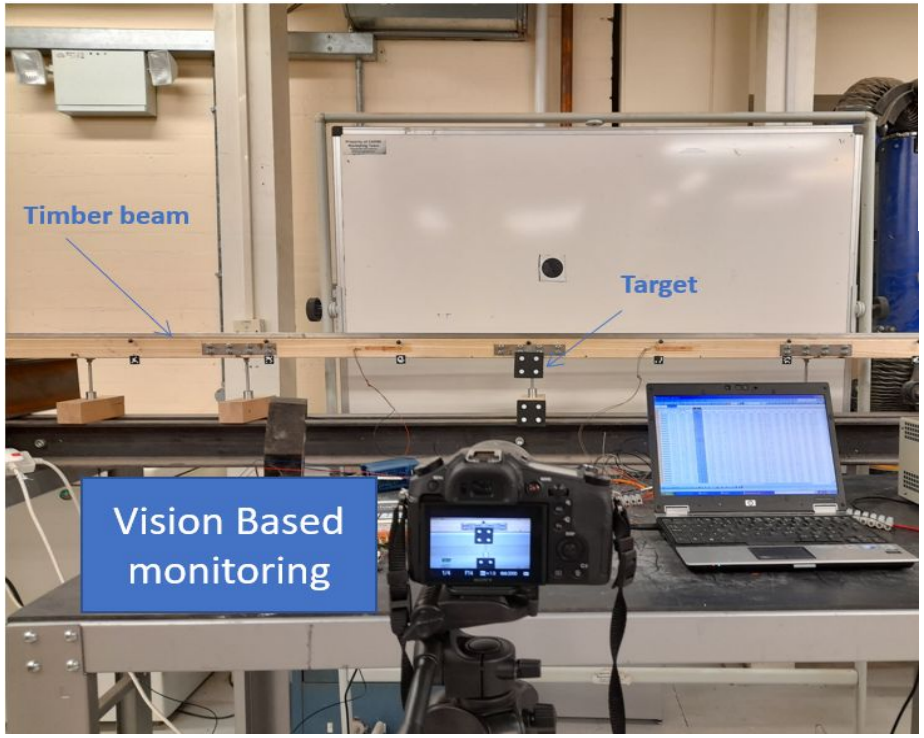


Typical configuration of vision-based monitoring systems, Hardware and software

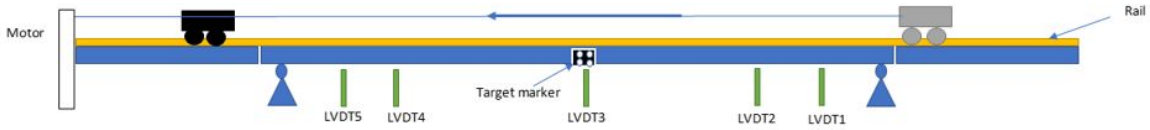
VBM (lab-scale)

NTU small-scale lab tests:

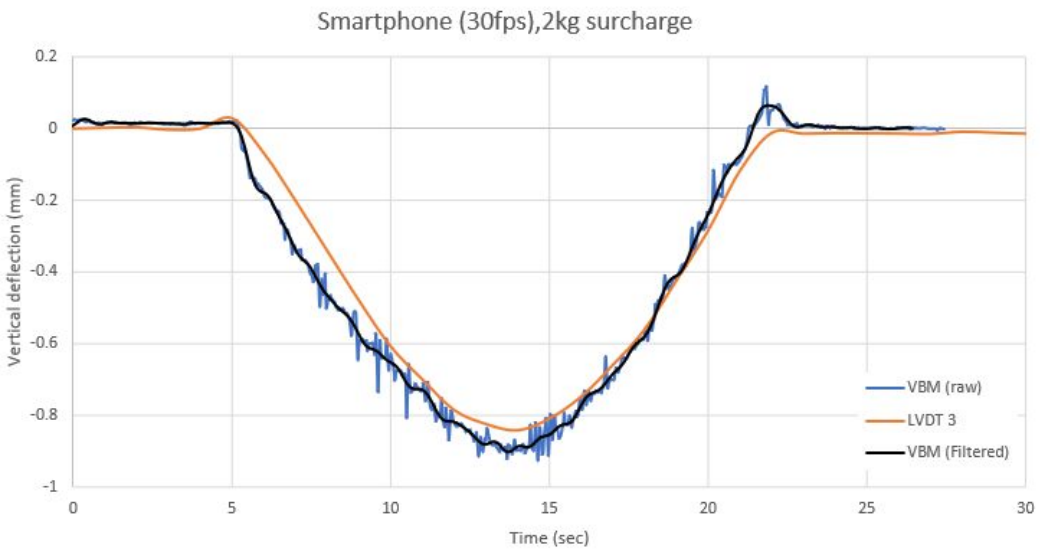
about 20 tests were conducted based on different loading and camera configurations.



NTU lab set-up
(for VBM validation)



Schematic of experimental setup.



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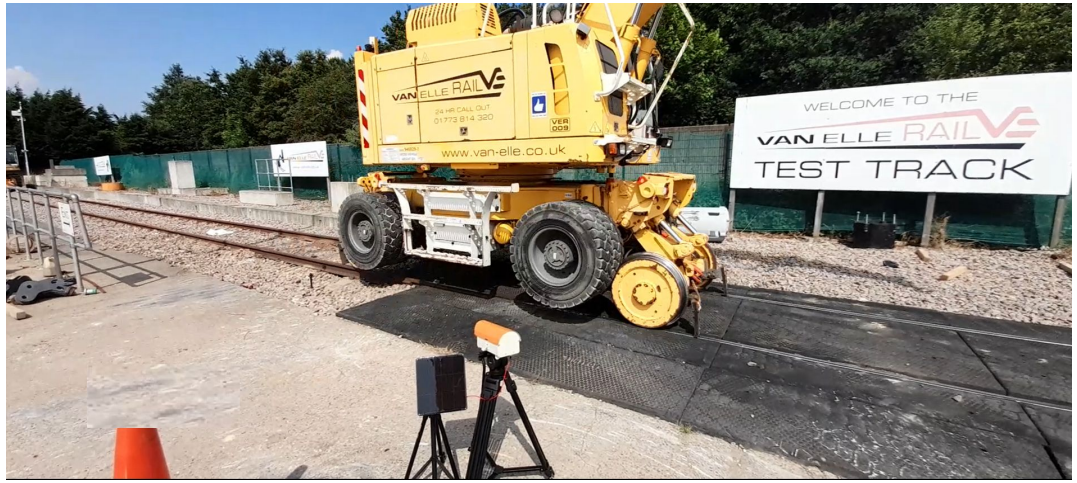
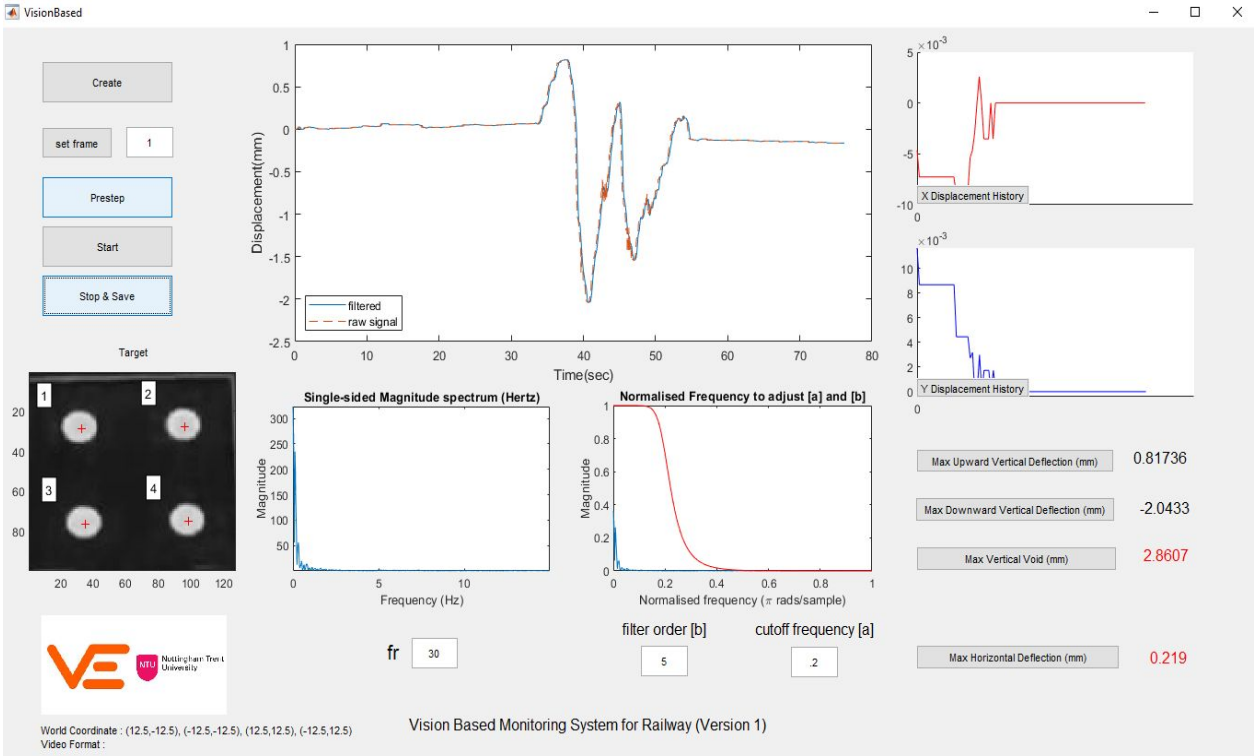
VBM (Large-scale)

Van Elle Rail Test Track :



High speed camera for VBM

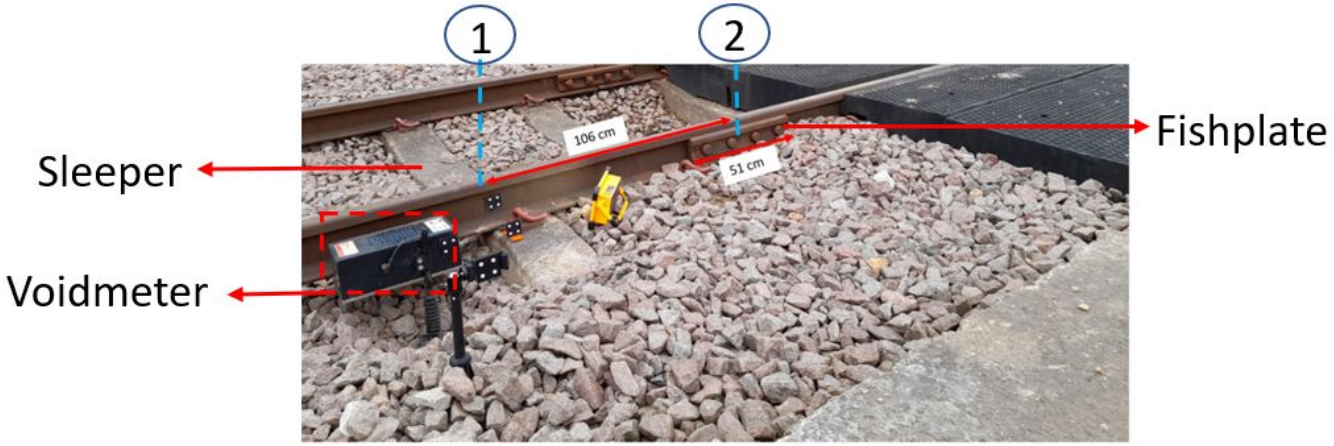


Graphical interface of VB in Matlab

VBM (Large-scale)

VE large-scale trials:

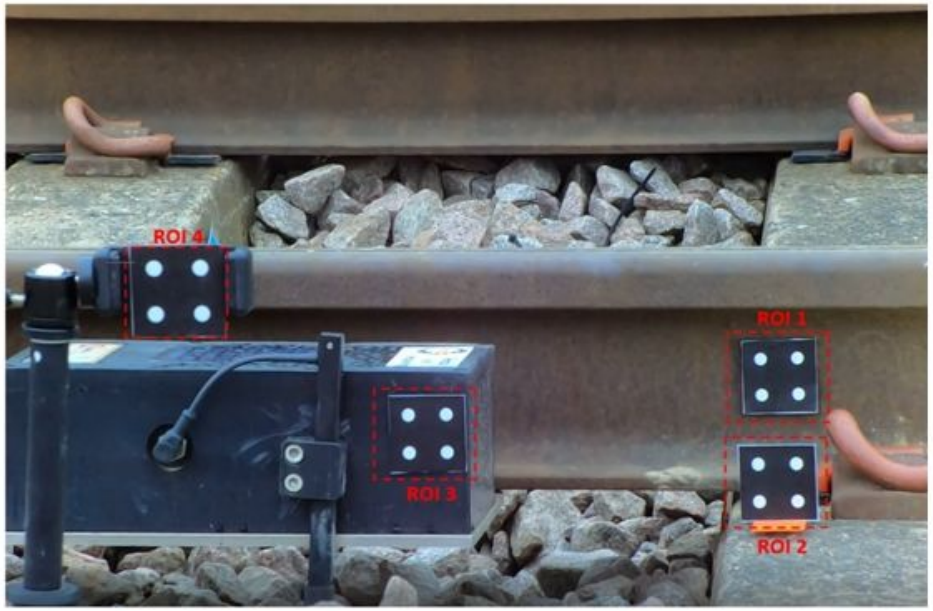
about 40 trials were conducted based on different loading and vehicle (train) configurations.



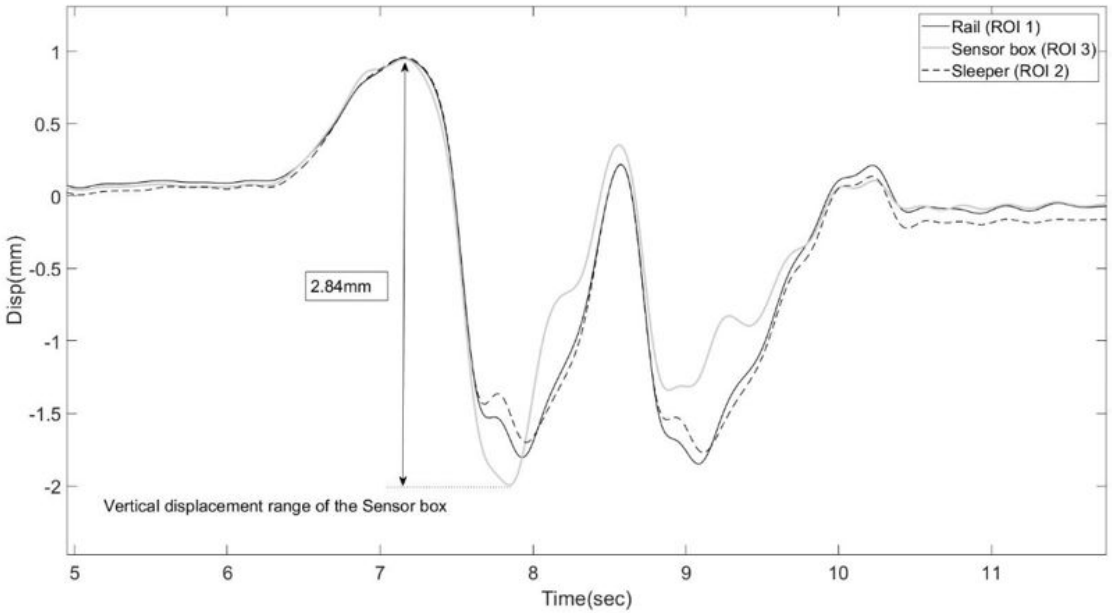
Van Elle's full-size outdoor test pit.

VBM

VE trial results:



A typical video image with Region of Interests (ROIs).

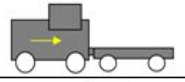
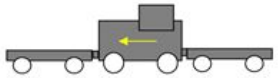
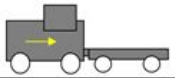
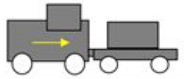


Vertical displacement versus Time for T3, obtained by VB system.

VBM (Large-scale)

VE trial configurations:

Summery of the trials

Test ID	Number of trailers	Clipped/ Unclipped	Rail/joint	Surcharge on the trailer	Vehicle, trailer arrangements and traveling direction
T1	No trailer	Clipped	Rail	-	
T2	No trailer	Clipped	Rail	-	
T3	No trailer	Clipped	Rail	-	
T4	1 trailer	Clipped	Rail	0	
T5	1 trailer	Clipped	Rail	0	
T6	2 trailers	Clipped	Rail	0	
T7	1 trailer	Unclipped	Rail	0	
T8	2 trailers	Unclipped	Rail	0	
T9	1 trailer	Clipped	Joint	0	
T10	1 trailer	Clipped	Rail	7.5 T	

VBM (Large-scale)

VE trial results

VBM compared with Voidmeter

Voidmeter

VBM

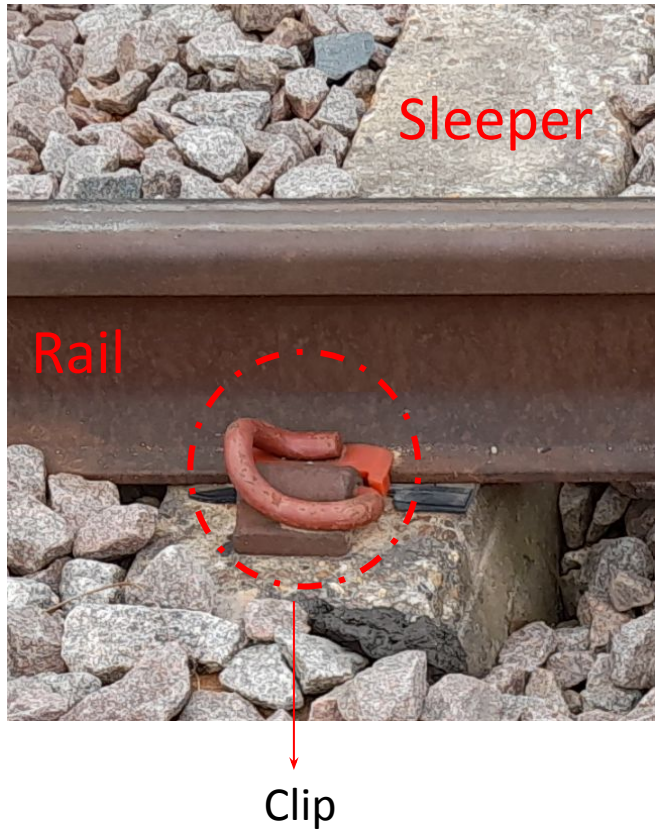
Comparing between Voidmeter and VB measurements

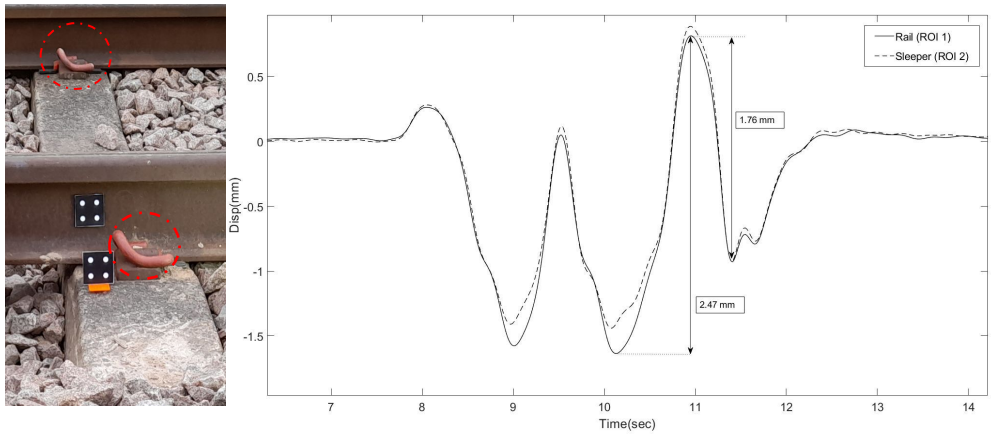
Test ID	Measured by Voidmeter (mm)	Measured by VB for ROI 3(mm)	Difference in percentage (%)
T1	2.7	2.84	5.2
T2	2.83	2.94	3.9
T3	2.74	2.84	3.6
T4	2.49	2.62	5.2
T5	2.29	2.31	0.9
T6	2.89	2.87	0.7
T7	2.56	2.66	3.9
T8	2.67	2.81	5.2
T9	-	-	-
T10	1.48	1.54	4.1

VBM (Large-scale)

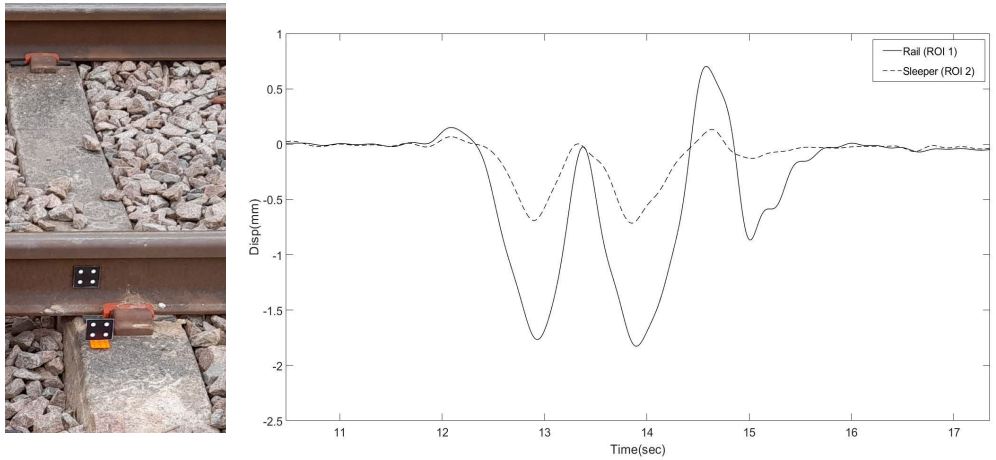
VE trial results

The effects of rail fastening systems (clip) on the trackbed deflection





Vertical displacement versus Time for T4, with maximum displacement range of 2.47mm for the rail on the sleeper, obtained by VB system.



Vertical displacement versus Time for T7, obtained by VB system.

Rail fastening failure

Rail Accident (Freight train derailment at Hampshire January 2020)

Some of the fastenings had fractured (or missing), prior to the passage of the train. This allowed one of the rails to move outwards under the train, breaking further fastenings.
This caused all of the locomotive's wheels to drop into the now-widened gap between the rails and to derail.

Source: Freight Train Derailment at Eastleigh, Hampshire: 28 January 2020
Publisher: RAIB, 2021

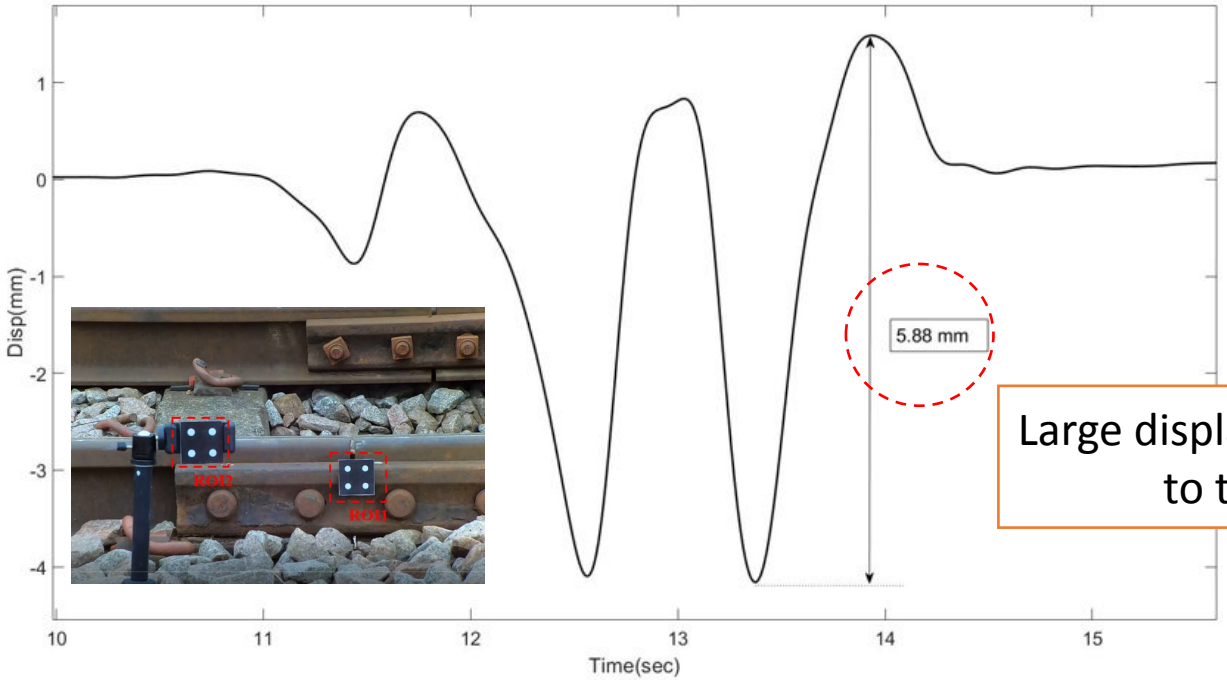
VBM can be used to improve railway safety by preventing future railway accidents or by mitigating their consequences

The derailed wagons following the accident (source: RAIB, 2021)

VBM (Large-scale)

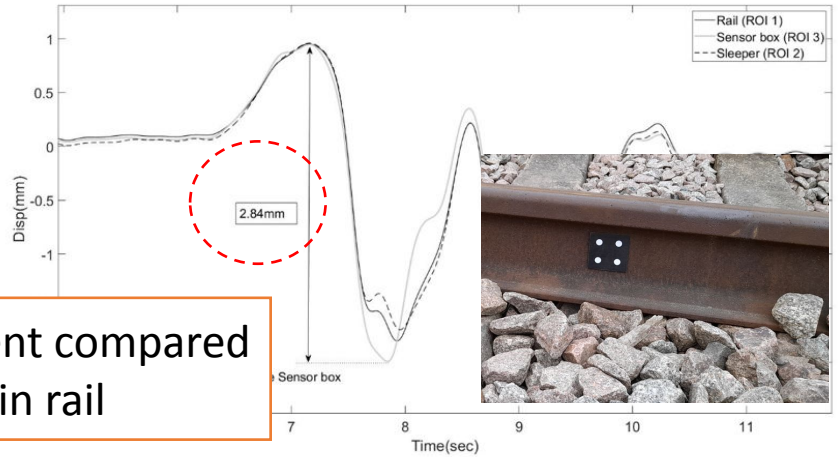
VE trial results

Vision-Based monitoring system was used to measure the vertical deflection at joint (fishplate)



Vertical displacement versus Time at joint (T9), with maximum displacement range of 5.88mm for the rail at joint, obtained by VB system.

Large displacement compared to the plain rail



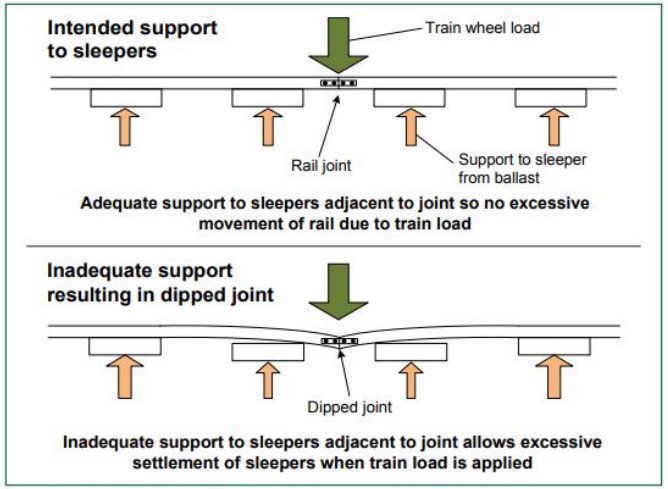
Vertical displacement versus Time for T3, obtained by VB system.

Rail fishplate failure

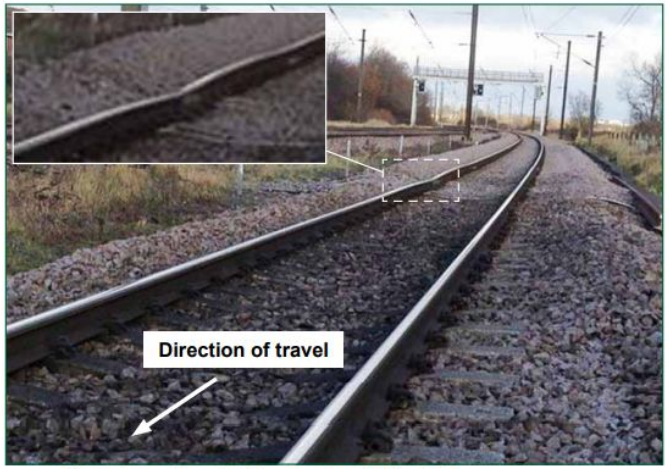
Rail Accident (fishplate failure)

Source: Class investigation into rail breaks on the East Coast Main Line
Publisher: RAIB, 2014

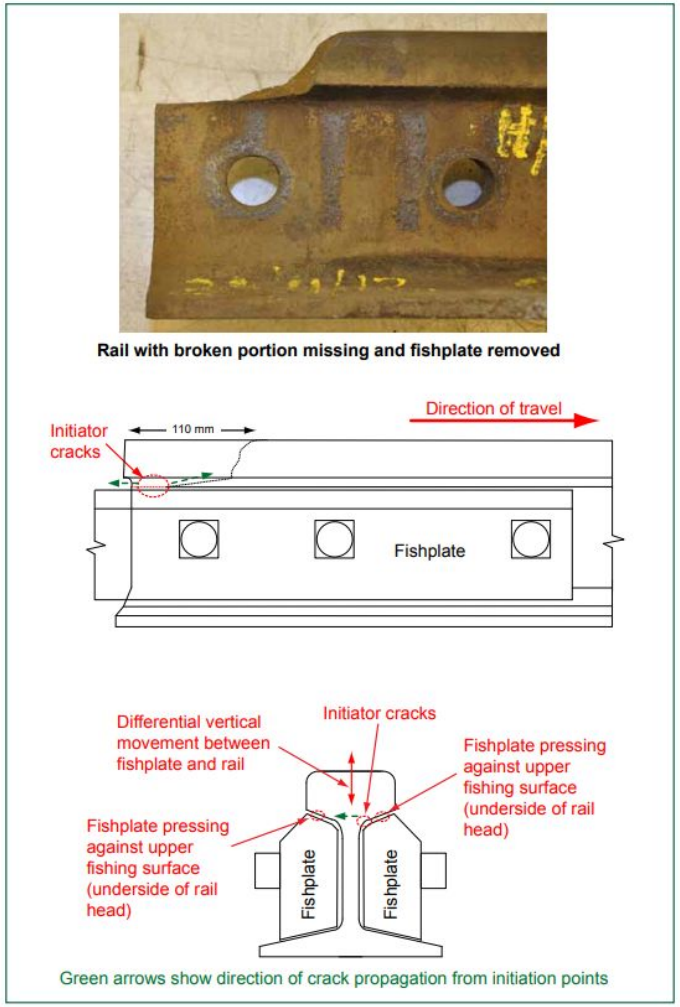
VBM can be used to improve railway safety by preventing future railway accidents or by mitigating their consequences



Effect of inadequate support from ballast



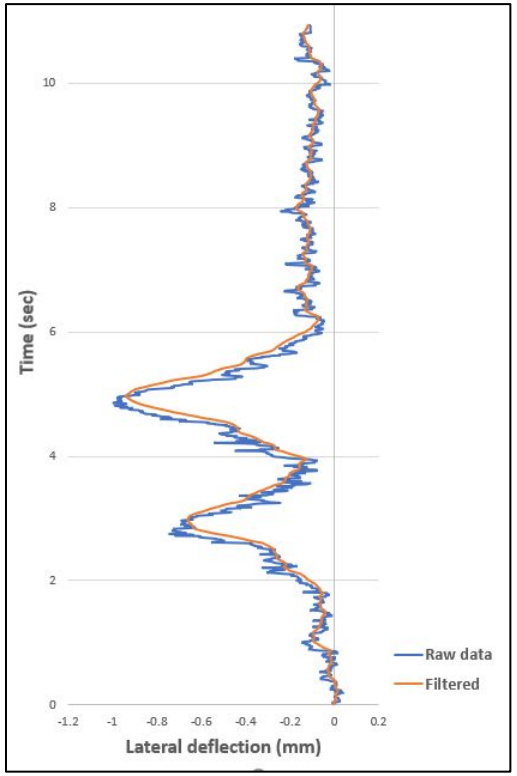
Copmanthorpe - Dipped joint (image courtesy of Network Rail)



VBM (Large-scale)

VBM can also be used to measure the Lateral Deflection

Van Elle trails



Lateral displacement versus Time obtained by VB system.

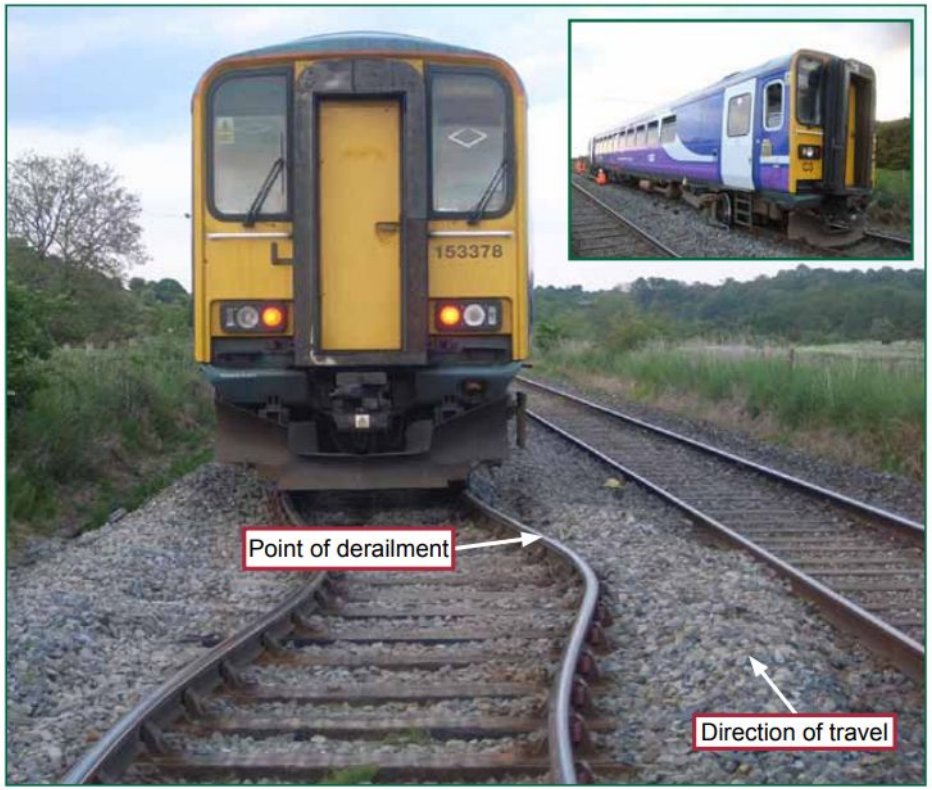
Rail buckling

Rail Accident (buckling)

There are several factors which are known to increase the vulnerability of a section of track to buckling:

- Tight or seized joints
- Rail creep
- The natural resistance of the track to lateral buckling, which is depende
  - •track construction (i.e type of rail, sleepers, fasteners, ballast);
  - •condition of the track and ballast (e.g ballast shortage or voided sleepers

Source: Derailment of a passenger train near Cummersdale, Cumbria 1 June 2009
Publisher: RAIB, 2009



The derailed train showing the track buckle and the rear of the train 2C31 and (inset) the front of the train and derailed leading bogie

VBM

Advantages of VBM used in trackbed monitoring:

- Known as **non-contact** measuring system with less access to the rail and provides high safety
- High accuracy in the **measurements of rail vertical deflection**
- **Cost** effective
- It can be used:
  - To measure the **void** between sleeper and rail and consequently detect faults in fastening systems, while the typical void meter cannot measure the gaps between the rail and sleepers
  - To measure the **lateral deflection** of rail, whereas the typical void meter measures only the vertical deflection
  - To estimate the **train velocity**, and **number of axles**

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Thanks for listening.

Any Questions?