Final Conference, WP4:Structures

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UIC Paris

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GA H2020 - 730841

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TD 3.5 intro: The bridges and tunnels of tomorrow…
Objectives

Sharpshooter bridge and tunnel asset management

- Tunnel vision
- Bridging the data gap
- It's not information if you can't find it
- So, are they working?

Repairs and refurbishing

- And what if they're not?
- Cleaning the pipes
- Why the sudden change?

Low-cost dynamic bridge design

- A new wave in bridge design
- The impact of statistics

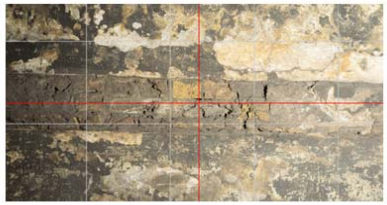
TD 3.5 intro: The bridges and tunnels of tomorrow…

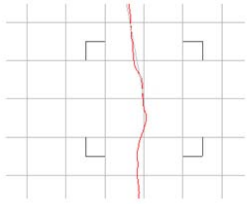
…are, mostly, **those of today!**:

- Line closure is rarely an option
- Replacing all “old” bridges is way too expensive…
- …and tunnels simply cannot be replaced…

…but still, thousands of them are too old, too damaged or too weak for present and future rail demand…

Photo 10 – Area of missing and eroded string course to Down side wall at south end.





or are they?

Objectives

As part of Shift2Rail TD3.5, WP4 strives to:

1. *Develop faster and more accurate methods for inspection and assessment of tunnels and bridges including improved repeatability, reproducibility, quality and effectiveness*

(**Non disturbing**, fast, reliable and continuous **status assessment**)

2. *Develop new repair, strengthening and upgrading techniques which result in reduced traffic disruption and fast installation with short track access time.*

(**Non disturbing**, fast and reliable **capacity upgrade**)

3. *Set the base for future development of noise and vibration damping methods for structures*

(**Non disturbing** mitigation of **noise and vibration externalities**)

IN2TRACK

Sharpshooter bridge and tunnel asset management:

Enhanced and exhaustive monitoring, inspection and evaluation for minimal traffic disturbance

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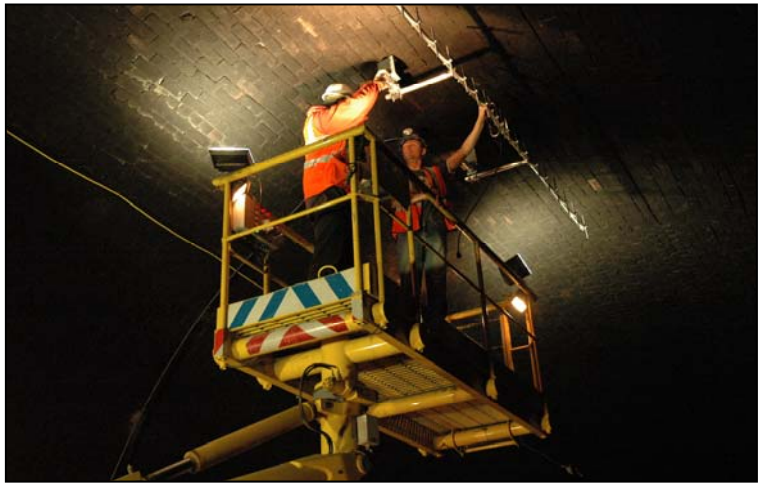
Tunnel vision: frome yore to today

Tunnel inspection has not progressed all that much in 60 years

UK Tunnel Examinations 1950s

Tunnel Examinations today



Tunnel vision: more than meets the eye

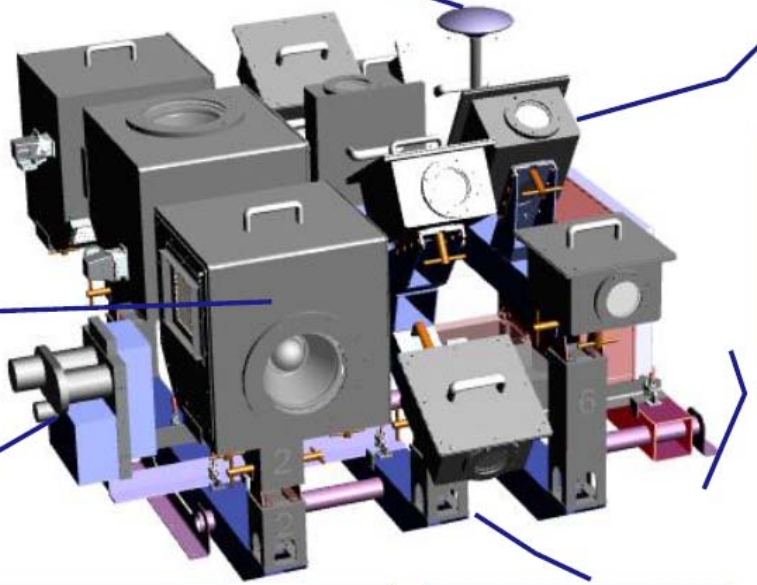
Tunnel activities require **possession time** for **safety** reasons, so how to **lower disruption**?
…either you *grab all you can as fast as you're able…*

Trolley acquisition system

DIFCAM

GPS
Accurate positioning reference point at the entrance to the tunnel

Camera System
9 computer-synchronised 24 MPx cameras & flash guns



Flash Lighting
3 studio quality rapid recharge flash units

Tachometer / Odometer
Accurate length measurement within the tunnel where GPS won't work

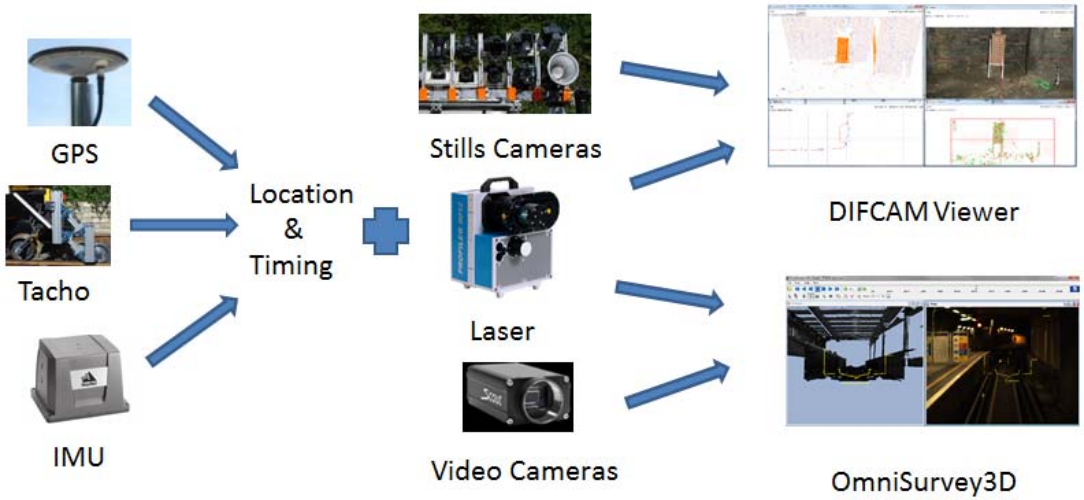
Laser Scanner
Measures the cross section of the tunnel producing a point cloud of data

Custom Mounting
Trolley or RRV system

Tunnel vision: more than meets the eye

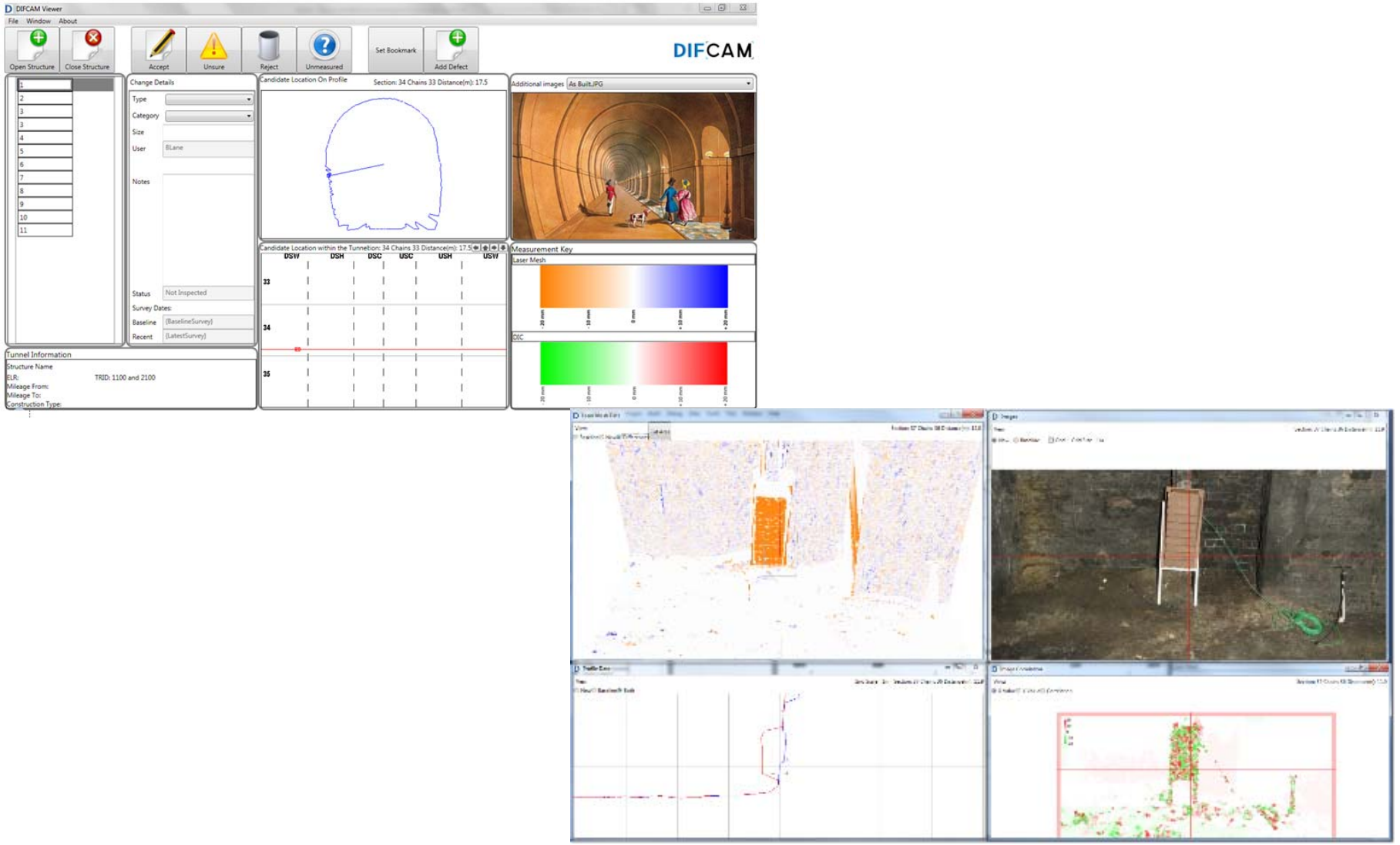
Tunnel activities require **possession time** for **safety** reasons, so how to **lower disruption**?
…either you *grab all you can as fast as you're able…*

- GPS+IMU+Tachometer for **accurate positioning**
- Synchronized multi-camera system for **Digital Image Correlation** analysis
- Laser scanner produces **accurate point cloud** of inner surface



Tunnel vision: more than meets the eye

Tunnel activities require **possession time** for **safety** reasons, so how to **lower disruption**?
…and look at it safely frome your office computer…



Tunnel vision: more than meets the eye

Tunnel activities require **possession time** for **safety** reasons, so how to **lower disruption**?
…to get automated detection of changes and new defects…

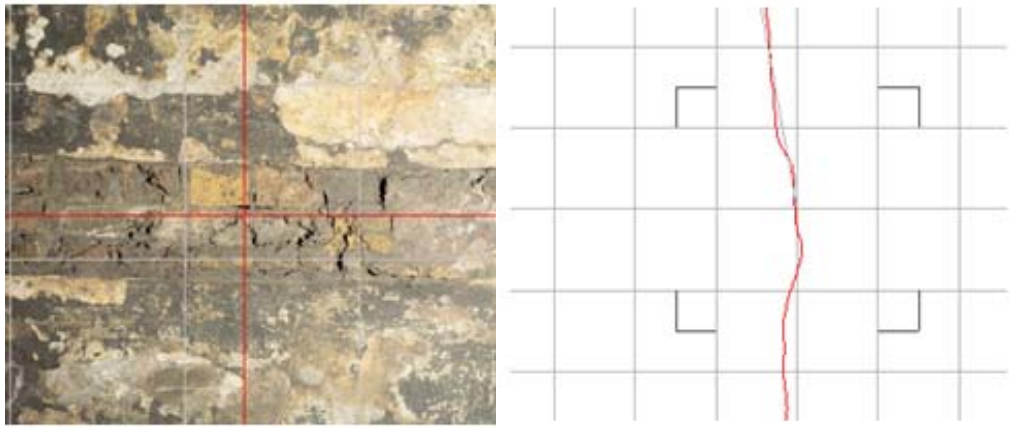
Before

After

Footsteps in ballast

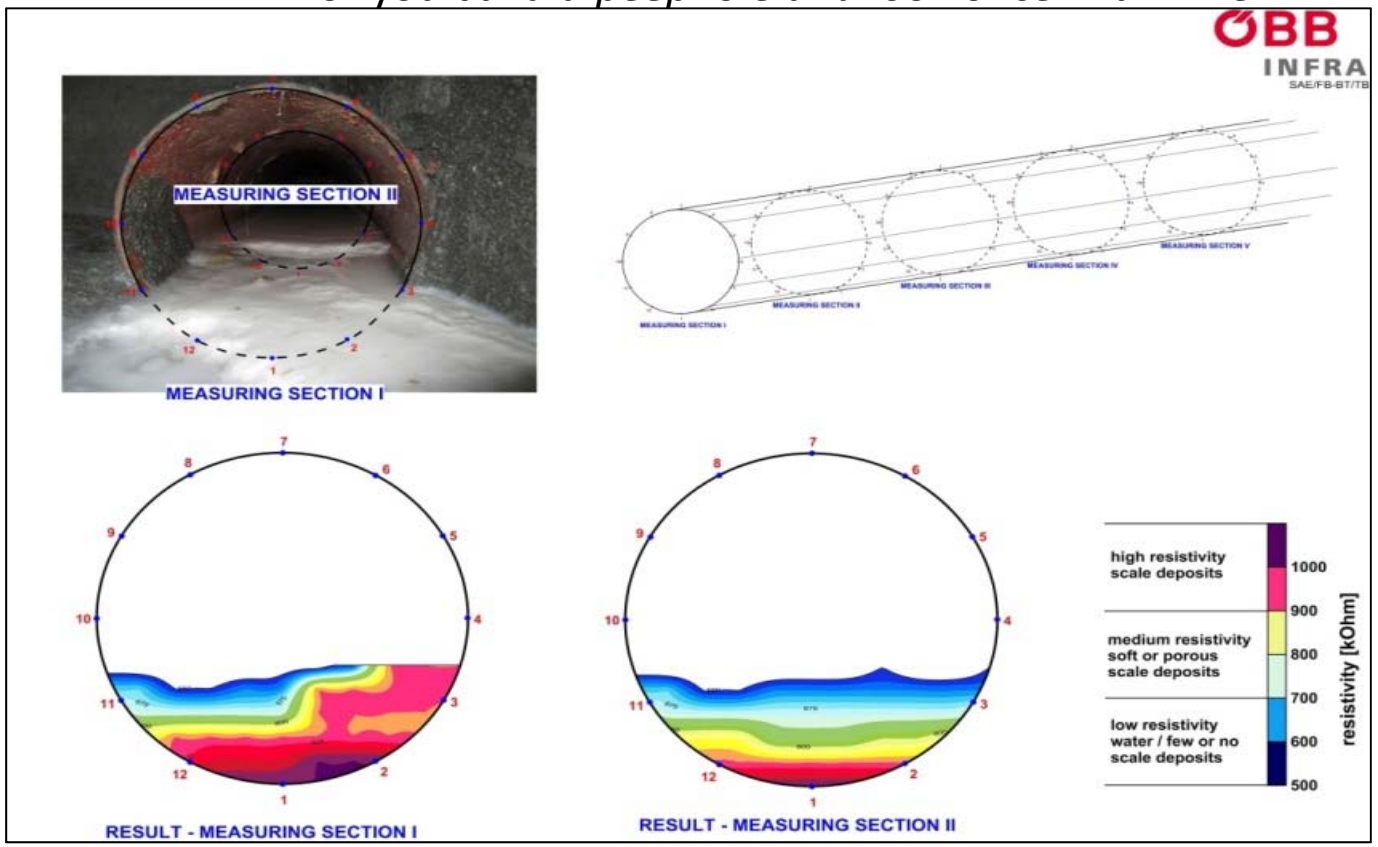
Manual damage identification Vs Automated damage detection and definition

Photo 10 – Area of missing and eroded string course to Down side wall at south end.



Tunnel vision: undercover data gathering

Tunnel activities require **possession time** for **safety** reasons, so how to **lower disruption**?
…or you *build a peephole and look once in a while*

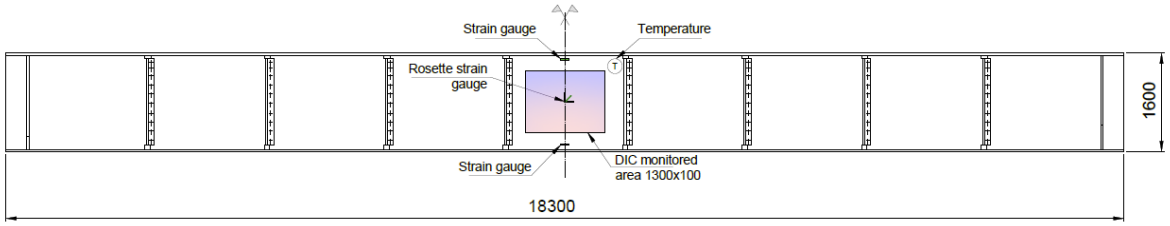


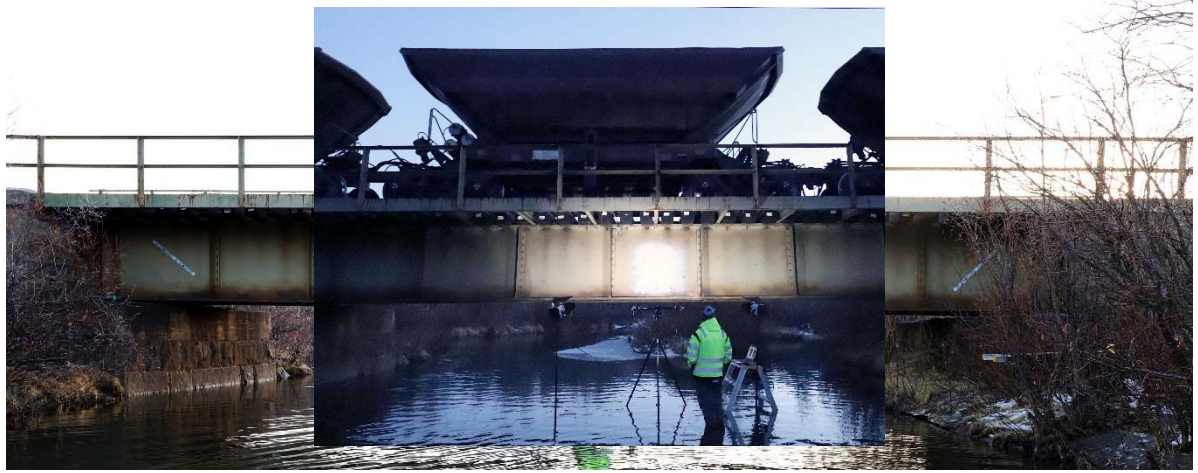
- **Permanent drainage monitoring :** capacitive tomography technologies, acoustic analysis of the drainage pipe and detection of the amount of scale deposits by monitoring the changes of the pipe's mass moment of inertia

Bridging the data gap: you look stressed

Optical methods reveal the stress state of steel plates

Mjellijokk Bridge

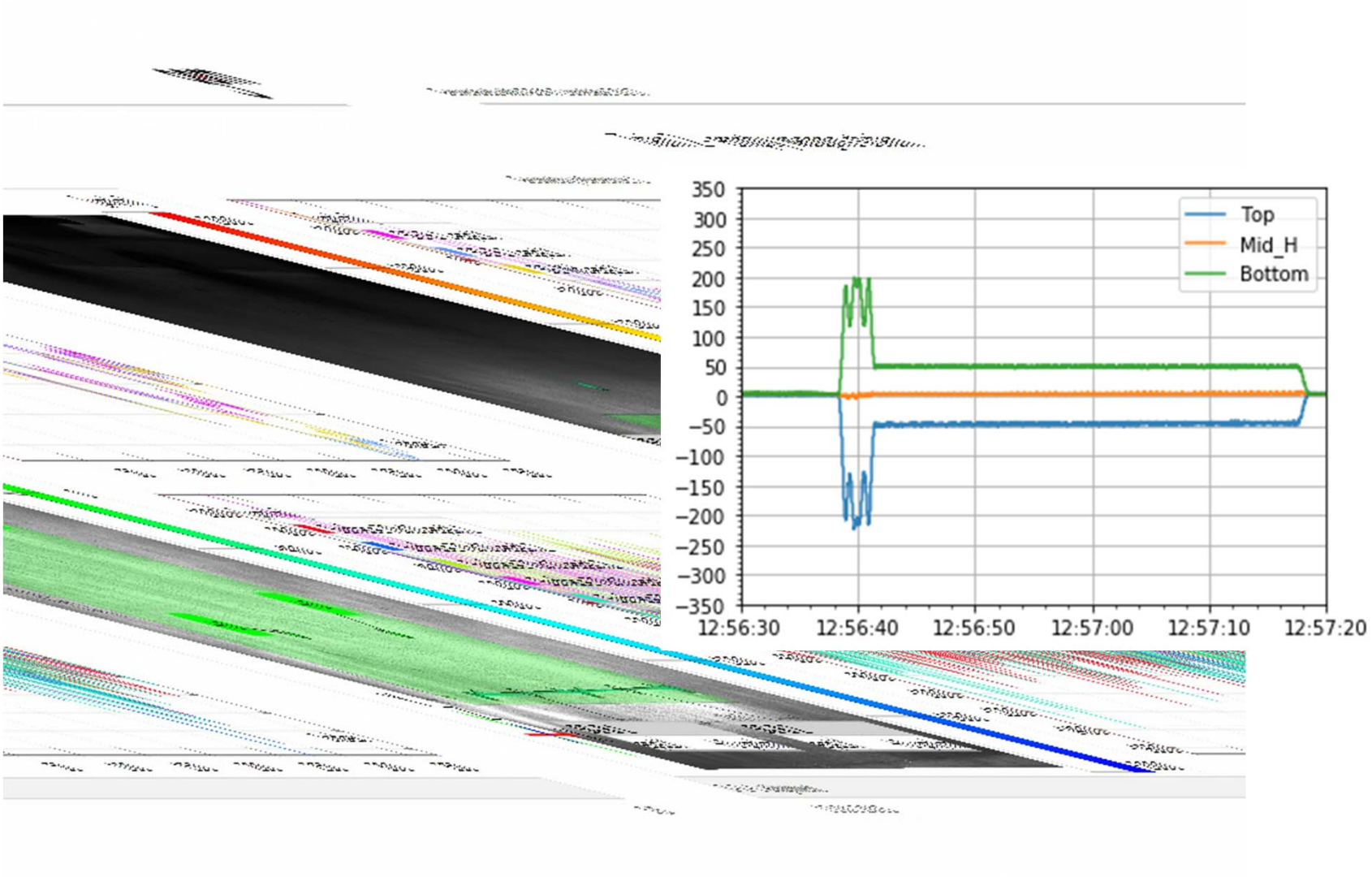




Bridging the data gap: you look stressed

Optical methods reveal the stress state of steel plates

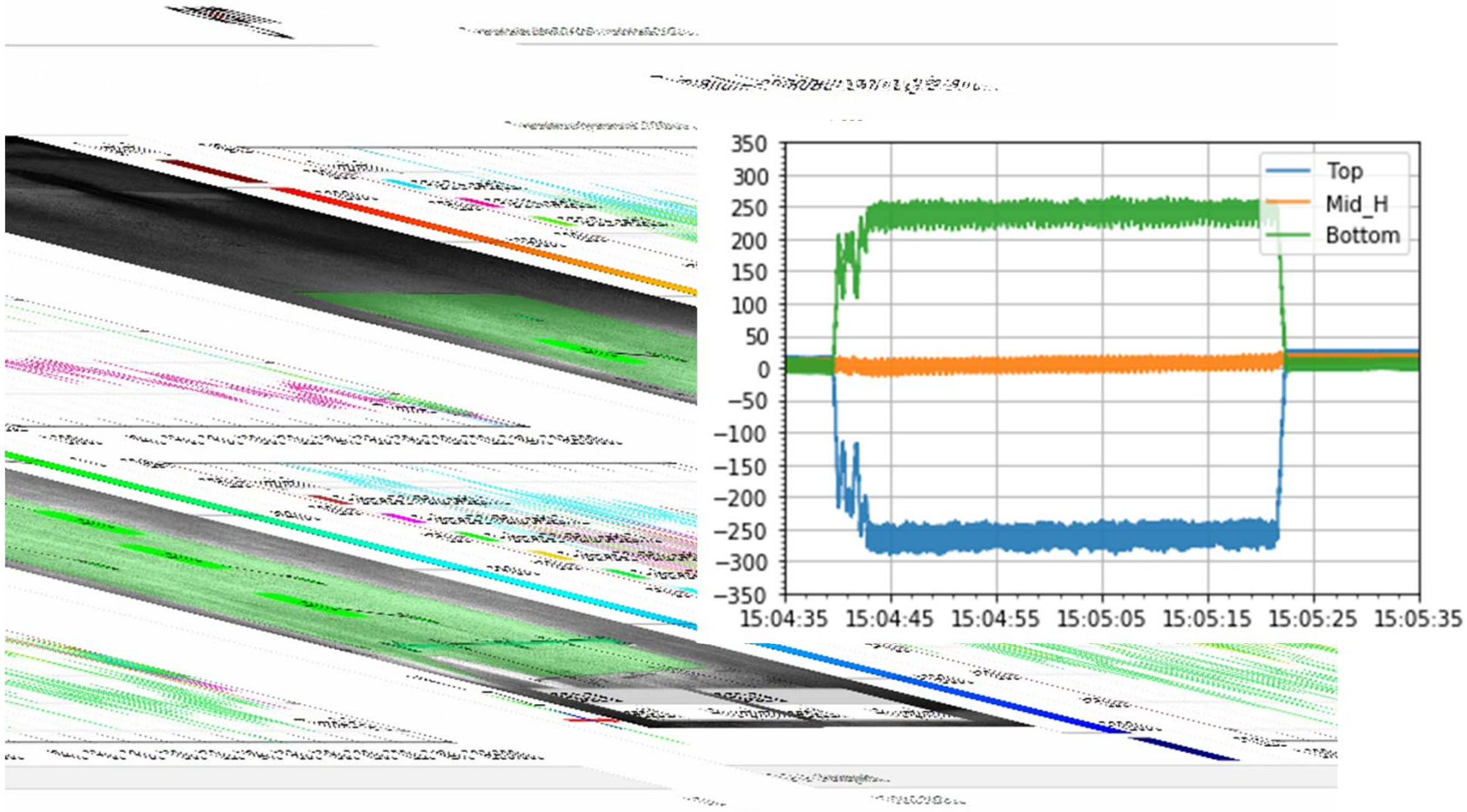
Results - Strain



Bridging the data gap: you look stressed

Optical methods reveal the stress state of steel plates

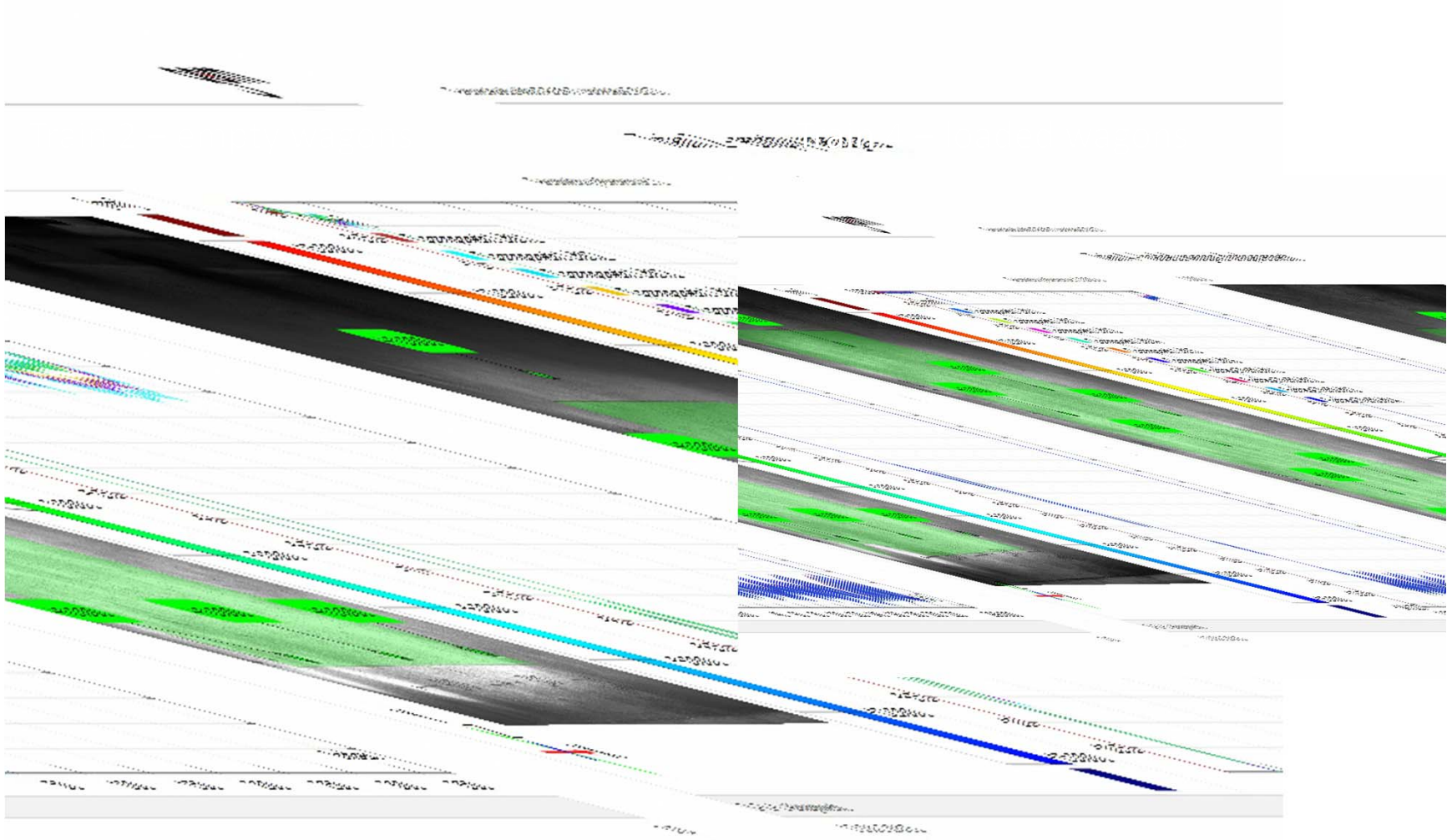
Results - Strain



Bridging the data gap: you look stressed

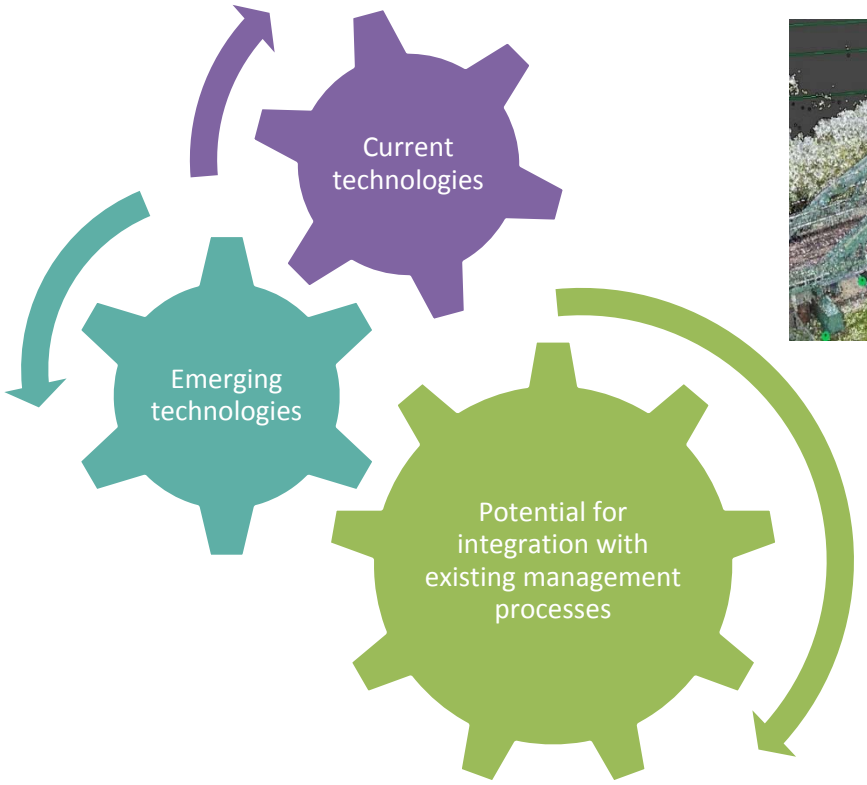
Optical methods reveal the stress state of steel plates

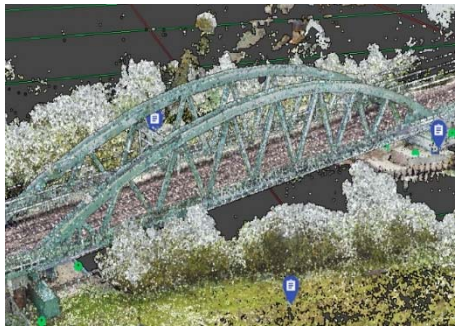
Results - Deflection



Bridging the data gap: helicopter parenting

UAV inspection strategies provide a close-up look at bridge status



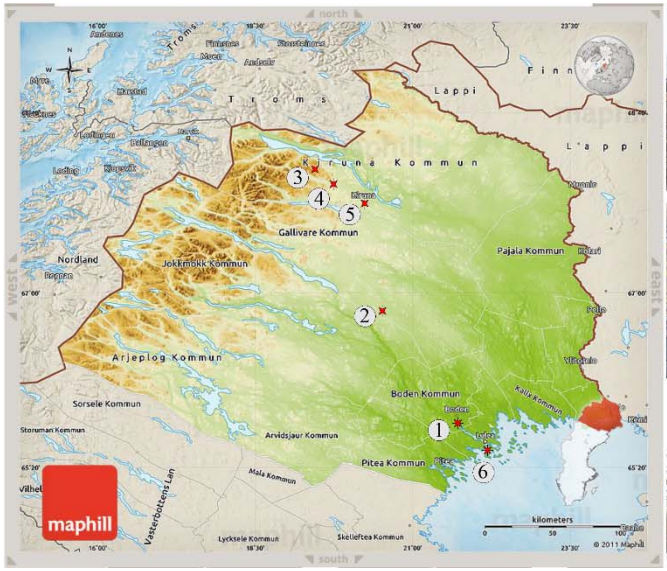


Bridging the data gap: the big picture

Structural behavior of bridges is complex, small defects may be symptoms of big trouble.

Technologies deployed

- Terrestrial-laser scanning (RIEGL VZ-400)
- Close-range/aerial photogrammetry (Canon 5D/3DR Site Scan drone)
- Infrared scanning (Mattterport 3D)



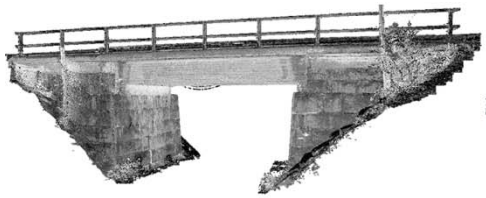
(b)

(d)

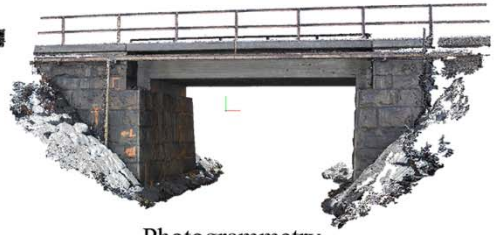
Bridging the data gap: the big picture

Structural behavior of bridges is complex, small defects may be symptoms of big trouble.

Visualization and geometry deviations



Terrestrial laser scanning



Photogrammetry

Infrared scanning

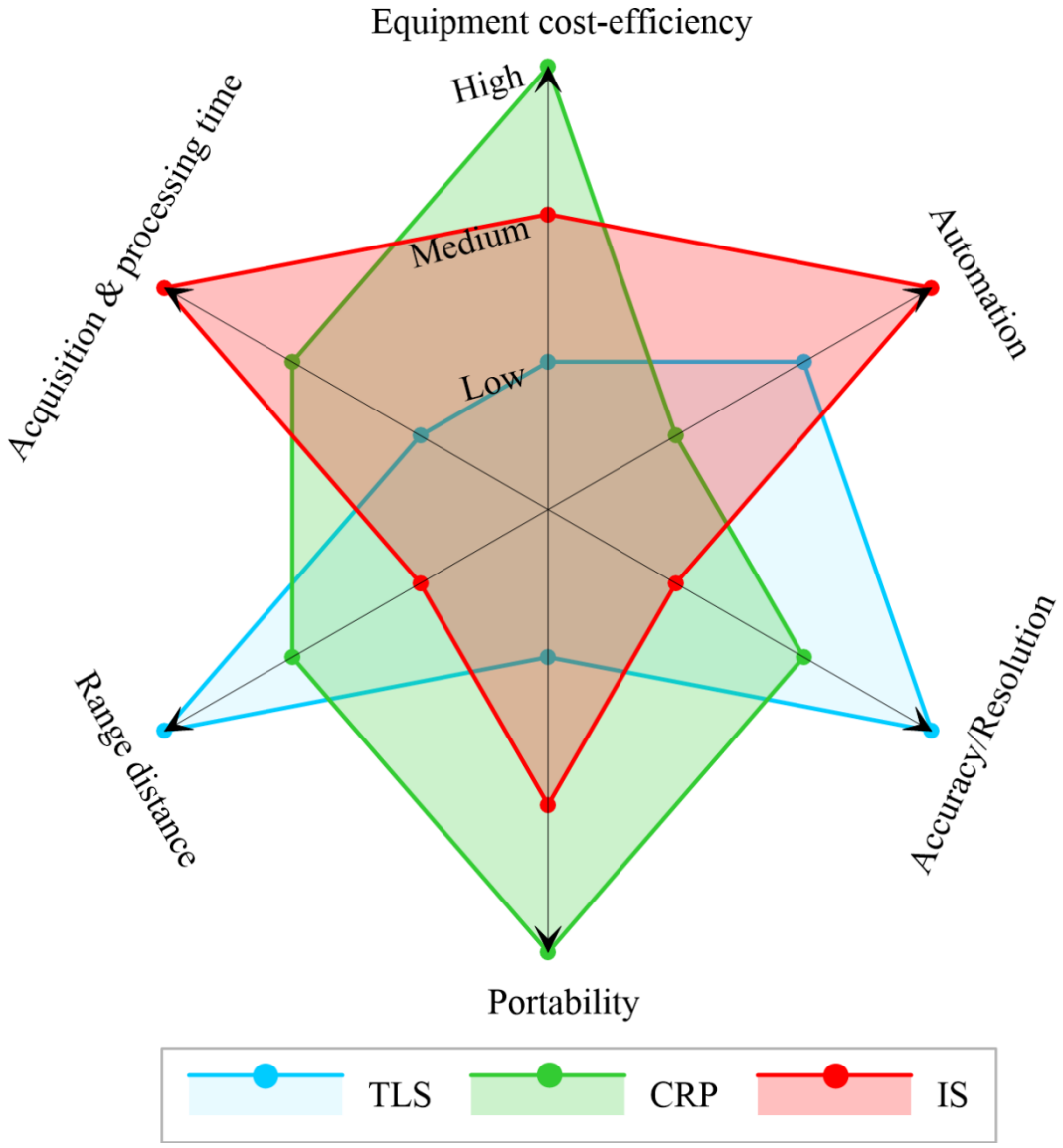
- 3D visualization models of Pahtajokk bridge

Accuracy of the studied methods

Bridge	As-built dimension	Terrestrial laser scanning		Close-range Photogrammetry		Infrared scanning	
	(mm)	(mm)	%ΔL	(mm)	%ΔL	(mm)	%ΔL
Edbäcken bridge							
Span	5800	5724	-1.31%	-	-	-	-
Width (deck)	3800	3882	2.16%	-	-	-	-
Påunakbäcken bridge							
Span	2950	2930	-0.68%	2947	-0.10%	2985	1.19%
Width (deck)	4500	4517	0.38%	4525	0.56%	4546	1.02%
Kedkejokk bridge							
Span	4000*	2750	-	3080	-	2727	-
Rise	2000*	1353	-	1540	-	1286	-
Juovajokk bridge							
Span	5500	5434	-1.20%	5412	-1.60%	5458	-0.76%
Width (deck)	3800	3780	-0.53%	3735	-1.71%	3780	-0.53%
Pahtajokk bridge							
Span	6900	6928	0.41%	7735	12.10%	6958	0.84%
Width (deck)	3900	3904	0.10%	4376	12.21%	3926	0.67%
Kallkällevägen bridge							
Central span (interax)	14500	14592	0.63%	14468	-0.22%	14828	2.26%
Width (deck)	4540	4526	-0.31%	4510	-0.66%	4628	1.94%
Diameter (pillar)	1000	1000	0.00%	977	-2.30%	1009	0.90%

Bridging the data gap: the big picture

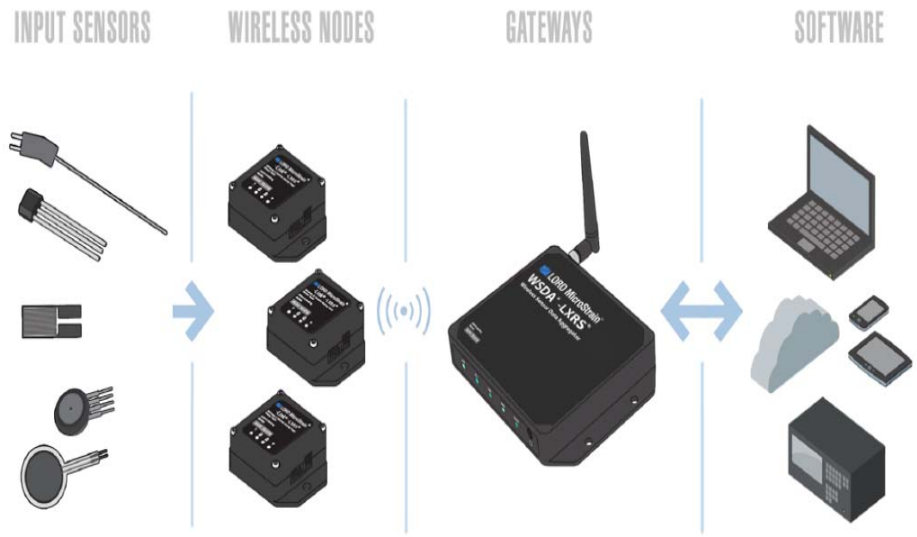
Structural behavior of bridges is complex, small defects may be symptoms of big trouble.



Performance of the 3D imaging methods (the *high* level represents the best performance with respect to the indicated item)

Bridging the data gap: old dogs and new tricks

Technological advances and falling prices in electronics give new strength to old methods



It is now affordable to monitor troublesome bridges on a continuous basis:

- Resilient, long-lived, low-consumption sensors
- Wireless data transmission negates need for cabling (work-intensive, fragile, exposed)
- Advanced batteries and energy harvesting concepts avoid need for continuous power supply
- Data may be gathered remotely via 3G/4G
- Big Data empowers management of continuous data streams

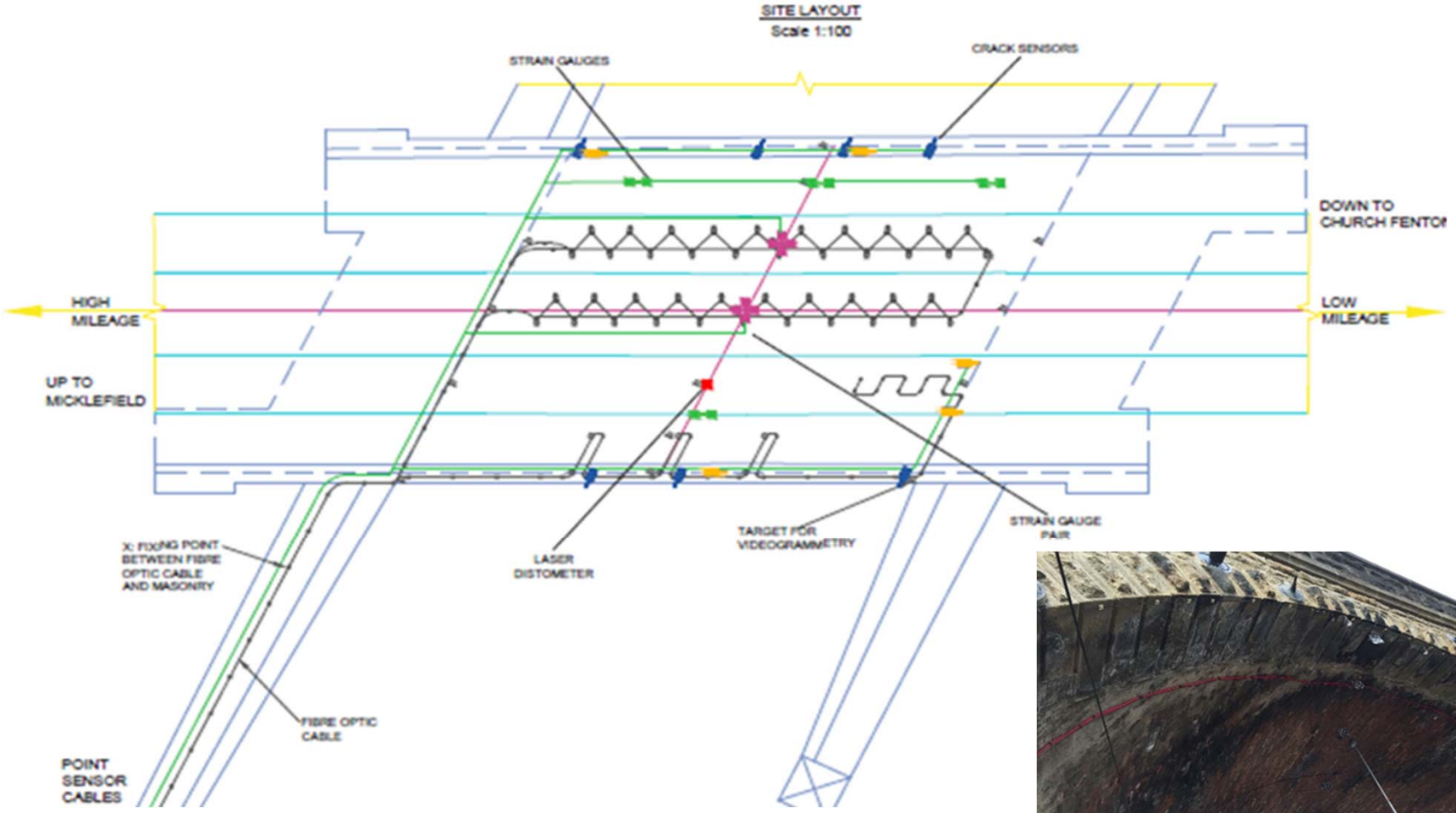
Bridging the data gap: old dogs and new tricks

Technological advances and falling prices in electronics give new strength to old methods

- Four stage research project on a masonry arch:
  - **Stage 1 Desk top study.**
  - **Stage 2 Site trials to install and monitor using range of techniques.**
  - Stage 3 Study detailing findings from site trials.
  - Stage 4 Final report recommending monitoring solutions for arches.

Bridging the data gap: old dogs and new tricks

Technological advances and falling prices in electronics give new strength to old methods



Bridging the data gap: perpetuum mobile

Ambient energy cuts sensor consumption to zero

Energy Harvesting on railway bridges bridges

Energy harvesting devices being installed on Pershagen bridge in Södertälje, Sweden, and (right) image of the vibrating energy harvesting devices sticking out from the edge beam. Cahill et al. (2018).

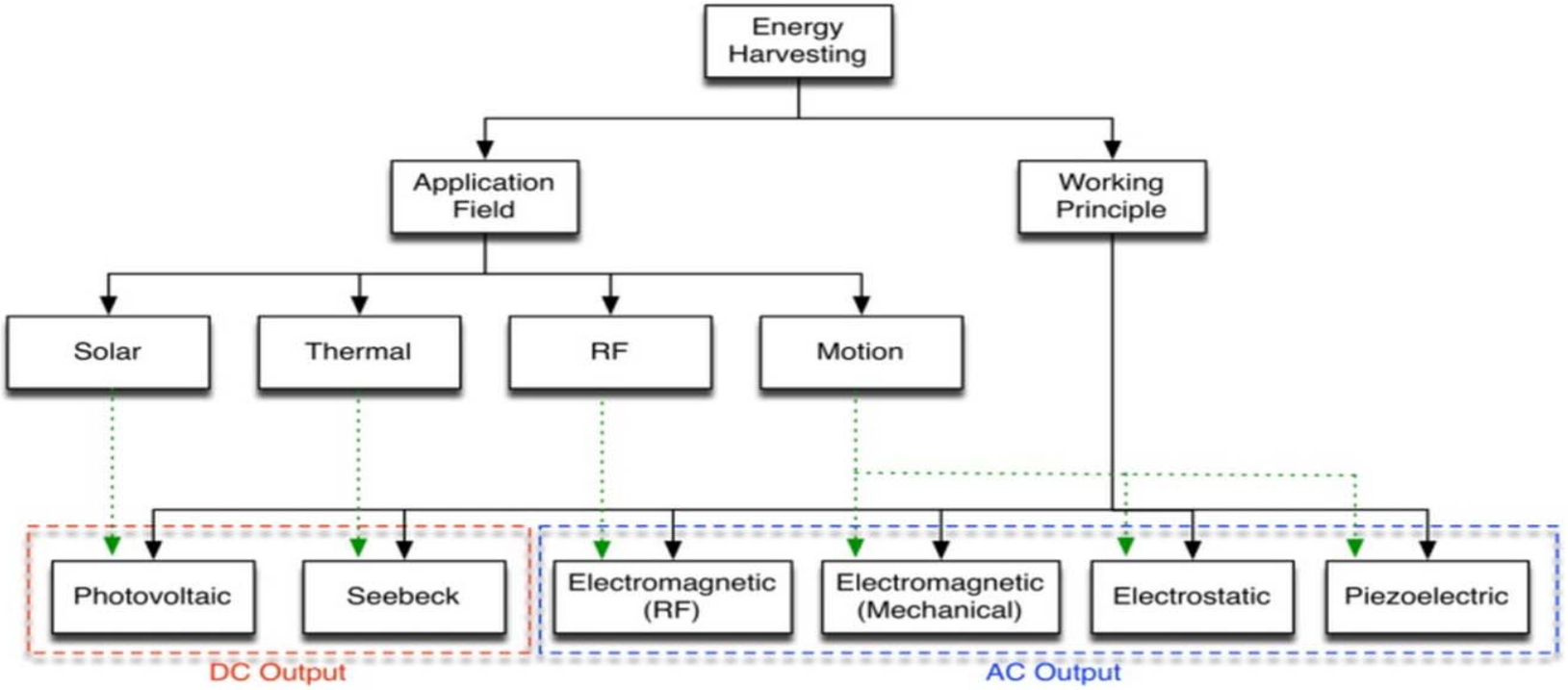
Bridging the data gap: perpetuum mobile

Ambient energy cuts sensor consumption to zero

Energy Harvesting

This presentation contain a desk study on energy harvesting with piezoelectric crystals for railway applications. The work has been compiled by Dr. Erik Elfgren and Prof. Lennart Elfgren

Energy can be harvested in many ways from e.g. light (sun) and mechanical sources and radio frequencies.

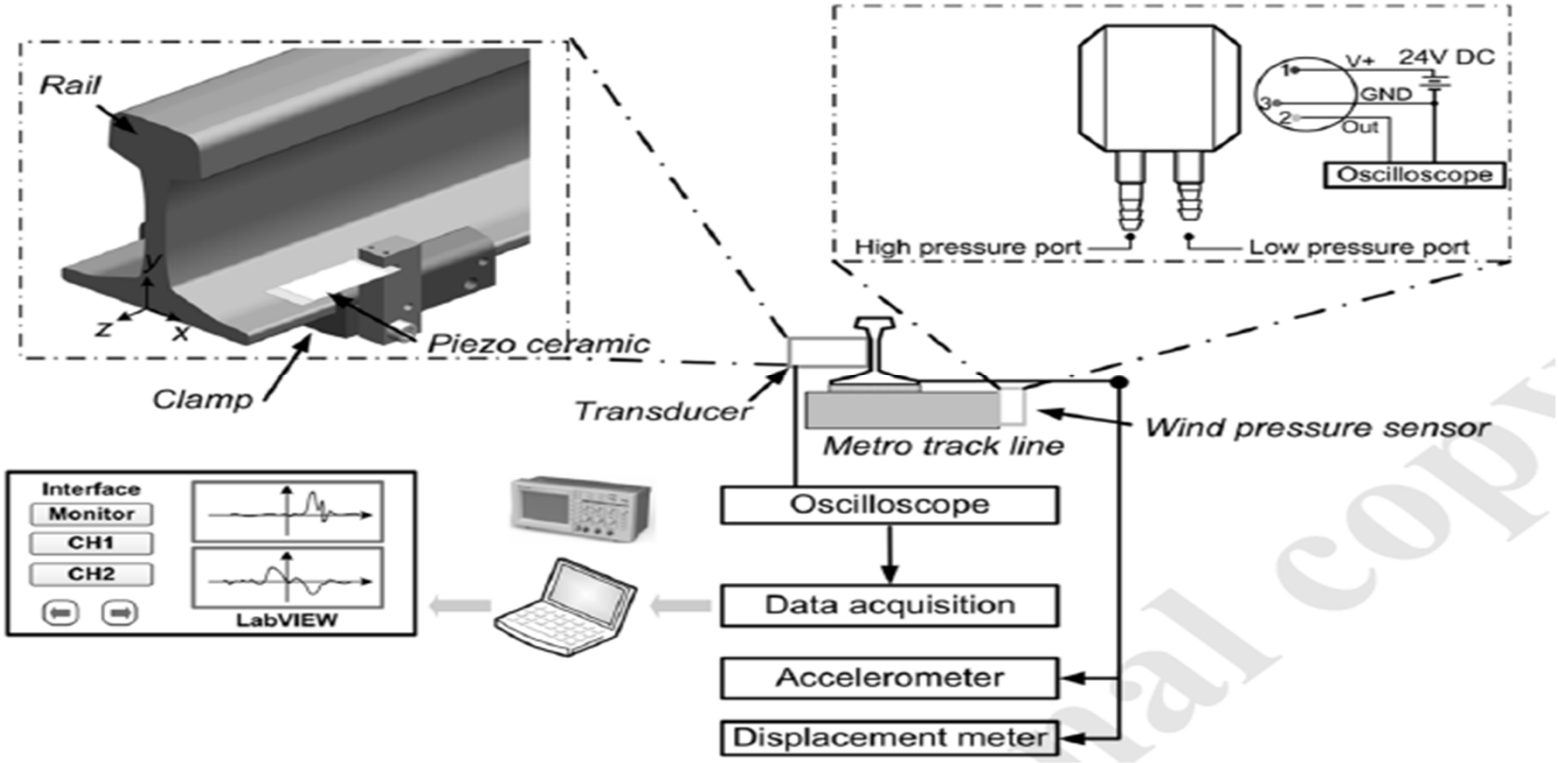


Hierarchy of main energy harvesting technologies, (Caliò et al. 2014).

Bridging the data gap: perpetuum mobile

Ambient energy cuts sensor consumption to zero

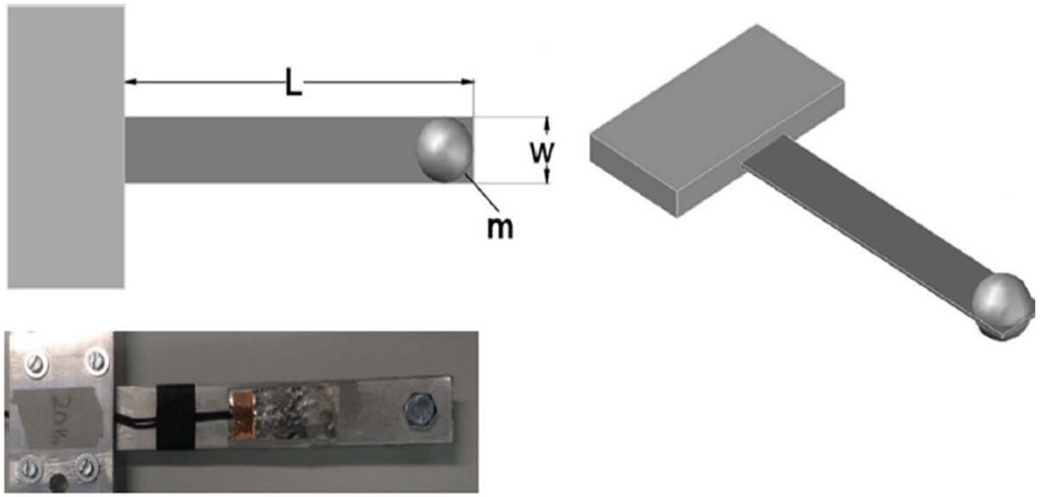
Examples



Field testsetup of piezoelectric energy harvesting under train-induced wind at Shengxian Lake Station, Metro line 1, Chengdu, China. Wang et al. (2017).

Bridging the data gap: perpetuum mobile

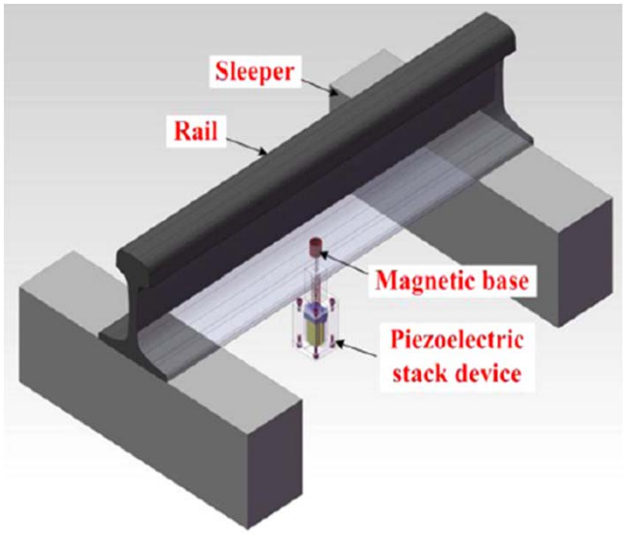
Ambient energy cuts sensor consumption to zero

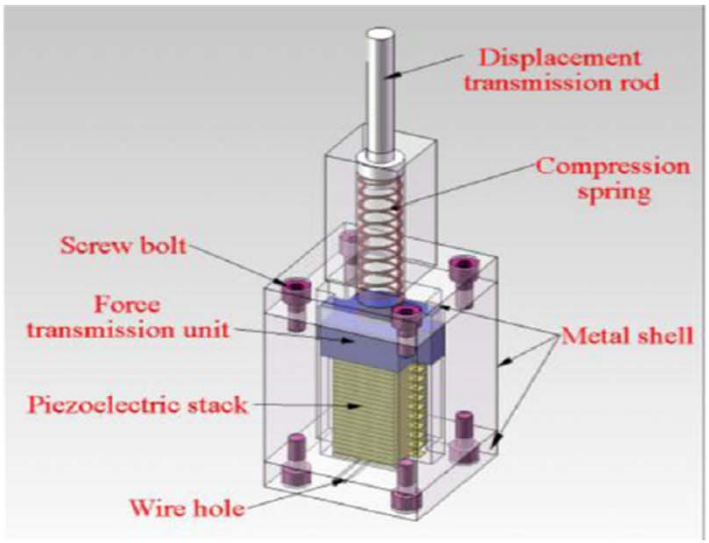


Schematic design of cantilever piezoelectric energy harvesting device. Cahill et al. (2018)

Bridging the data gap: perpetuum mobile

Ambient energy cuts sensor consumption to zero

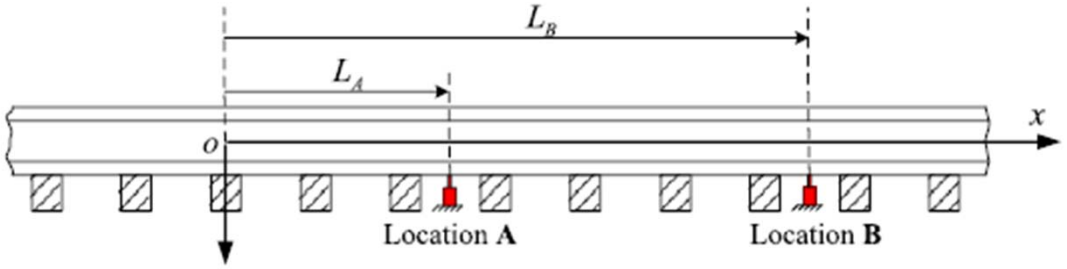


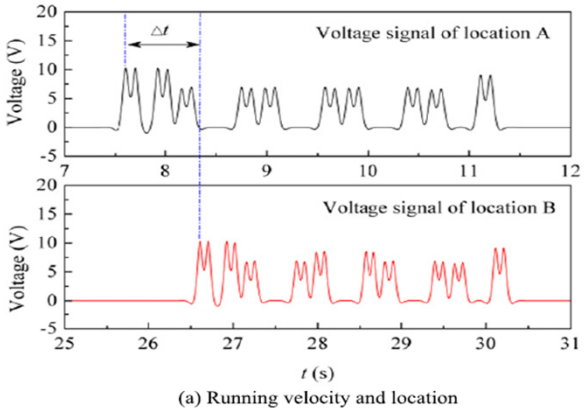


Installation schematic of piezoelectric stack. Wang et al. (2015)

Bridging the data gap: perpetuum mobile

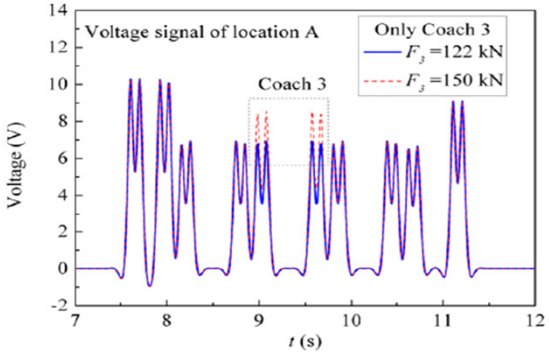
Ambient energy cuts sensor consumption to zero





(a) Running velocity and location

According to Wang et al (2015), the aim of the harvested energy can be to supply power to a wireless sensor network node. A necessary minimum energy of a wireless sensor network node in a working cycle can be 13 mJ. When a whole train consists of four coaches, and about 100 trains run each day at v = 30 m/s, the maximum total energy produced is 85 mJ for a patch transducer and 22 mJ for a stack transducer respectively

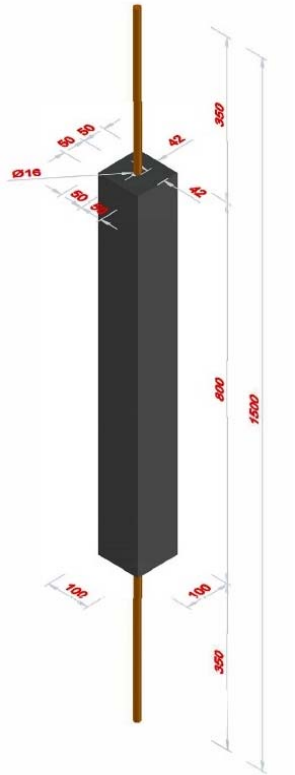


(b) Axle load

Bridging the data gap: rethinking the basics

Classical rebar strain measurement techniques are analyzed for accuracy

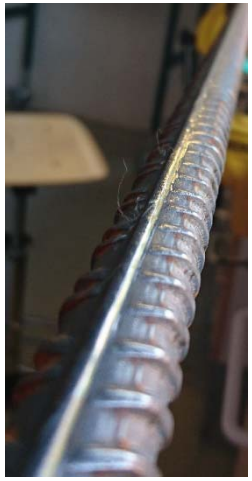
Axially loaded tension ties



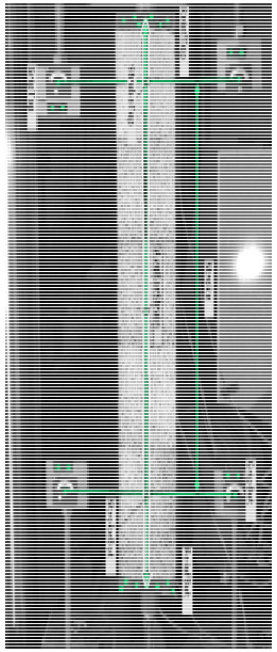
Direct reinf. strain measurement

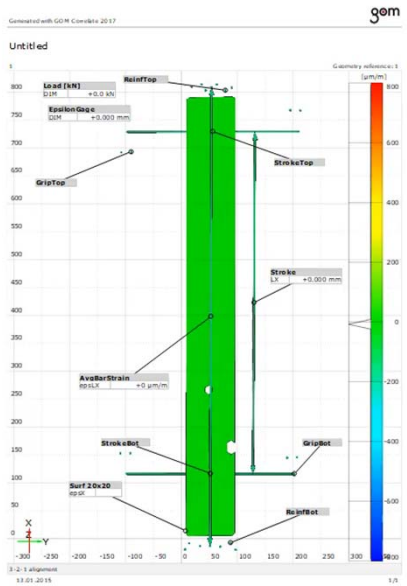
Strain Gauges

Fiber optic sensor



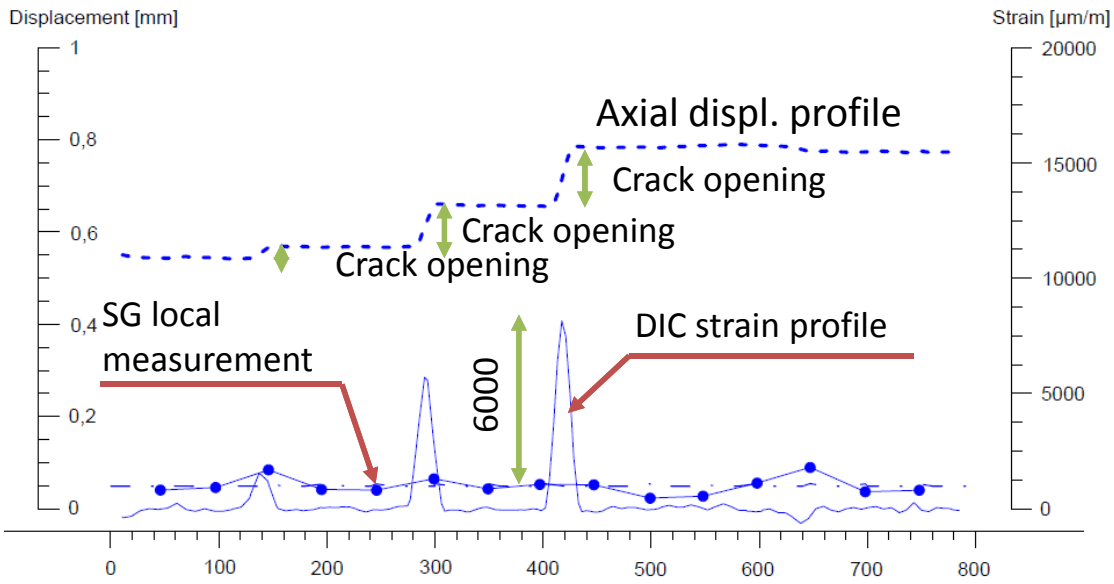
Surface strain measurement

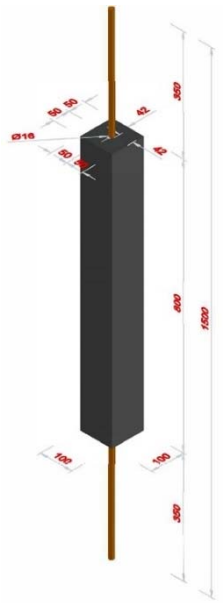




Bridging the data gap: rethinking the basics

Classical rebar strain measurement techniques are analyzed for accuracy

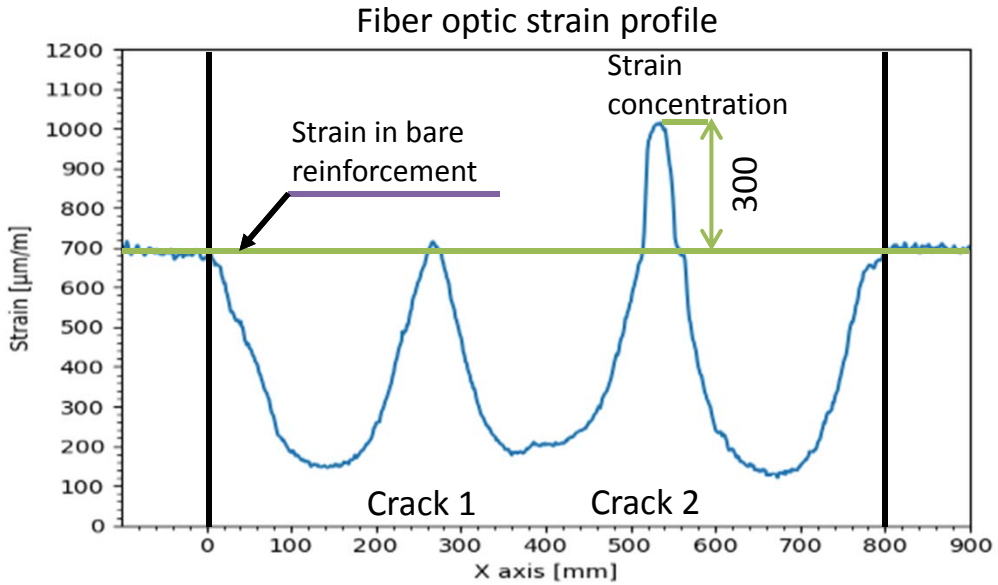




Typical axial strain and displacement profile for tested tension ties at 40 kN applied load

Bridging the data gap: rethinking the basics

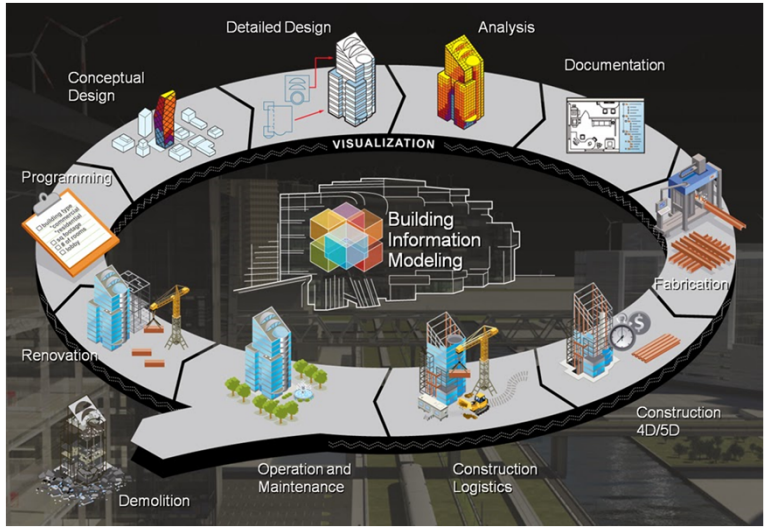
Classical rebar strain measurement techniques are analyzed for accuracy

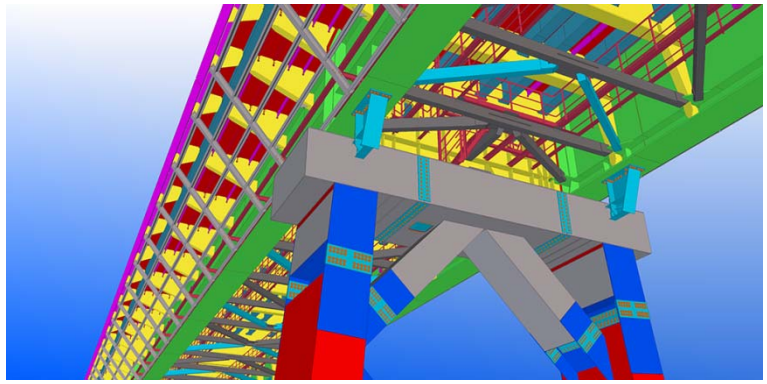


Axial strain profile for tested tension tie with fiber optics sensor at 30 kN applied load

It’s not information if you can’t find it!

Digital twins of bridges & tunnels fit just right in overarching BIM-based asset management





By producing or taking advantage of existing digital twins of assets, new managing options, enhanced follow-up of inspections and better assessment is possible:

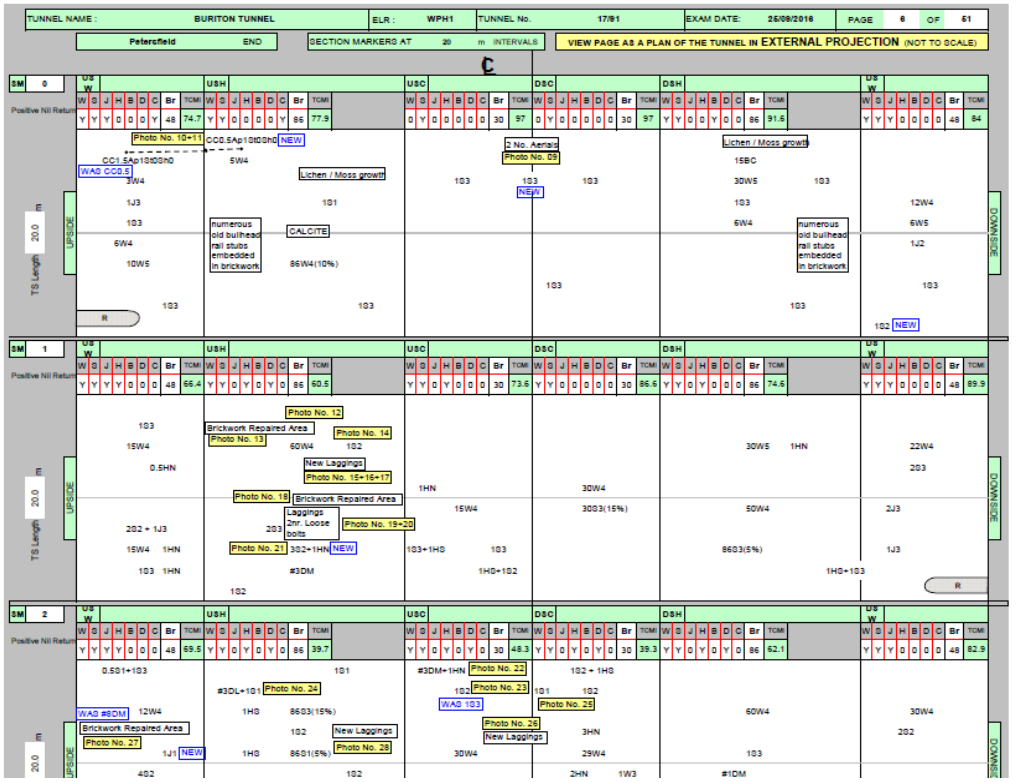
- Defect catalogue may be geolocated within the asset 3D model, easening the location of previously detected problems in subsequent inspections
- Historical information on damage, repairs and upgrades available in a single interconnected information nexus
- Potential for trend detection and decision-support tools
- Pushes information “up the ladder” to larger, less defined digital twin of track section, line, network, etc

So… Are they working? : TCMI turns to boundaries

Tunnel Condition Marking Index scores were used to study the effect of tunnel surroundings

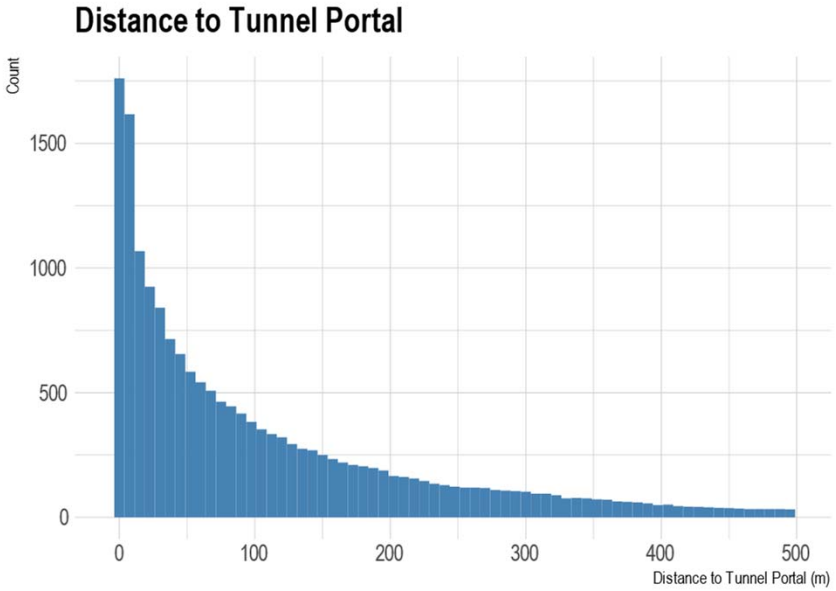
NR's tunnel marking index strives to improve repeatability of assessments and avoid loss of knowledge when old inspectors retire:

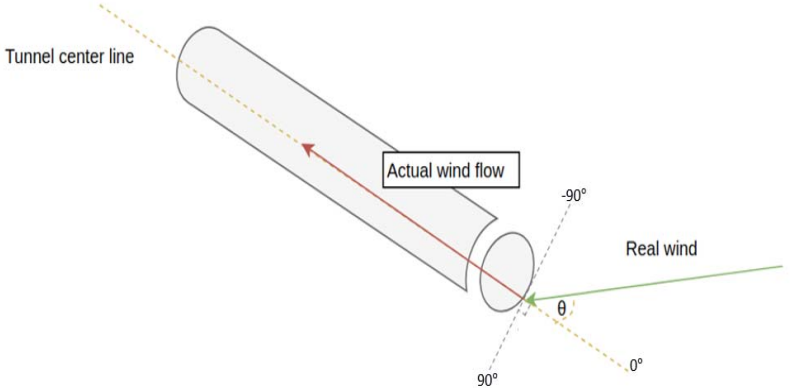
- Better directions for locating old defects
- Scoring based on objective KPIs, algorithms and measurements
- Collected data to be used for degradation prediction



So… Are they working? : TCMI turns to boundaries

Tunnel Condition Marking Index scores were used to study the effect of tunnel surroundings



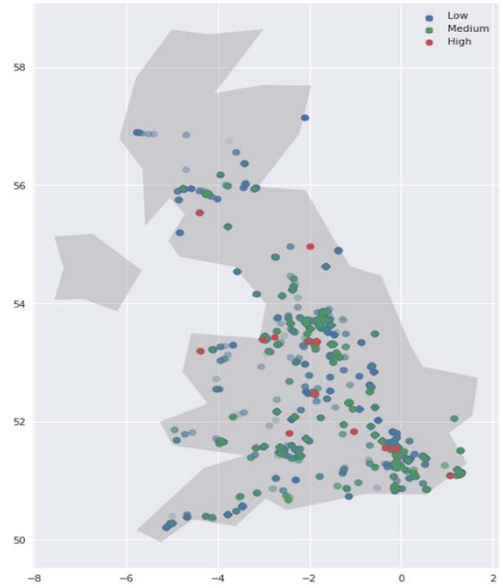


The above graph is an example of how some of the data looked

So… Are they working? : TCMI turns to boundaries

Results of the study confirm or dismiss the influence of different conditions in degradation

Average rainfall	Extremely high or low rainfall causes an increased degradation rate	Evidence suggests possible
Average snowfall	High rates of snowfall cause an increased degradation rate	Yes
Consecutive dry days	High numbers of consecutive dry days benefit the degradation rate, i.e., decrease the degradation rate	Yes
Ground Frost Days	No effect seen	No
Relative Humidity	No effect seen	No
Air Frost Days	High numbers of air frost days positively impact degradation. This may be due to a smaller sample size.	Evidence suggests possible
Average Wind Speed	No effect seen. The wind flow into a tunnel should be measured more accurately before any conclusions are drawn. More analysis could be done to identify the tunnel start/ends, and if the portal is exposed or is, for example, the end of a bore that leads in to another bore.	No
Bedrock Type	Different types of bedrock have different mean degradation rates	Yes
Material ID	Different Materials have different mean degradation rates	Yes
Distance to tunnel portal	No effect seen	No
Distance to closed EO shaft	No effect seen	No



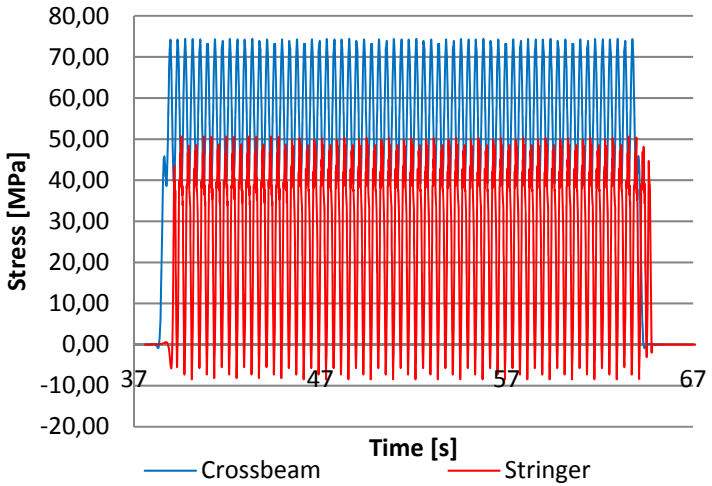
So… Are they working? : …and for how long?

Fatigue consumption follow-up technique enhances estimation of remaining life

Calculation and register of stress levels in sensible areas of steel bridges give a more precise insight on remaining fatigue capacity.

Thus, life of bridges may be extended without further investment and maintaining safety levels

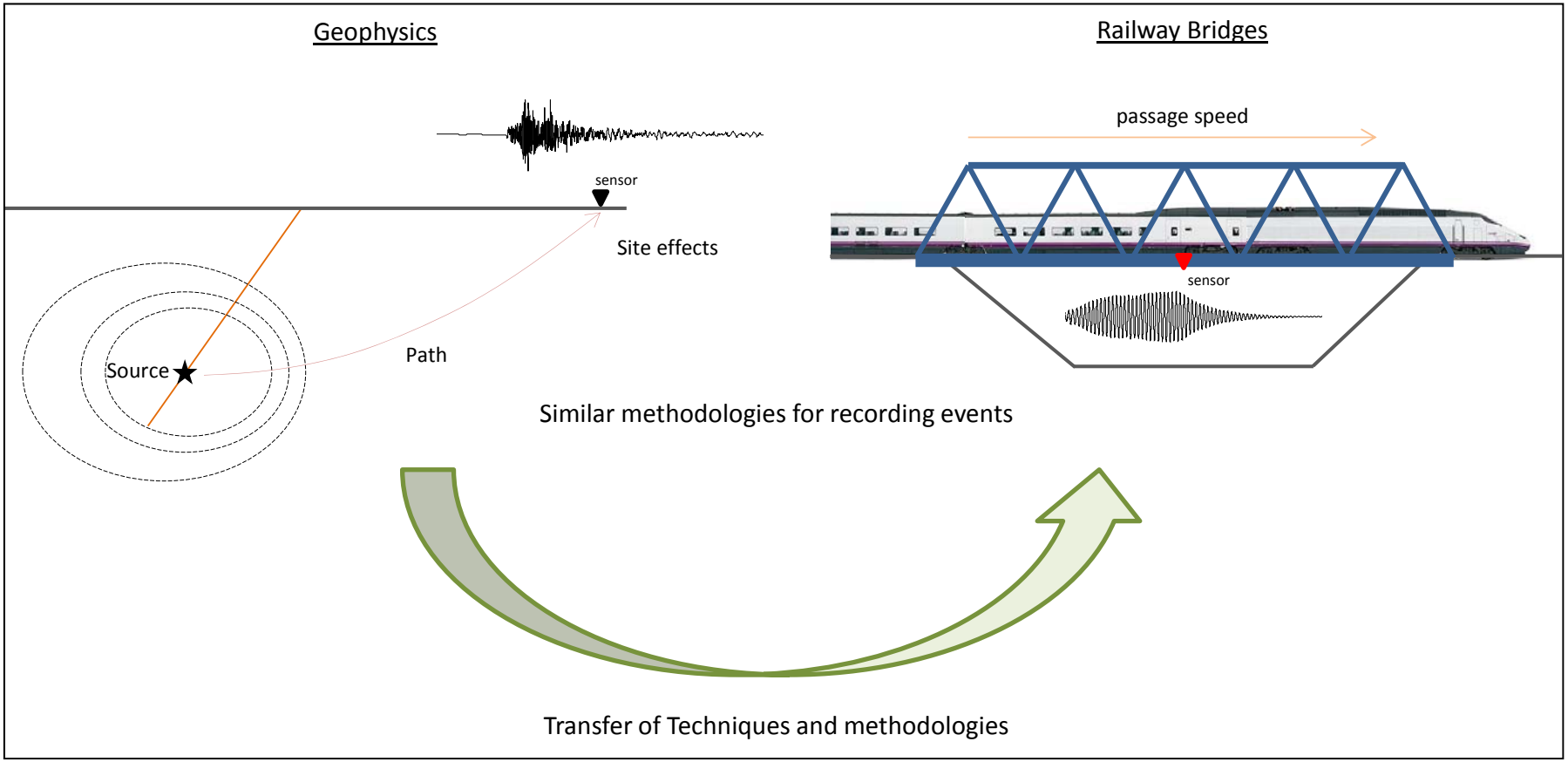
- Reduced sensoring to a few critical spots
- Advanced FE modelling extrapolates stress in all critical areas
- Traffic load data gathered from on-board systems provides input long after model calibration is over



So… Are they working? : Will they hold?

Advanced mathematical prediction of bridge behavior under future load/speed requirements

Semi-empirical approach applied to railway bridges



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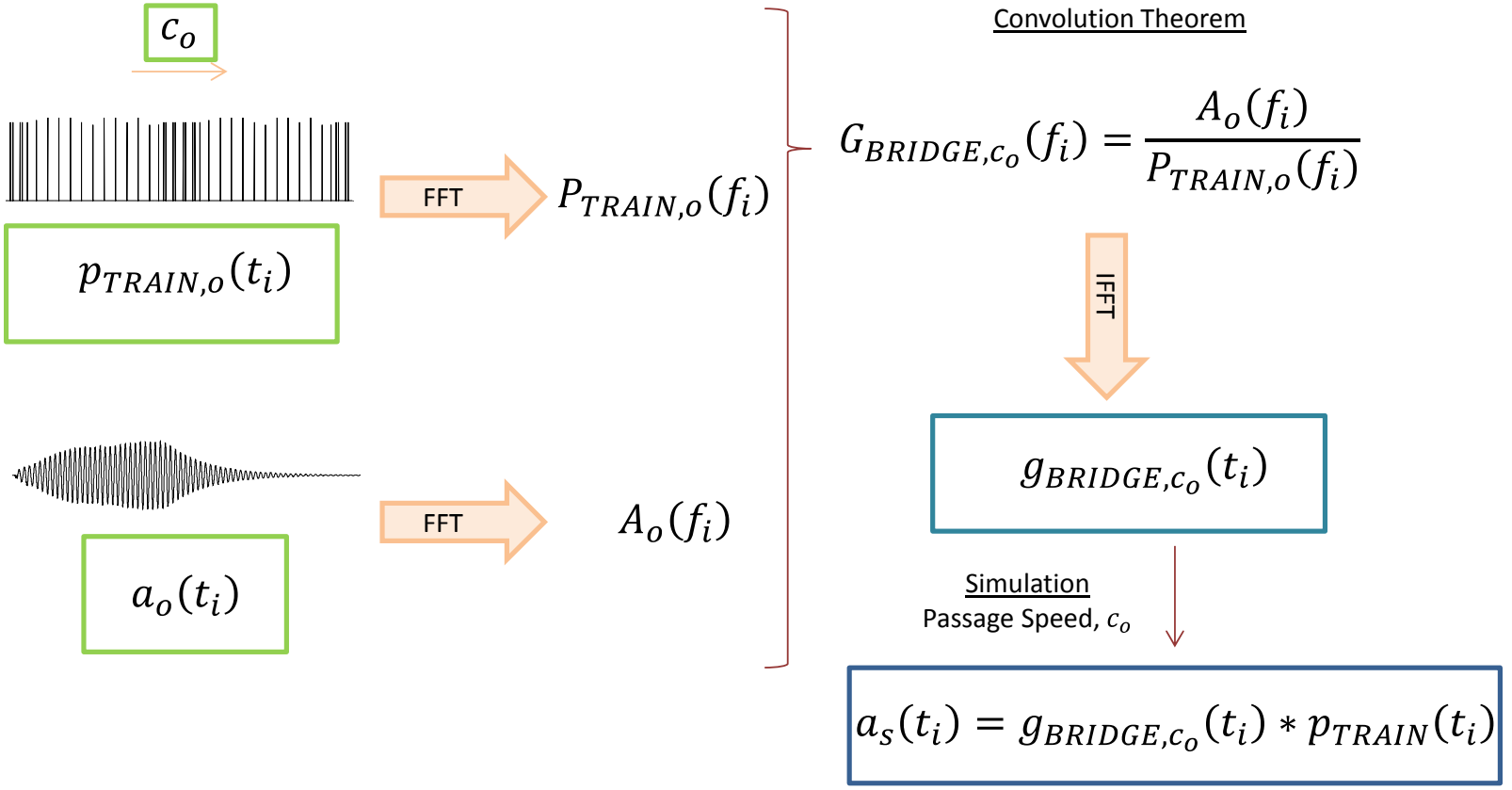

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Advanced mathematical prediction of bridge behavior under future load/speed requirements

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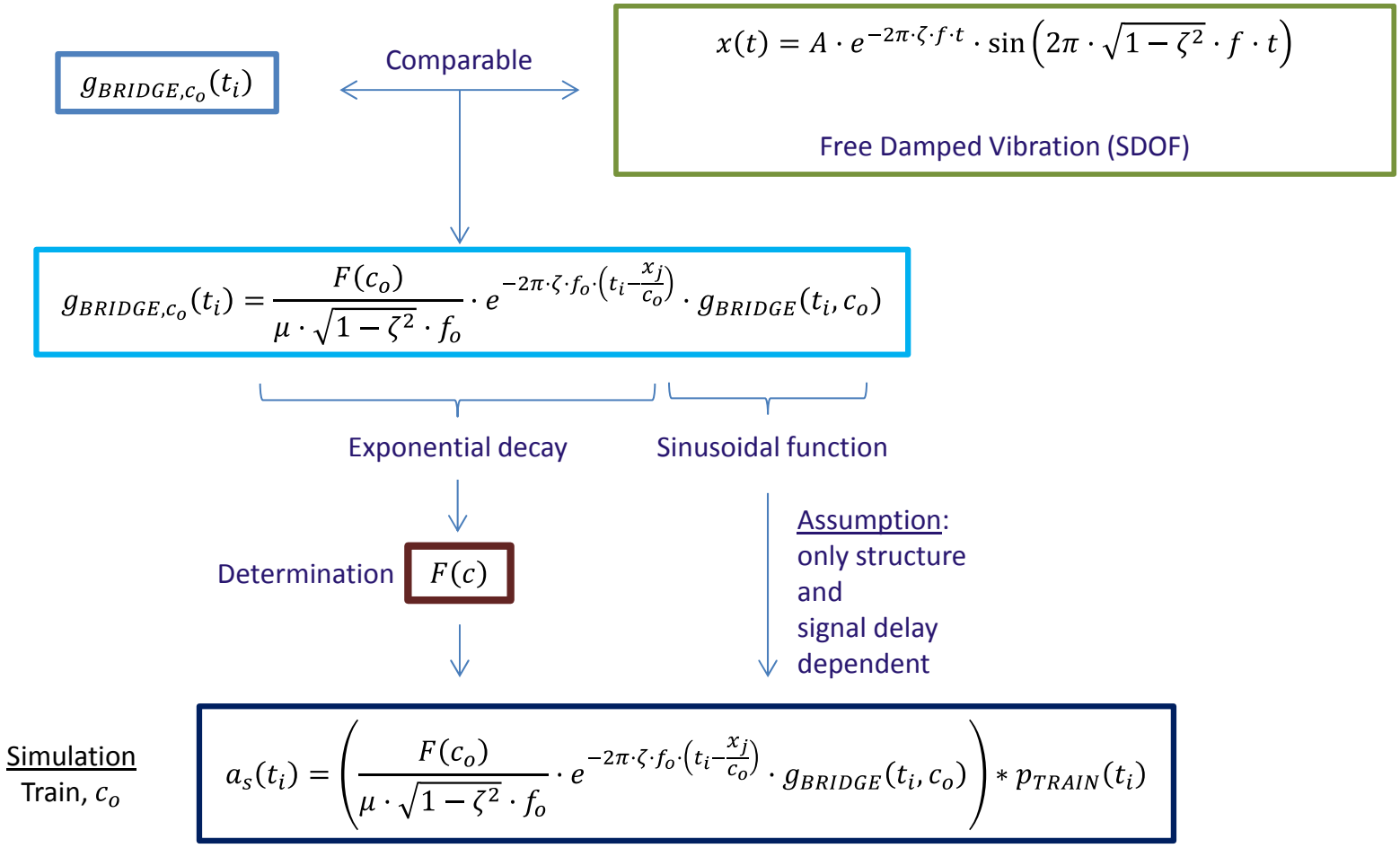


So… Are they working? : Will they hold?

Advanced mathematical prediction of bridge behavior under future load/speed requirements

Numerical Demonstration

Simulation 3: $g_{BRIDGE,280}\left(g_{BRIDGE,240}(t_i), F(280) = 0{,}90\right) * p_{AVE\ S100}(t_i)$

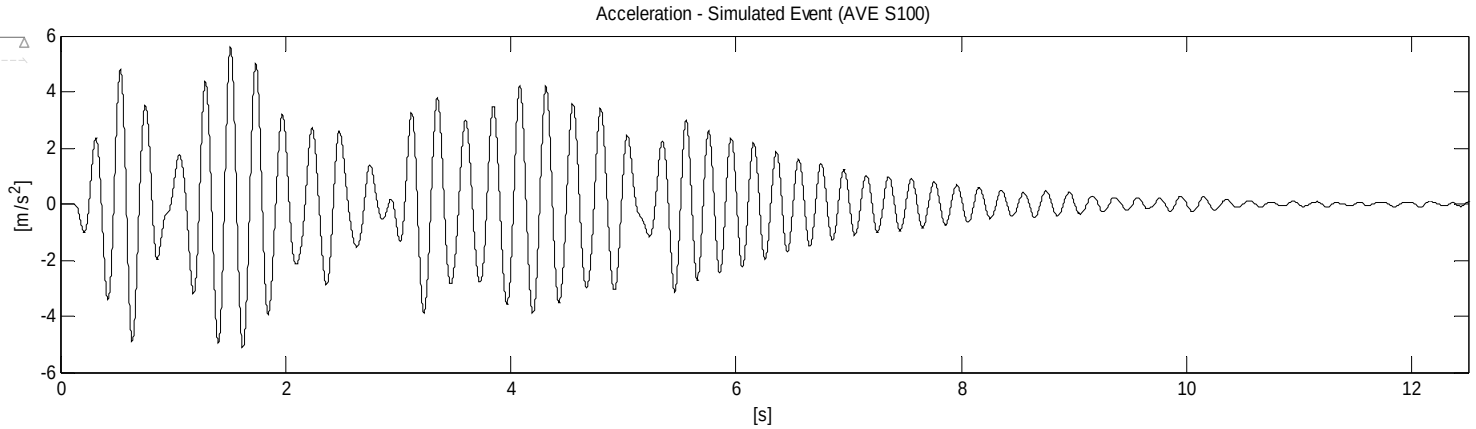
Rail Bridge

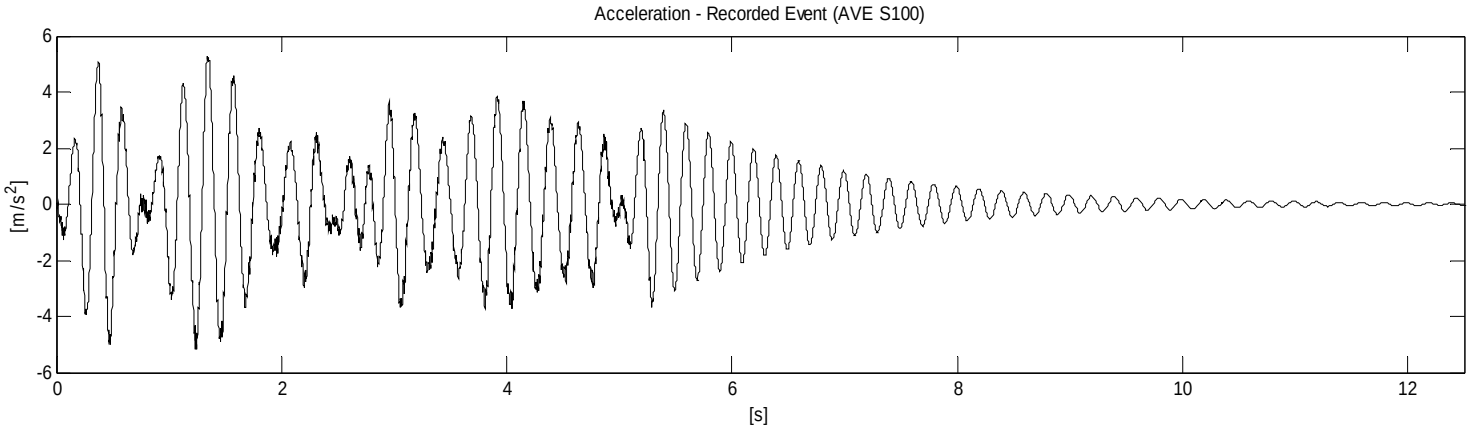
$L = 15\ m$

$EI = 7{,}69 \cdot 10^6\ kNm^2$

$\mu = 15.000\ kg/m$

$\zeta = 2\%$





So… Are they working? : curving the risk

Fragility curves provide a spectral image of risk and its consequences

Development of a methodology for construction of the fragility curves - FC

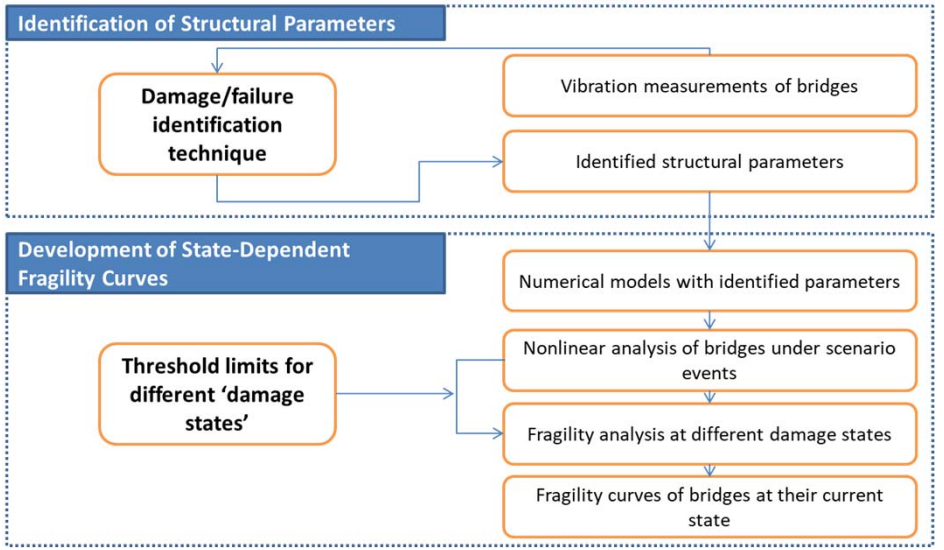
I. Selection of structural parameters
   a) Damping
   b) Long span
   c) Operational speed

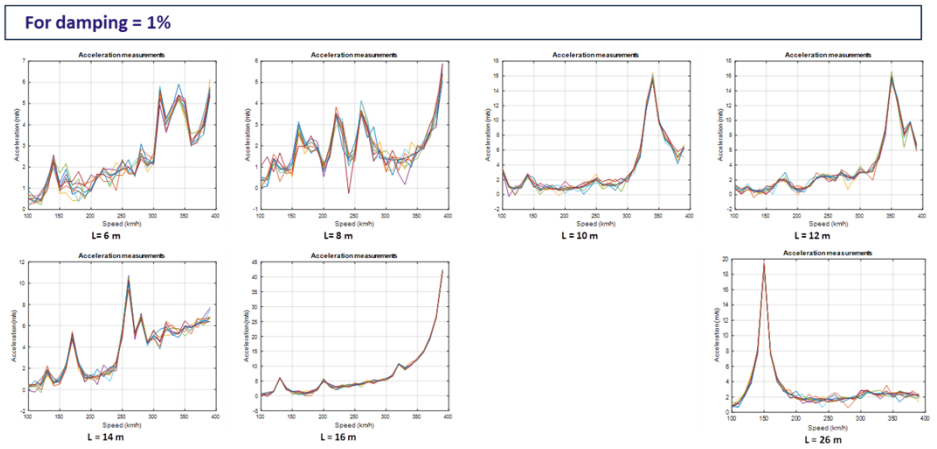
II. Determination of inputs/outputs in FC
   a) Vertical accelerations
   b) Vertical displacements

III. Definition of thresholds

IV. Numerical simulation/real data
   a) Random variability according Normal distr.

V. Algorithms for construction FC
   a) Probability Density Function (PDF)
   b) Lognormal distribution λ and ς
   c) Probability of excedance
   d) Construction of a curve for every threshold



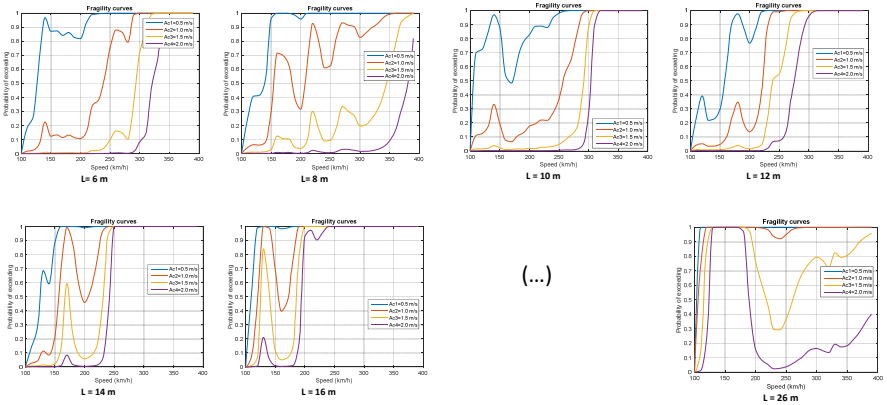


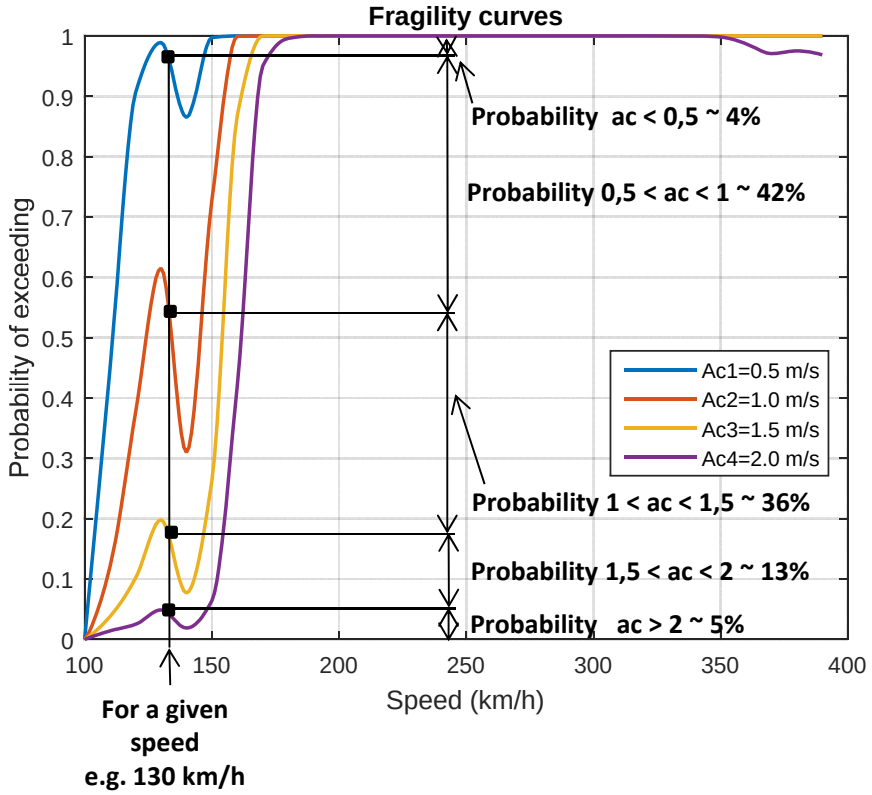
So… Are they working? : curving the risk

Fragility curves provide a spectral image of risks and their consequences

Clusters of fragility curves for accelerations and displacement

For damping = 5%





Inputs

- Damping
- Long span
- Speed

Output

- Probability of a given value of acceleration/displacement to be in a certain range (between thresholds)

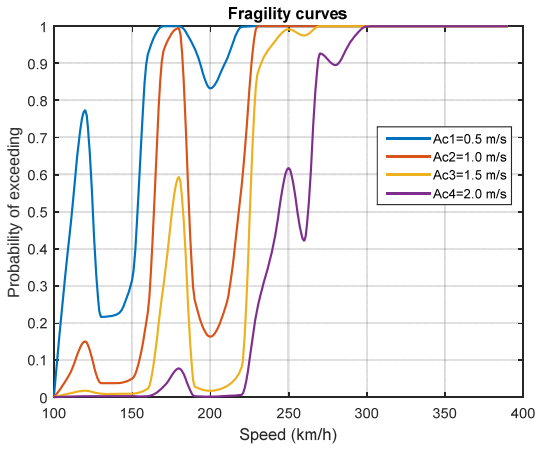
So… Are they working? : curving the risk

Fragility curves provide a spectral image of risks and their consequences

Potential analysis

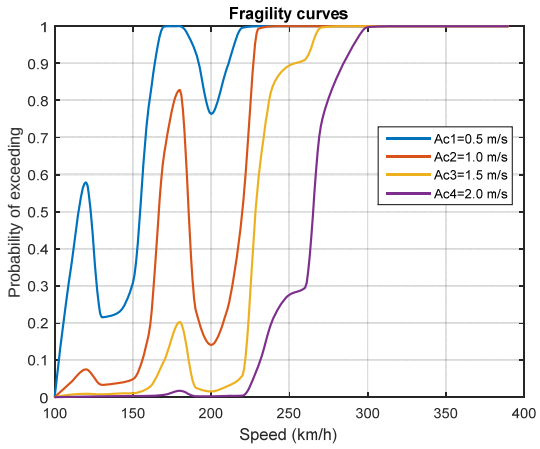
- Remaining useful life
- Changes/evolution in the value of damping
- Loss of stiffness → cracks, creep,…
- Loss of supports → failures in bearings,…
- Expected structural behaviour for new loads and speeds → higher speeds, different model of train/loads,…

Damping 1%



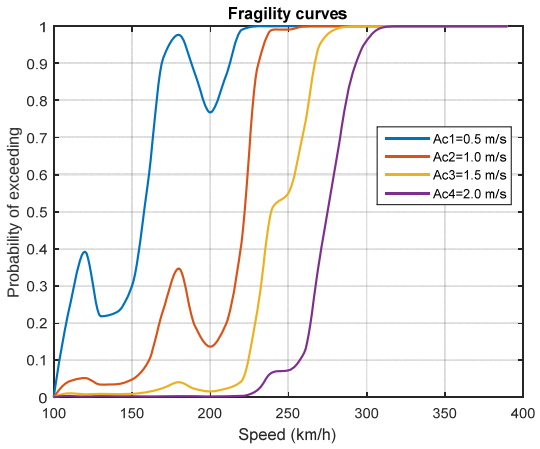
Prob. *0,5 m²/s < ac < 1 m²/s*
<< 1%

Damping 2%



Prob. *0,5 m²/s < ac < 1 m²/s*
~ 18%

Damping 5%

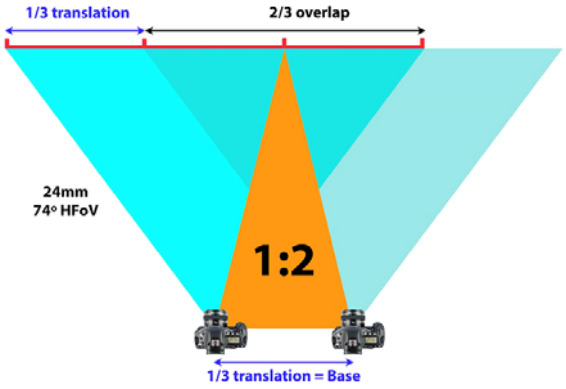


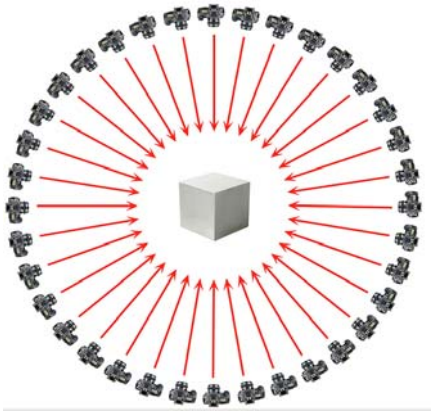
Prob. *0,5 m²/s < ac < 1 m²/s*
~ 62%

So… Are they working? : slowly driftin’

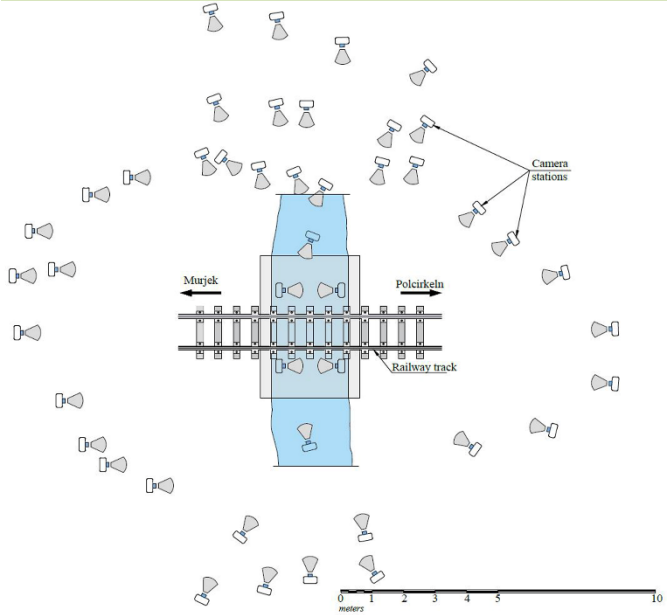
Optical measurement-based model comparison detects small progress of big problems

- Photogrammetry is about measurement: the measuring of the imaging subject
- Photos taken with an overlap of about 60-80%
- Use prime lenses, wide-angle
- Similar settings in each photo (aperture, focus, ISO, etc.)





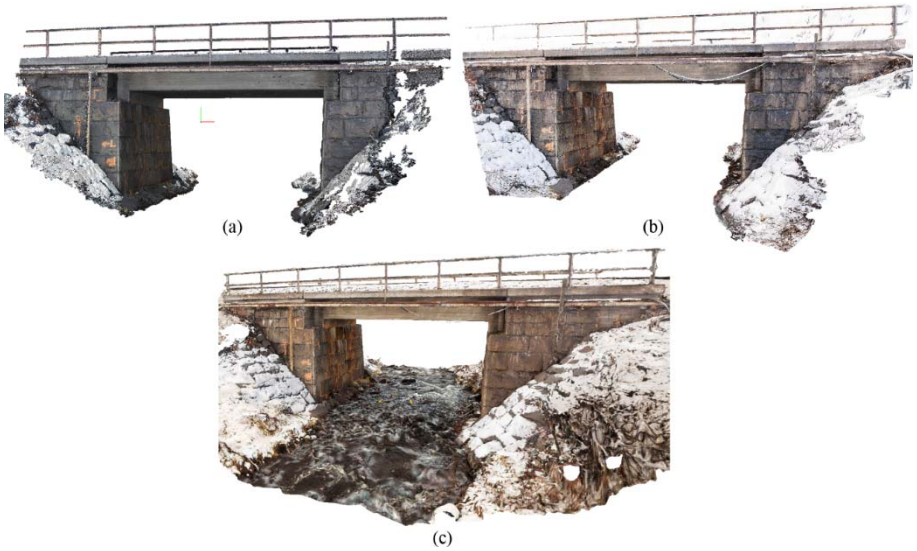
Different viewpoints and the resulting camera position triangulation of Påunakbäcken



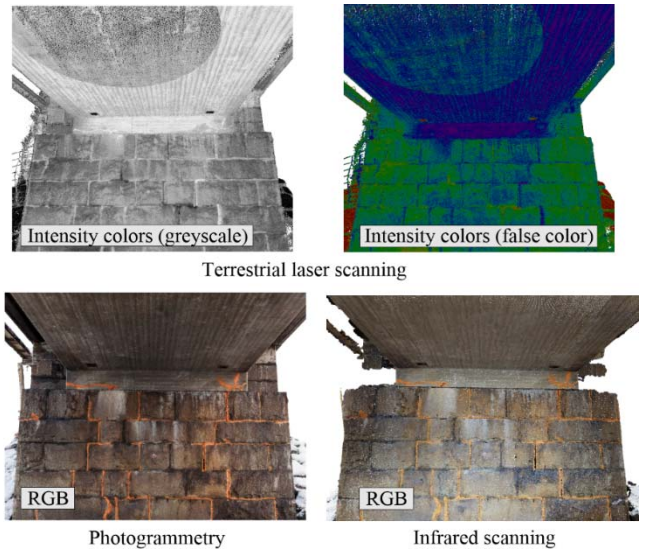
So… Are they working? : slowly driftin’

Optical measurement-based model comparison detects small progress of big problems

Documentation and Visualization



Phototograph



Photogrammetry models of Pahtajokk bridge

a) Agisoft PhotoScan Pro + Canon 5D
b) Bentley ContextCapture + Canon 5D
c) Bentley ContextCapture + Canon 5D Mark II + 3DR Site Scan drone

Point cloud visualizations of the abutment of Pahtajokk bridge based on the laser scanning, photogrammetry, and infrared scanning models, with a field photograph for comparison.

So… Are they working? : slowly driftin’

Optical measurement-based model comparison detects small progress of big problems

Virtual models for off-site bridge inspection

October 2017

October 2018

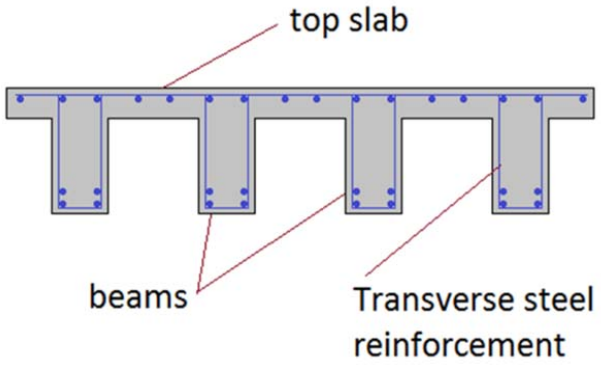
Repairs and refurbishing

Techniques to extend the life and enhance the capacity of existing bridges and tunnels

GA H2020 - 730841

And what if they're not? : A stitch and a patch

Using FRP reinforcements to enhance shear capacity of concrete elements

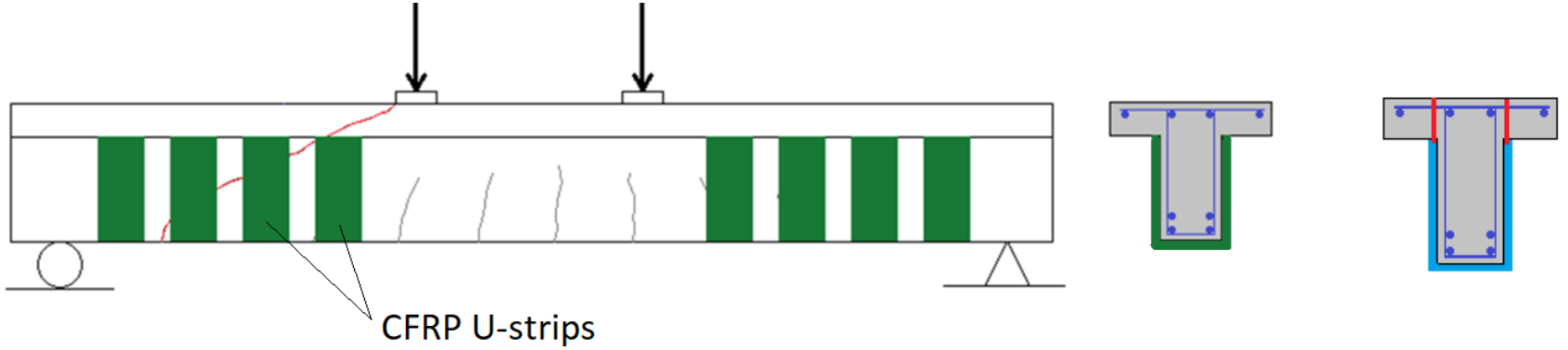


1. Interaction between internal (steel) transverse reinforcement and externally bonded FRPs

- Two different transverse steel ratios: ϕ8 @300; ϕ10 @300
- Two different transverse FRP ratios: 0.5 x 70mm @300; 2.0 x 70mm @300
- Comparison between FRP ***strengthened*** and ***non-strengthened*** beams

2. Effectiveness of the anchorage system and its influence on shear strength

- Comparison between ***anchored*** and ***non-anchored*** FRP strengthened beams

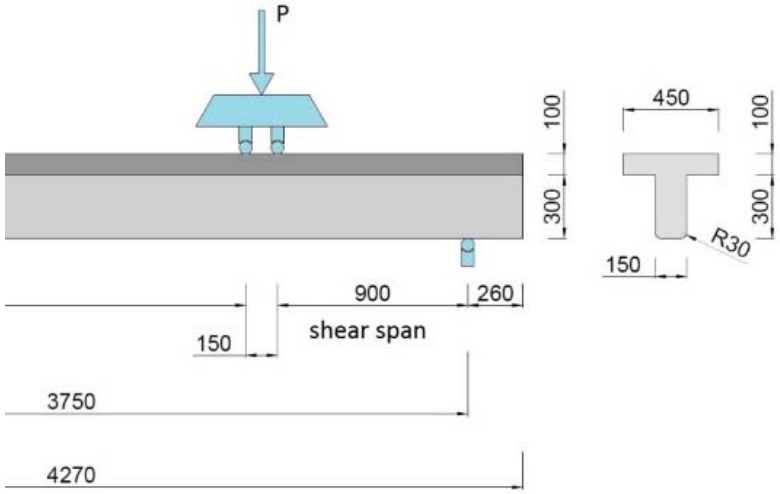


And what if they're not? : A stitch and a patch

Using FRP reinforcements to enhance shear capacity of concrete elements

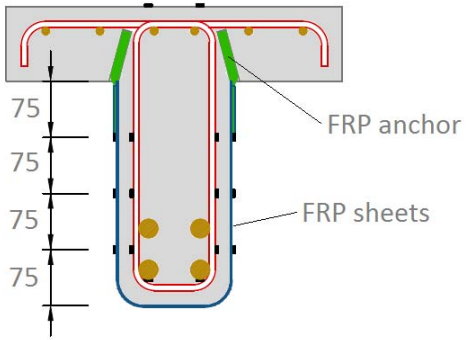
Laboratory tests

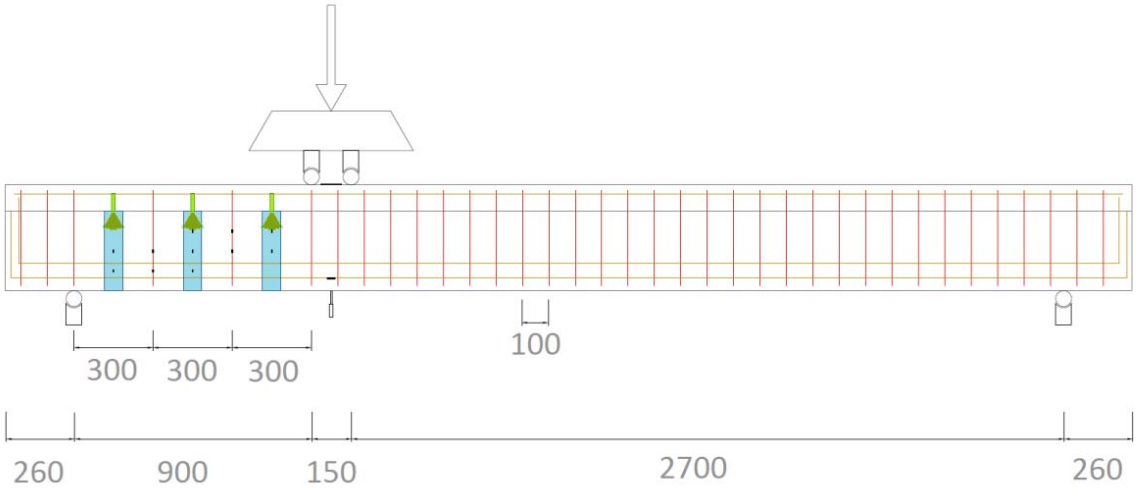
Steel	FRP	Anchorage	Nomenclature	Beam
NO	-	-	Control	Beam 01
ϕ8 @ 300	NO	-	8mm	Beam 02
	0.5 x 70 mm	NO	8mm_0.5_N	Beam 03
		YES	8mm_0.5_A	Beam 05
	2.0 x 70 mm	NO	8mm_2.0_N	Beam 04
		YES	8mm_2.0_A	Beam 06
ϕ10 @ 300	NO	-	10mm	Beam 07
	0.5 x 70 mm	NO	10mm_0.5_N	Beam 08
		YES	10mm_0.5_A	Beam 11
	2.0 x 70 mm	NO	10mm_2.0_N	Beam 09
		YES	10mm_2.0_A	Beam 10

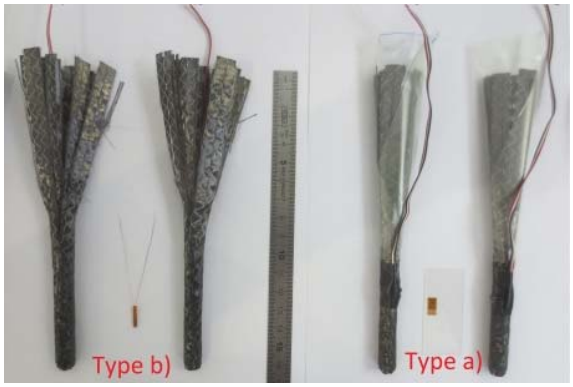


And what if they're not? : A stitch and a patch

Using FRP reinforcements to enhance shear capacity of concrete elements



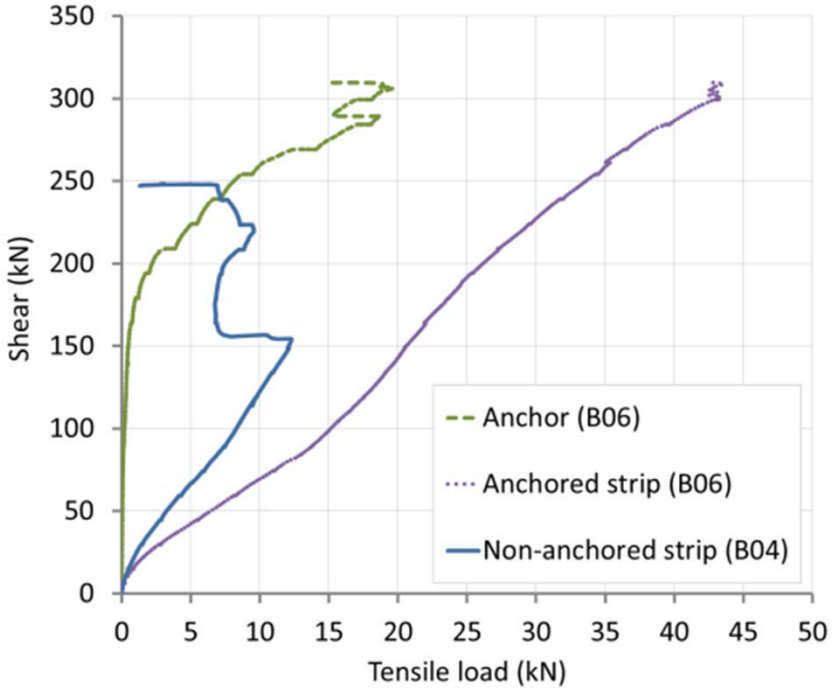




Installation of strain gauges in the CFRP spike anchors

And what if they're not? : A stitch and a patch

Using FRP reinforcements to enhance shear capacity of concrete elements

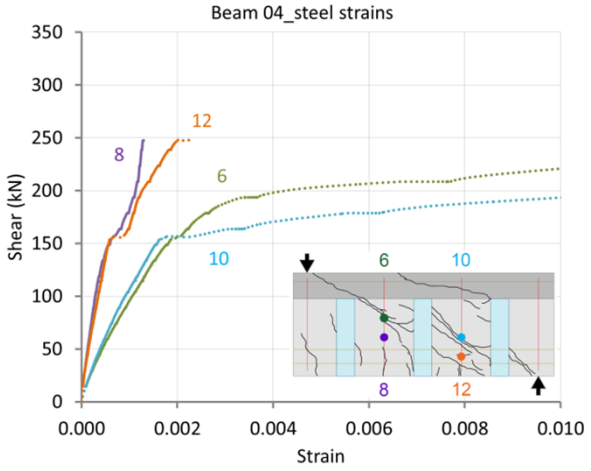


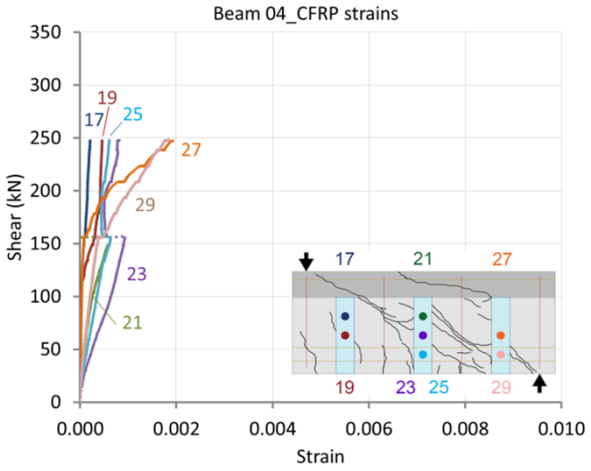
Tensile loads in CFRP strips and anchors

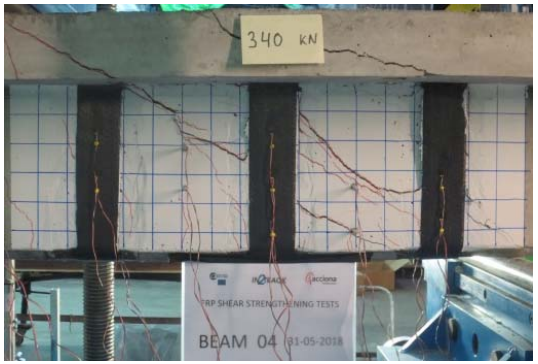
Pull-out failure of spike anchor
Beam B06

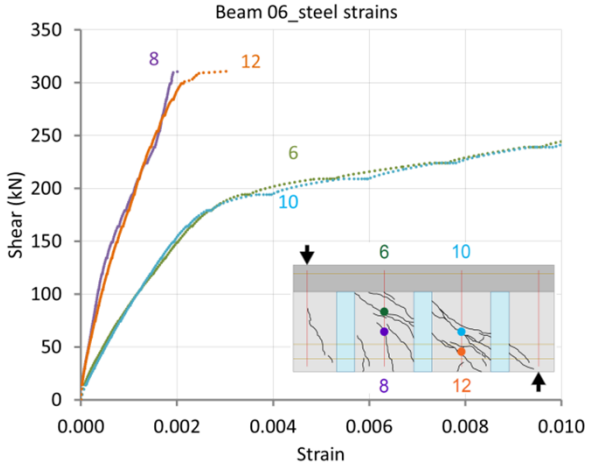
And what if they're not? : A stitch and a patch

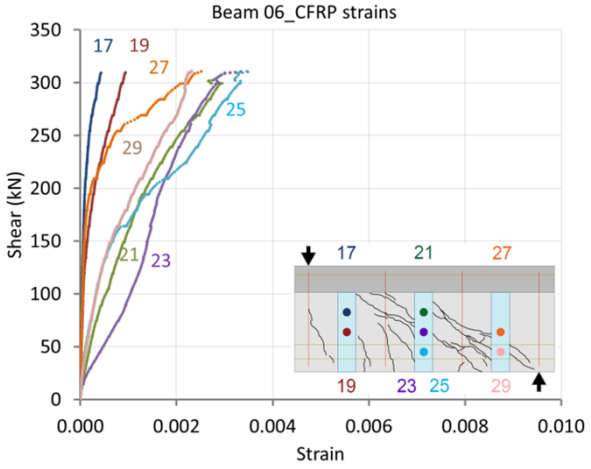
Using FRP reinforcements to enhance shear capacity of concrete elements

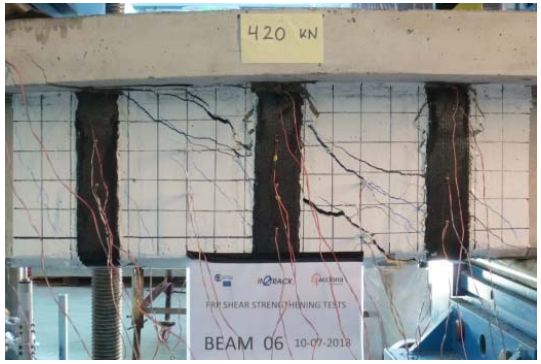






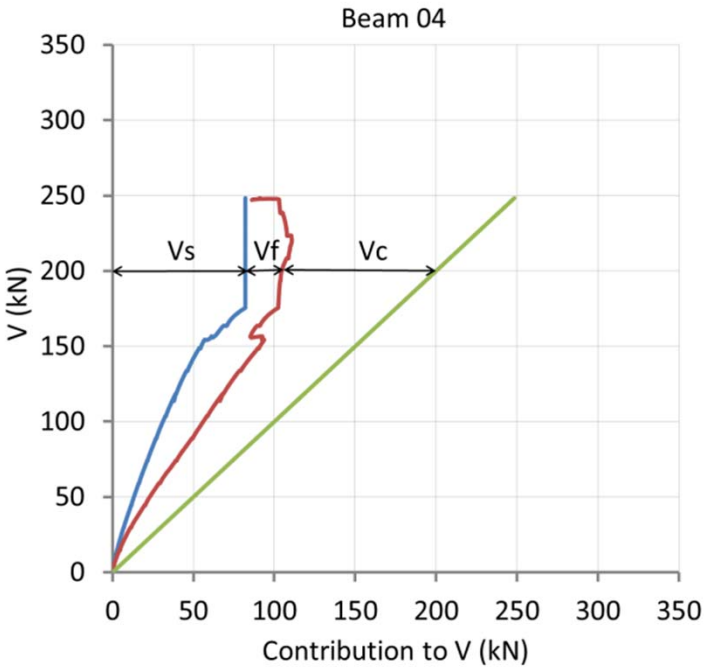




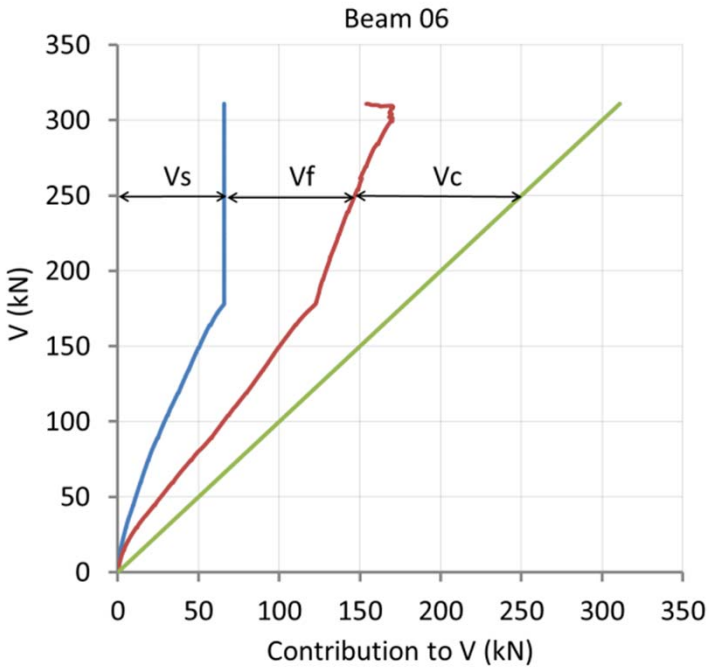


And what if they're not? : A stitch and a patch

Using FRP reinforcements to enhance shear capacity of concrete elements



8 mm steel stirrups
2 x 70 mm CFRP **non-anchored**



8 mm steel stirrups
2 x 70 mm CFRP **anchored**

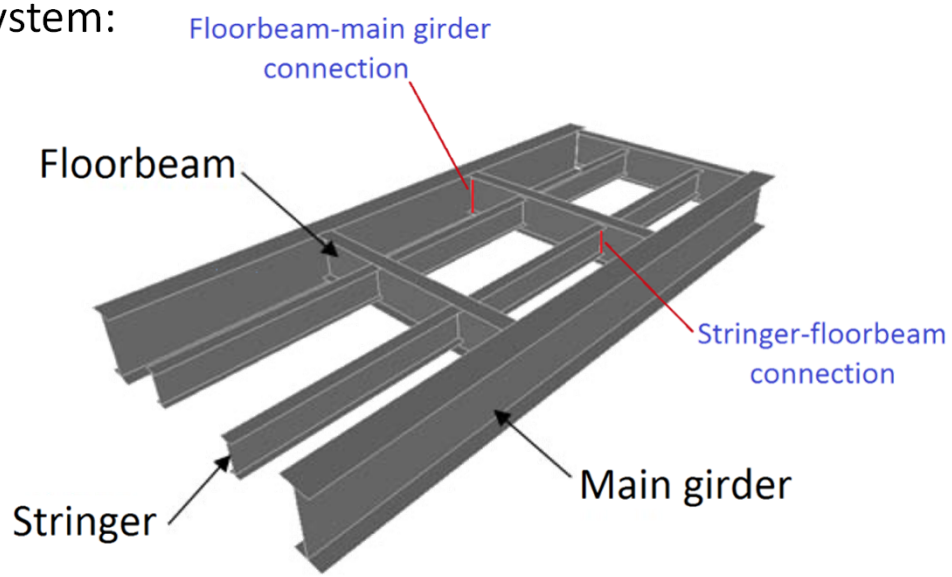
Shear contribution of each material: steel Vs, CFRP Vf and concrete Vc

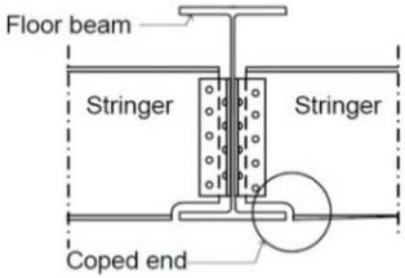
And what if they're not? : taking a breather

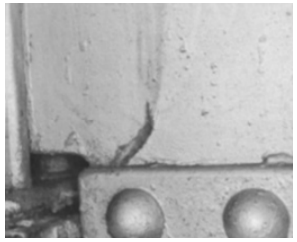
Using FRP reinforcements to extend the fatigue life of steel connections

Fatigue prone detail in railway steel riveted truss bridges

Floor system:

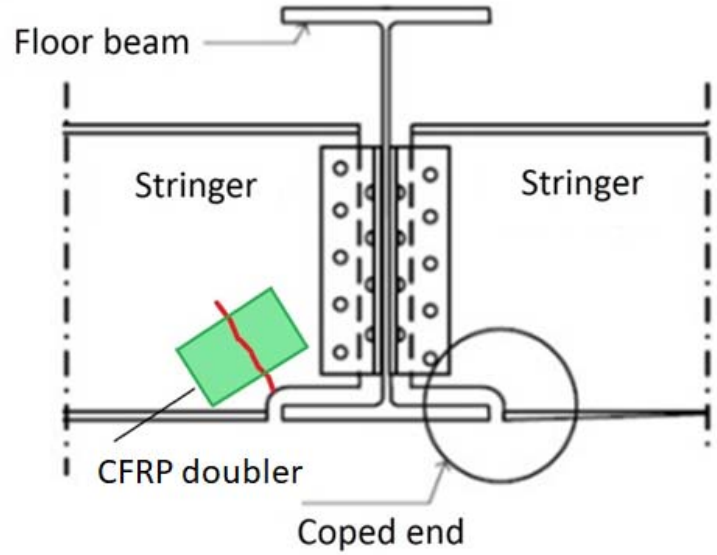






And what if they're not? : taking a breather

Using FRP reinforcements to extend the fatigue life of steel connections

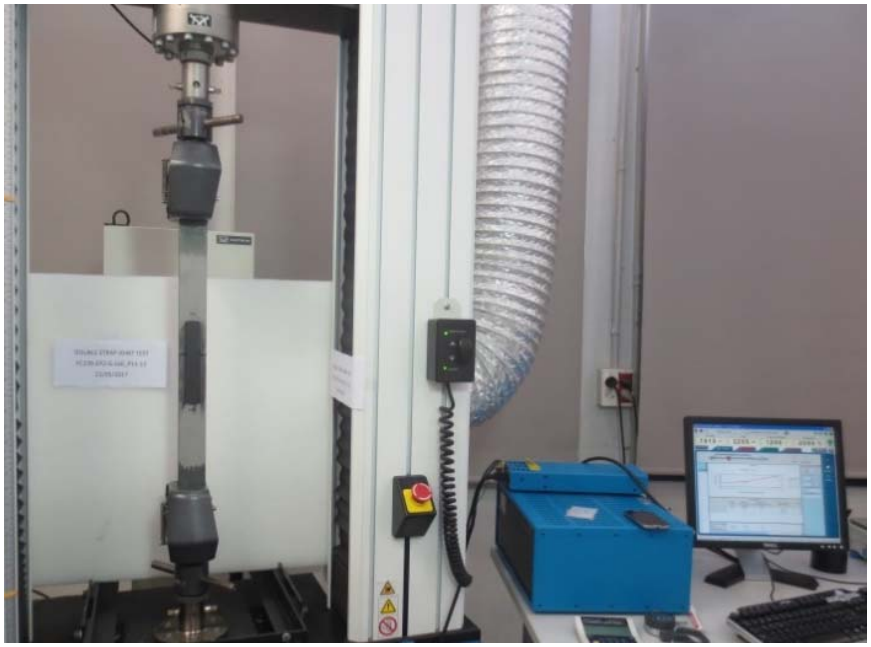


Adhesively-bonded CFRP doubler repair

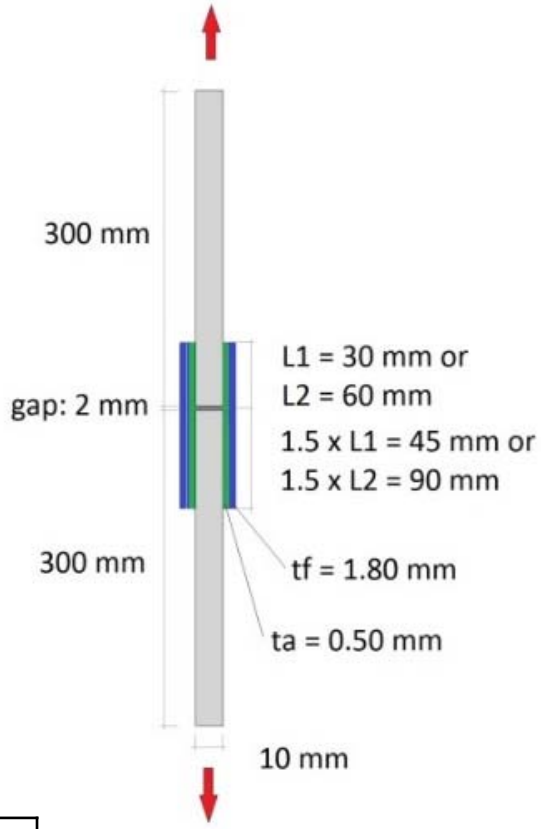
Bolted steel doubler

And what if they're not? : taking a breather

Using FRP reinforcements to extend the fatigue life of steel connections



Double-strap joint tests

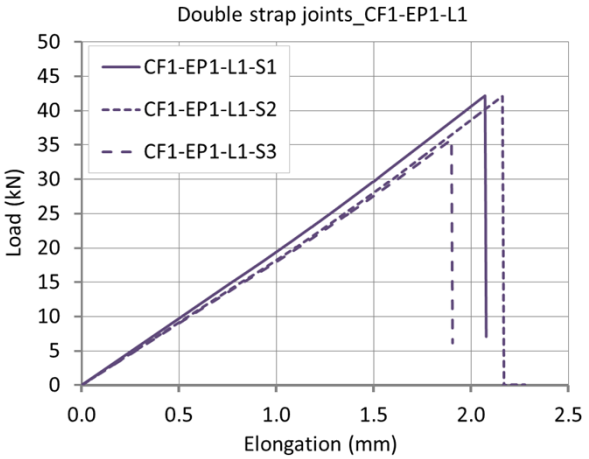


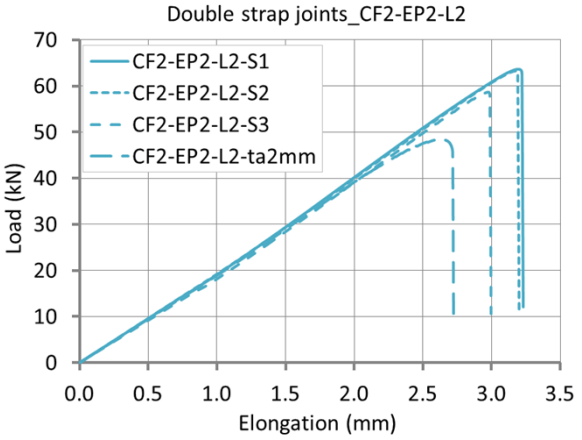
	CF1	CF2	EP1	EP2	Steel
Tensile strength (MPa)	1930	1660	30	19	450
Yield strength (MPa)	-	-	-	-	310
Tensile modulus (GPa)	117.1	183.6	4.95	1.45	200
Failure strain (%)	1.65	0.91	0.62	2.98	37.20

And what if they're not? : taking a breather

Using FRP reinforcements to extend the fatigue life of steel connections

Bond length (mm)	Adhesive	Carbon fibre	t_a (mm)	t_f (mm)	P_u (kN)	δ_u (mm)	K (kN/mm)	Failure mode*
L1 =30	EP1	CF1	0.74	1.88	40.03	2.04	19.46	A
		CF2	0.68	1.91	35.41	1.82	19.55	A
	EP2	CF1	0.50	1.81	26.83	1.62	17.15	A
		CF2	0.49	2.03	28.47	1.56	18.58	A
L2 = 60	EP1	CF1	0.92	1.78	40.73	2.12	19.18	C
		CF2	0.73	1.93	56.92	2.74	19.97	C
	EP2	CF1	0.78	1.80	57.74	3.12	19.48	C
		CF2	0.65	1.84	61.85	3.12	21.01	C
	EP1	CF1	2.16	1.93	43.14	2.15	19.90	C
		CF2	2.06	2.01	51.10	2.46	20.30	C
	EP2	CF1	2.05	1.84	49.57	2.82	19.05	C
		CF2	1.93	1.71	48.41	2.63	19.86	C





And what if they're not? : taking a breather

Using FRP reinforcements to extend the fatigue life of steel connections

Redondela Bridge (North of Spain)

Original replaced stringers

Testing of double-strap joints specimens with old steel

Steel plates cut from bridge stringer

And what if they’re not?: concreting fatigue damage

Testing of a strengthened R C Bridge 2006 in Örnsköldsvik, Sweden

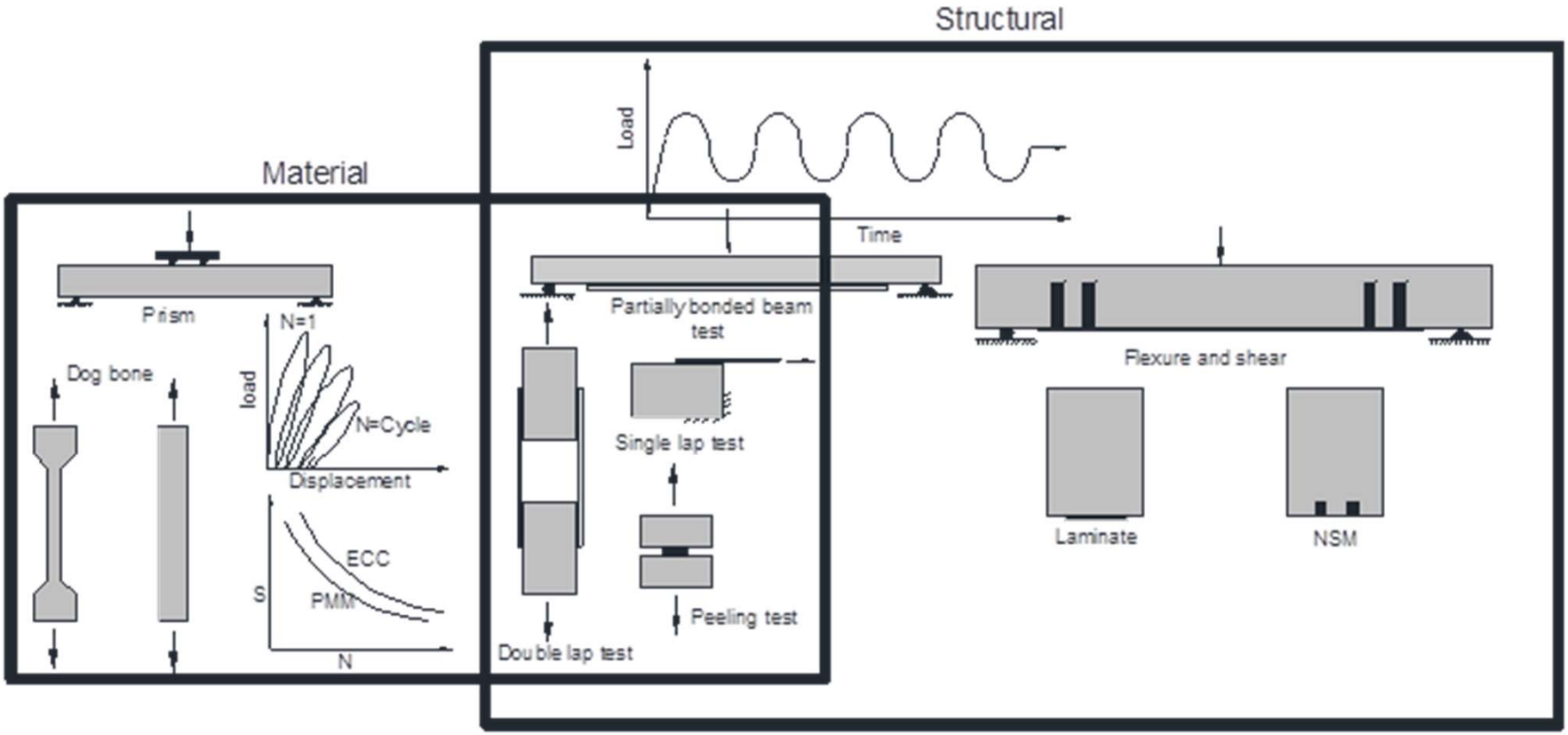
And what if they're not?: concreting fatigue damage

Fatigue loads can be divided into low and high stress type:

- Low Fatigue Stress (High cycle fatigue) to simulate traffic loads on bridges. In this type, the maximum effective equivalent stress resulting from maximum cyclic load in the first cycle is lower than the yield stress of the structure.

- High Fatigue Stress (Low cycle fatigue) for seismic investigation purpose, in this type, the maximum effective equivalent stress resulting from maximum cyclic load is above the yield stress of the structure.

And what if they're not?: concreting fatigue damage



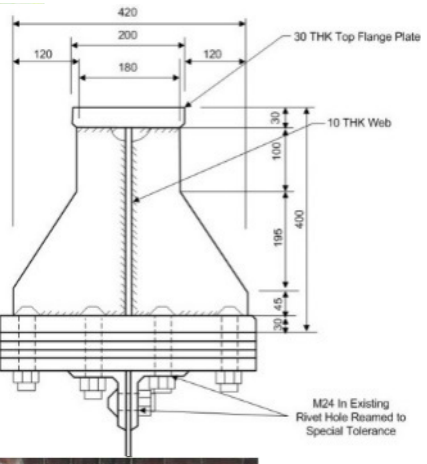
And what if they're not?: concreting fatigue damage

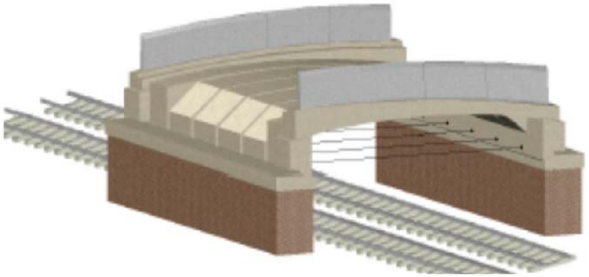
Extensive laboratory testing

Debonding failure after rebar failed due to fatigue

And what if they're not?: the axe of my forefathers

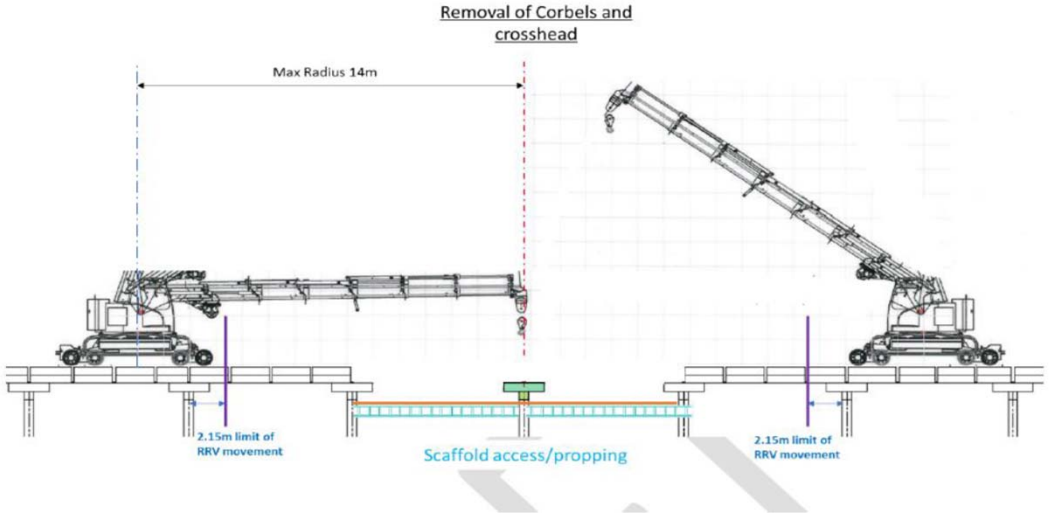
Sometimes the old just needs some sharpening and patching up…





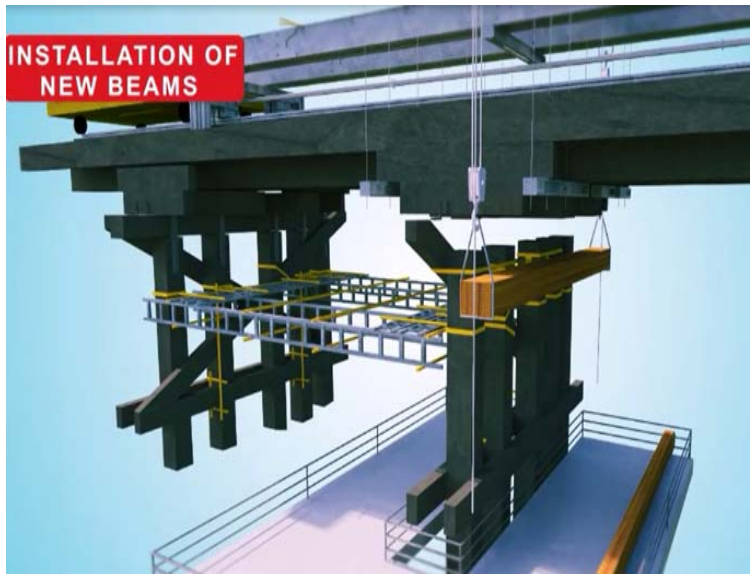
And what if they’re not?: the axe of my forefathers

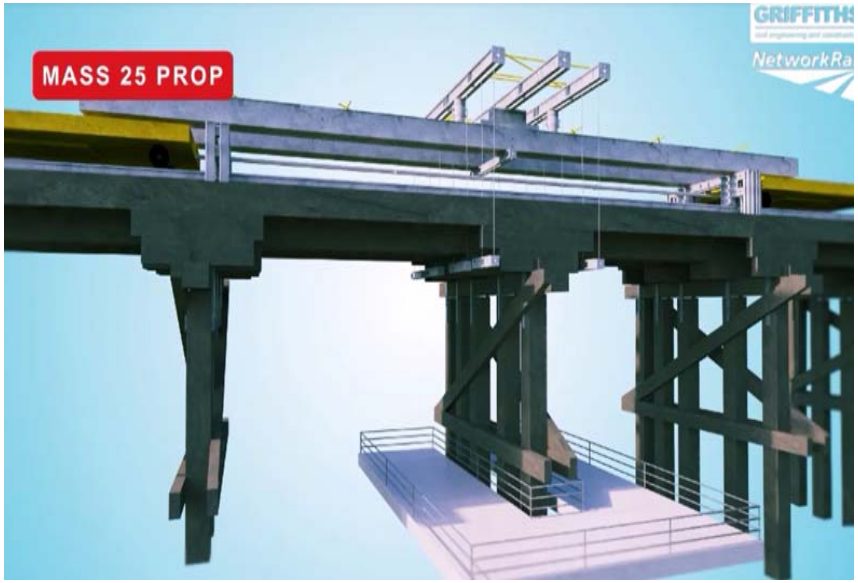
… and sometimes it needs a new deck…

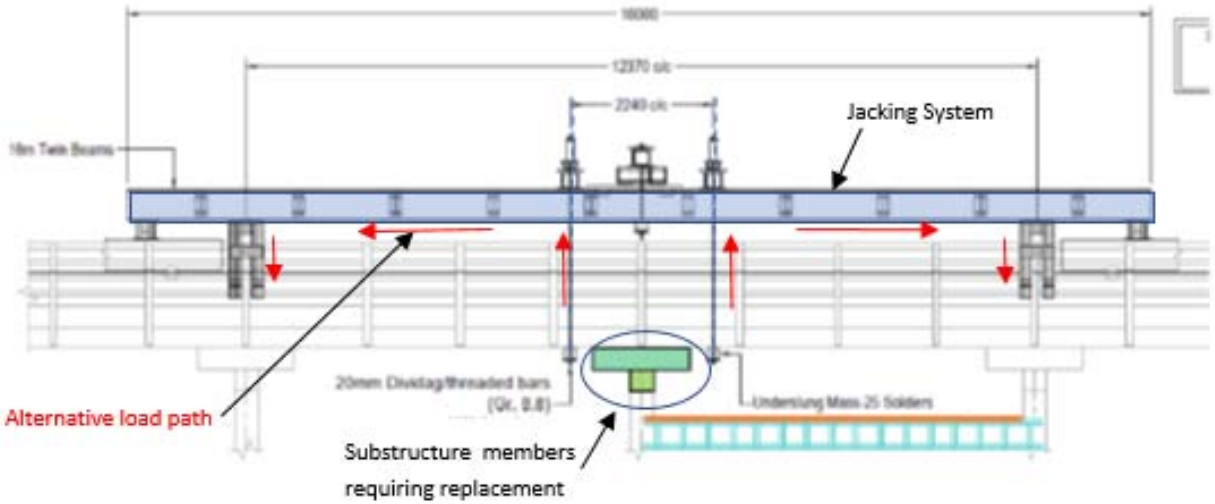


And what if they're not?: the axe of my forefathers

… or a new pillar…







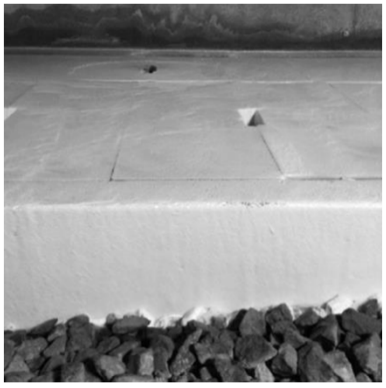
And what if they're not?: the axe of my forefathers

… But is it not the same bridge?

Cleaning the pipes: line those gutters up

Study on calcite precipitation strives to prevent/mitigate/repair drainage pipe blockages

Objectives	
1	Identify the key factors involved in the process of calcite precipitation in tunnel drainage systems
2	Identify existing solutions to prevent precipitation and/or dissolve calcite
3	Develop an innovative method to improve maintenance of drainage systems in tunnels with problems due to calcite

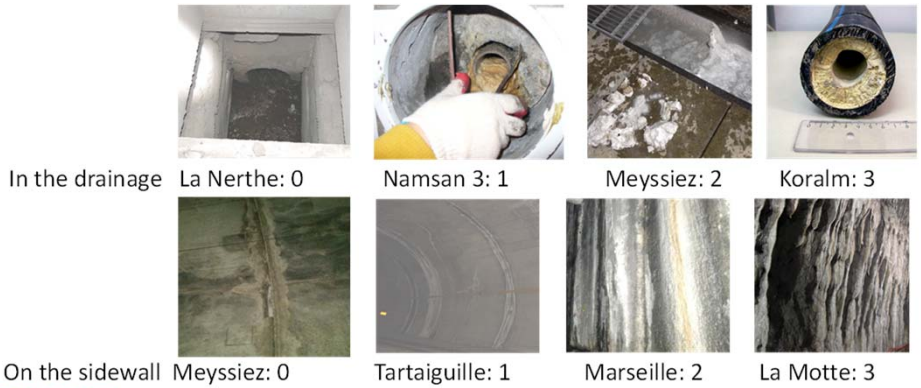


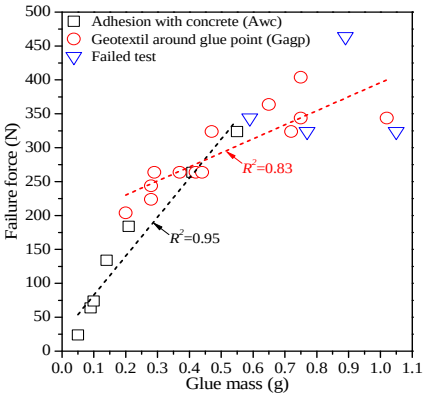
Cleaning the pipes: line those gutters up

Study on calcite precipitation strives to prevent/mitigate/repair drainage pipe blockages

Main Results

1	Information on railways tunnels affected by the calcification problems in France was collected, enabling an in-depth analysis of the key influencing factors.
2	Review of existing maintenance techniques showed there is a need to develop a reliable method to improve these operations. A new method was proposed which consists in covering the inside of existing concrete gutters with an easily removable material (liner) to simplify extraction of calcite deposits. The idea is to protect the drainage structures, facilitate maintenance operations and extraction of deposits by reducing the contact surface between calcite and concrete, and decrease overall costs.
3	The results obtained from laboratory suggest that the proposed method (using geotextile lining and acrylic) is feasible and should be tested in the field. Research on other possible types of liners such as resins should also be developed.





Cleaning the pipes: reinforcing the new, repairing the old

Study on calcite precipitation strives to prevent/mitigate/repair drainage pipe blockages

Objectives

1	inventory of tunnel drainage systems regarding calcium carbonate scale deposits
2	Evaluation and improvement of tunnel drainage pipe materials
3	Development of sensors for remote scale deposits monitoring
4	Research on repair works for drainage pipes

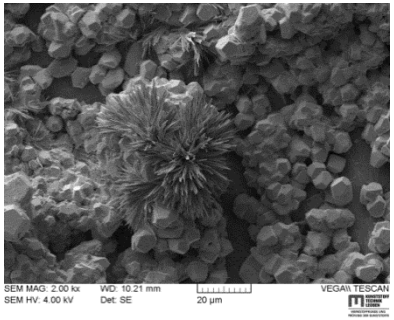
Bezeichnung	Eintrag	Schachtfoto
Blocknummer	68	
Drainage	Ulmendrainage Gleis 1	
Jahr der letzten Spülung	-	
Probenentnahme	Wasser- und Feststoffprobe	
Datum	21.11.2016	
Uhrzeit	09:13	
Rohrdurchmesser	DN/ID250	
Wassertemperatur [°C]	9,6	
Elektr. Leitfähigkeit [µS/cm]	573	
pH-Wert [-]	8,35	
Abstichmaß Wassertiefe im Rohr	5,5 cm	
Versinterung im Rohr	ja	
Versinterung im Schacht	ja	
Mächtigkeit Versinterung	bis 3,0 cm	
Zustand Versinterung	hart	Foto: Draufsicht Schacht (Fließrichtung von rechts nach links
Anmerkungen	Fließgeschwindigkeit ca. 0,13 m/s	

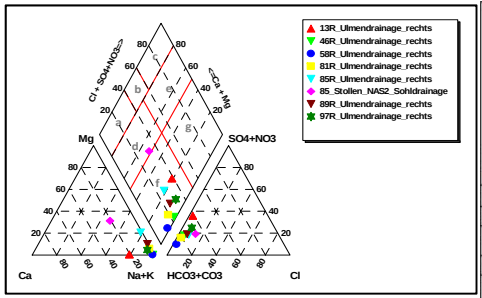
Cleaning the pipes: reinforcing the new, repairing the old

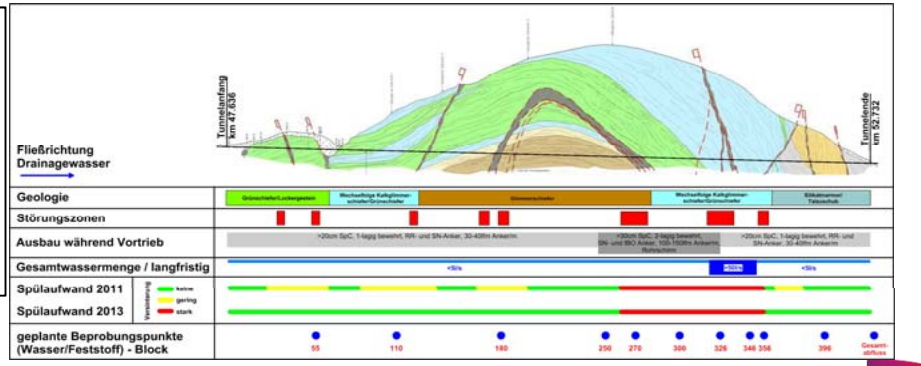
Study on calcite precipitation strives to prevent/mitigate/repair drainage pipe blockages

Main Results

1	Data collection of drainage water and sampling of scale deposits had been carried out in 15 railway tunnels. Data interpretation is currently under way. First results show influence of cement bearing support elements.
2	Literature study and preliminary tests had been carried out regarding properties of various thermoplastic pipe materials and various additives in order to enable the extension of its lifespan and to get an increased resistance to the cleaning processes.
3	Small scale tests are under way out using capacitive tomography technologies, acoustic analysis of the drainage pipe and detection of the amount of scale deposits by monitoring the changes of the pipe's mass moment of inertia.
4	Literature study and a first test have been carried out using cured-in-place pipes. It seems that all repair procedures are developed for sewage pipes only. Apparently none of the methods is suitable for repairing broken drainages in tunnels so that they are fully functional again and have the full lifespan.

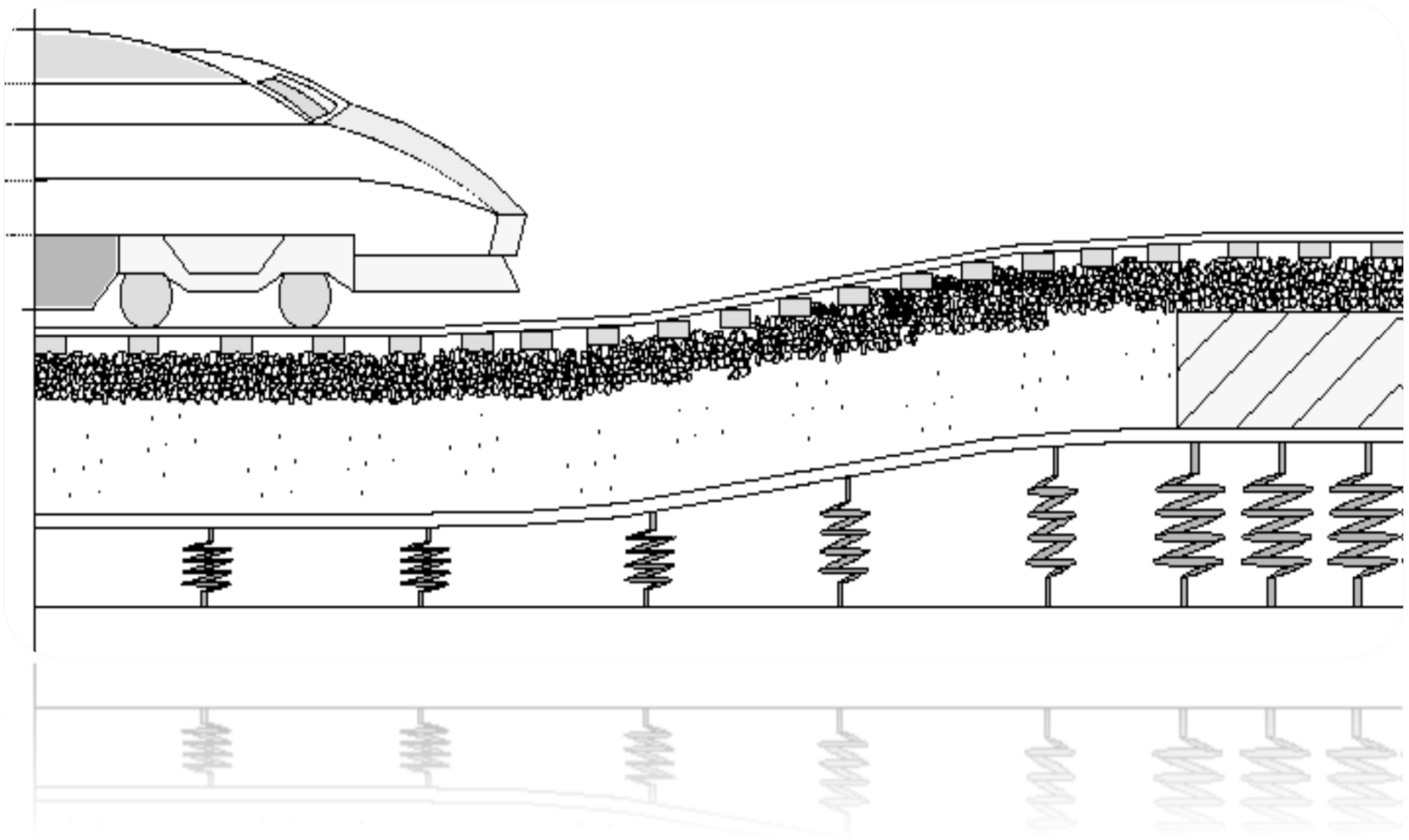






Why the sudden change?

Understanding the process of transition zone degradation to enhance malfunction diagnostics



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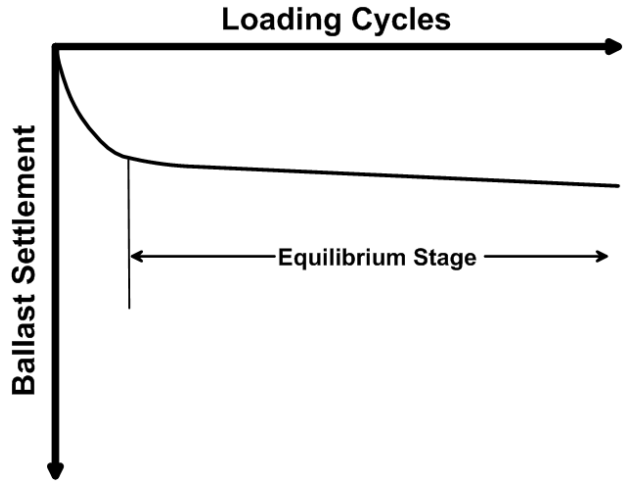

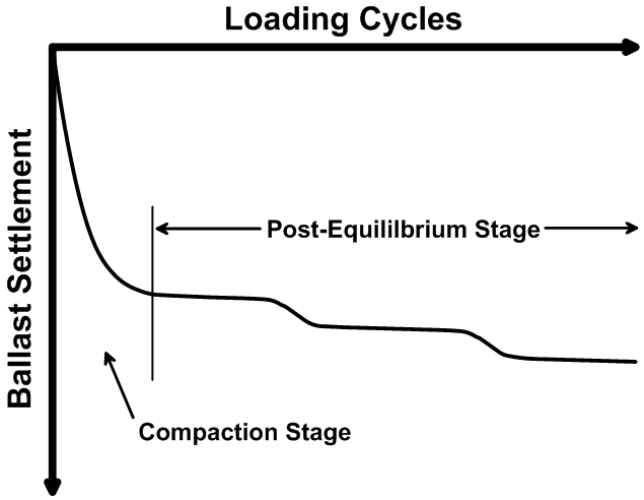

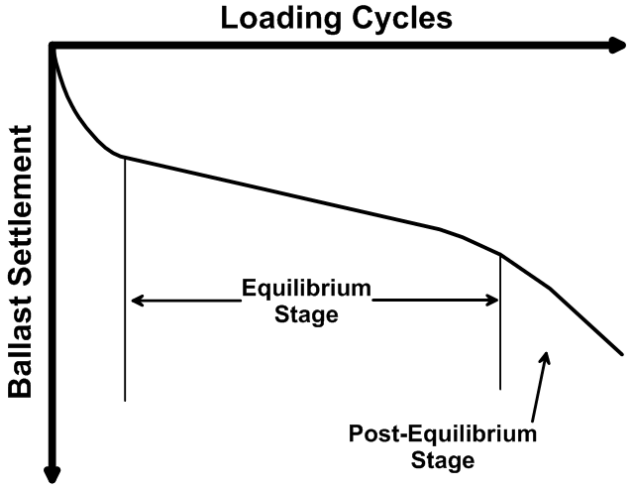

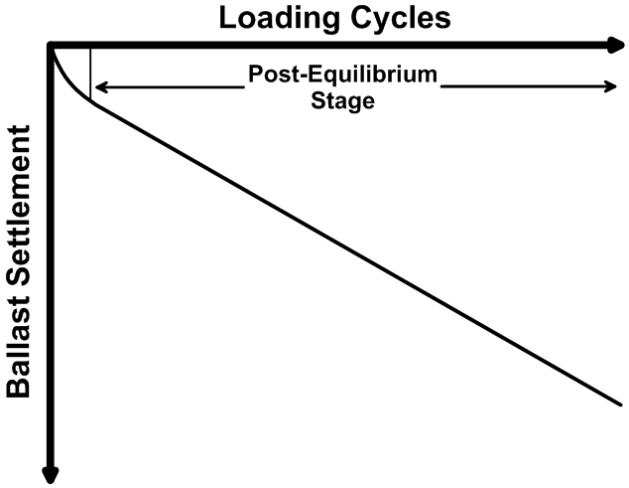

Why the sudden change?

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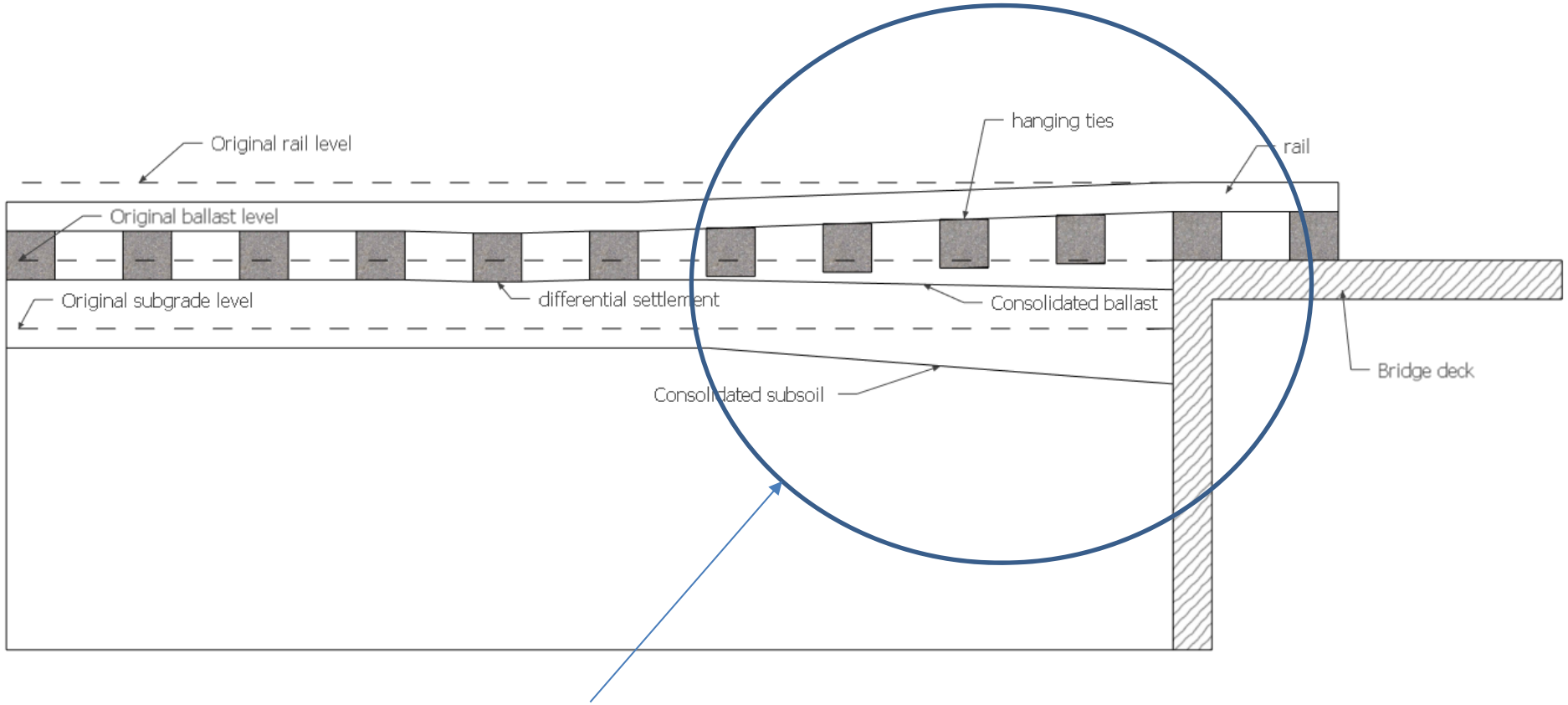
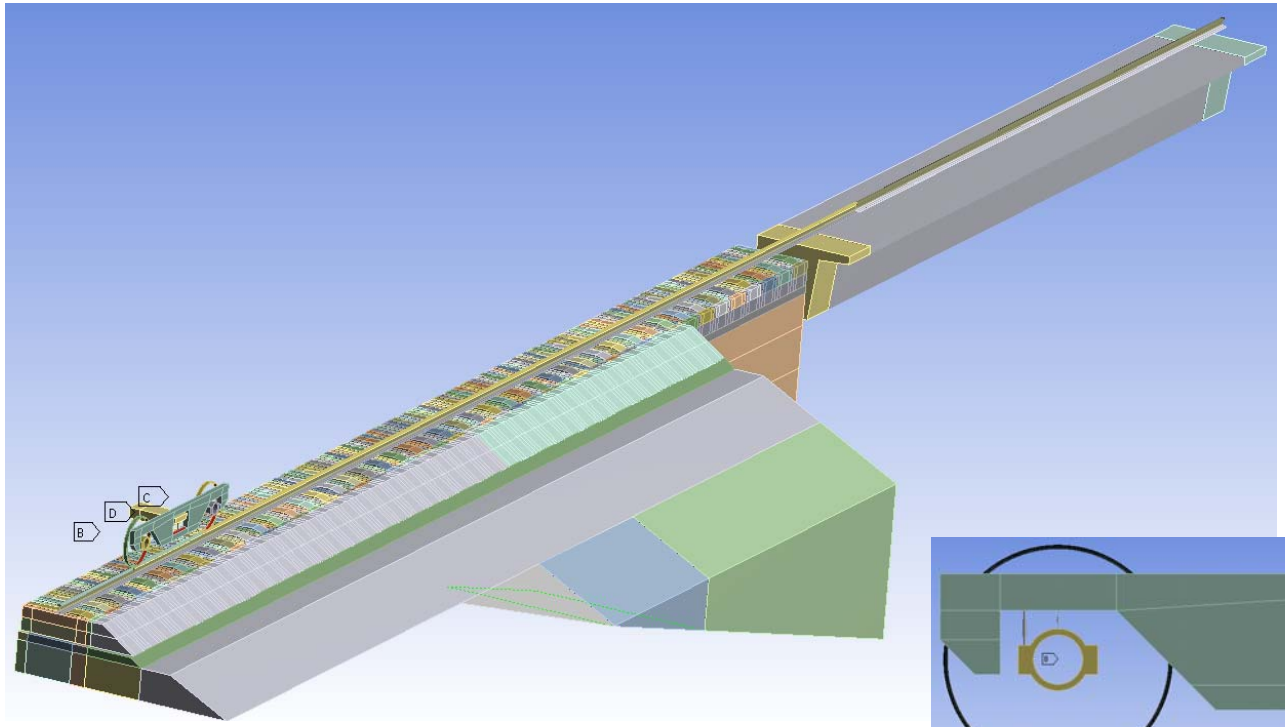
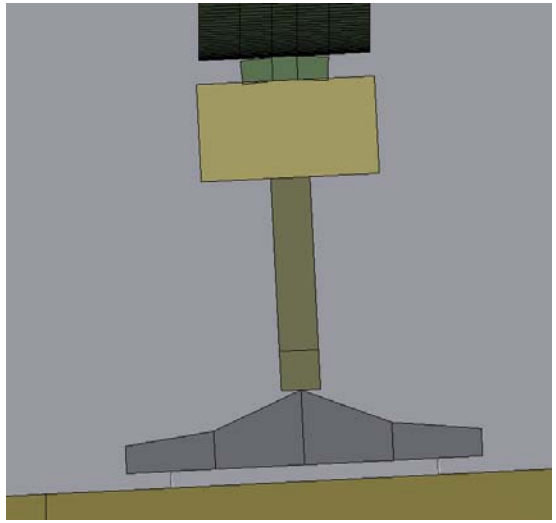


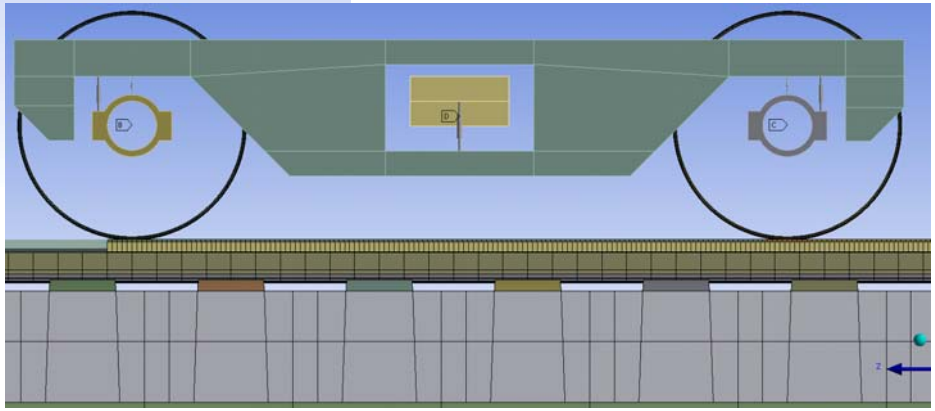
KEY GOVERNING FACTOR: FIXED vs FLOATING GEOMETRY (transient AND static!)

Why the sudden change?

Understanding the process of transition zone degradation to enhance malfunction diagnostics







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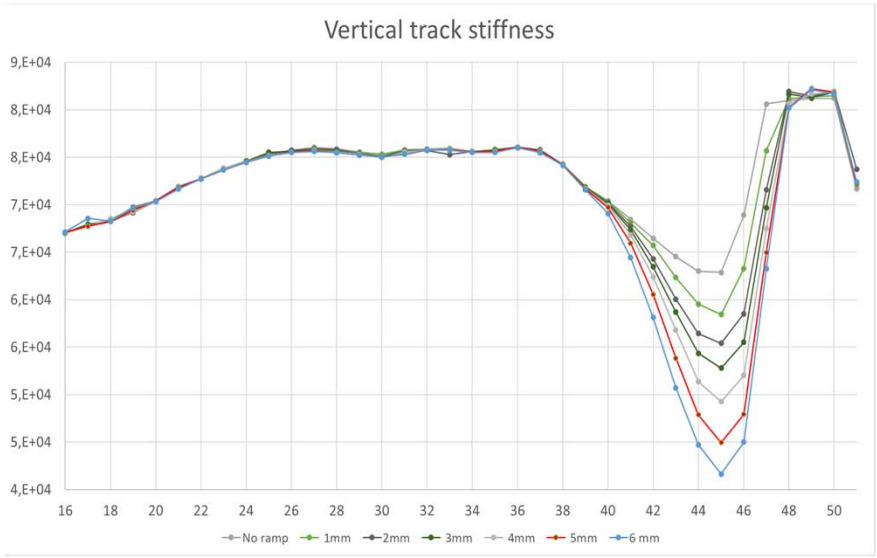
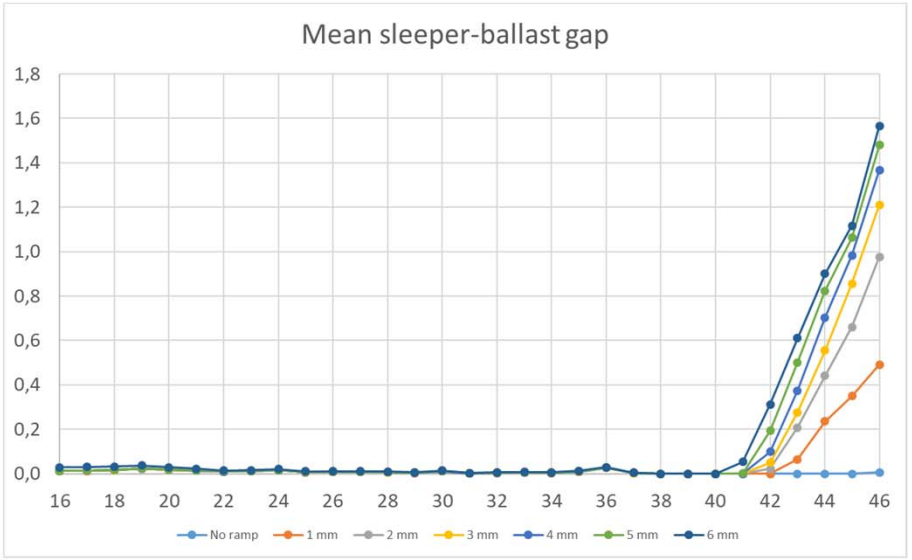
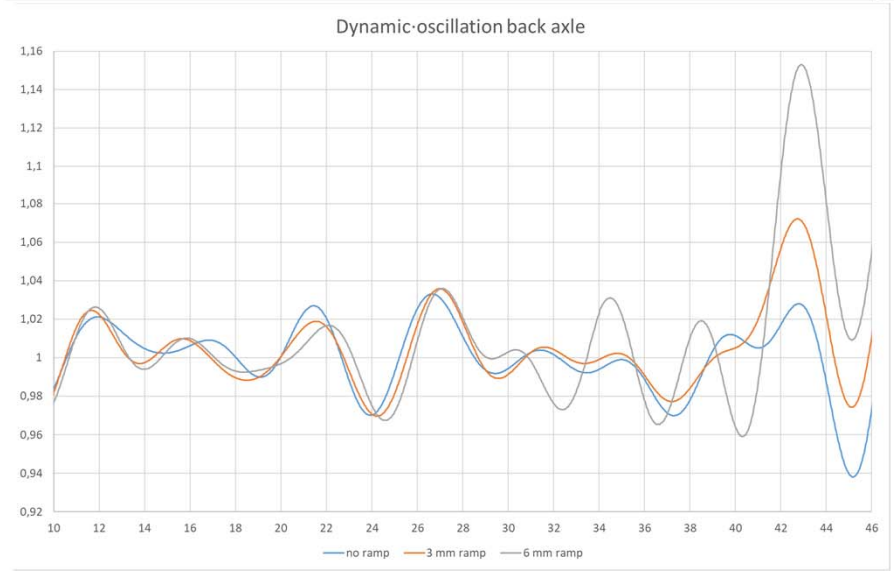
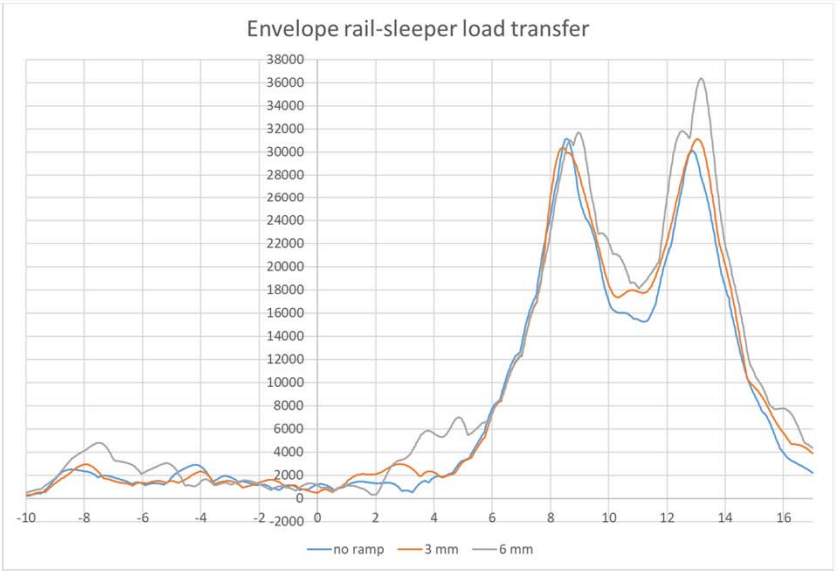








IN2TRACK

Low-cost dynamic bridge design:

enhancing the understanding of bridge dynamics to optimize high-speed bridge costs.

GA H2020 - 730841

A new wave in bridge design: shaking the house down

Empirical exploration of bridge dynamics evolves current high-speed bridge design regulations

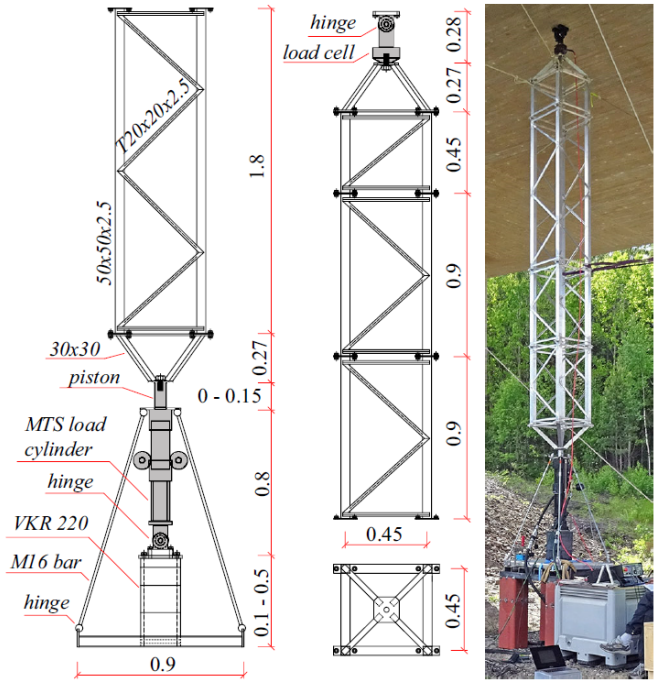
Response of railway bridges to passing trains depends on their dynamic properties: frequencies, damping ratios, etc

BUT, also dynamic soil-structure interaction, boundary conditions and amplitude dependencies.

To understand the real behaviour of bridges, full-scale testing using controlled excitation by a load shaker is necessary.

By recovering valuable data on real dynamic behavior of bridges, more accurate assessment of structural needs for high-speed bridges shall be obtained…

…a crucial input for **future bridge design regulation** with great potential to **reduce costs**



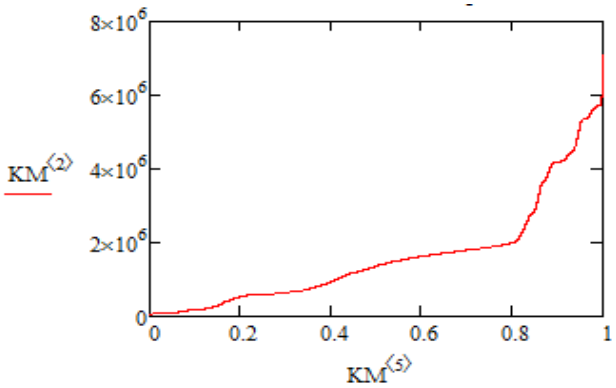
The impact of statistics

Generating random traffic loads from impact load detector data

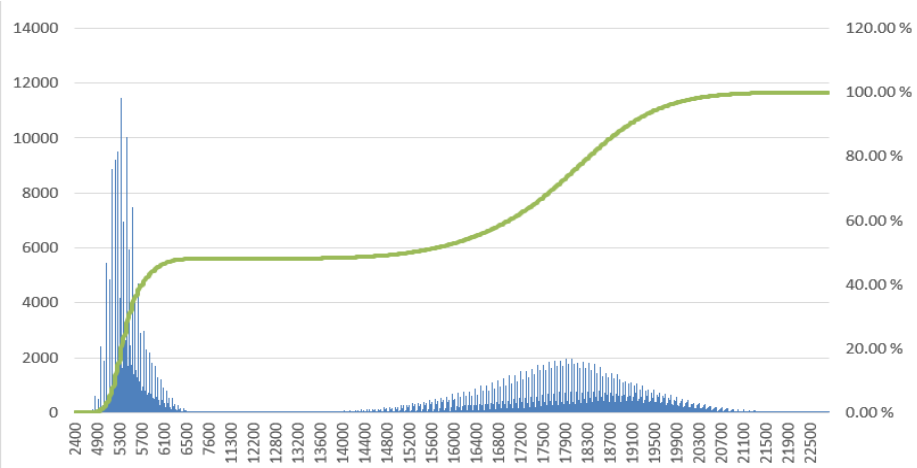
The impact of statistics

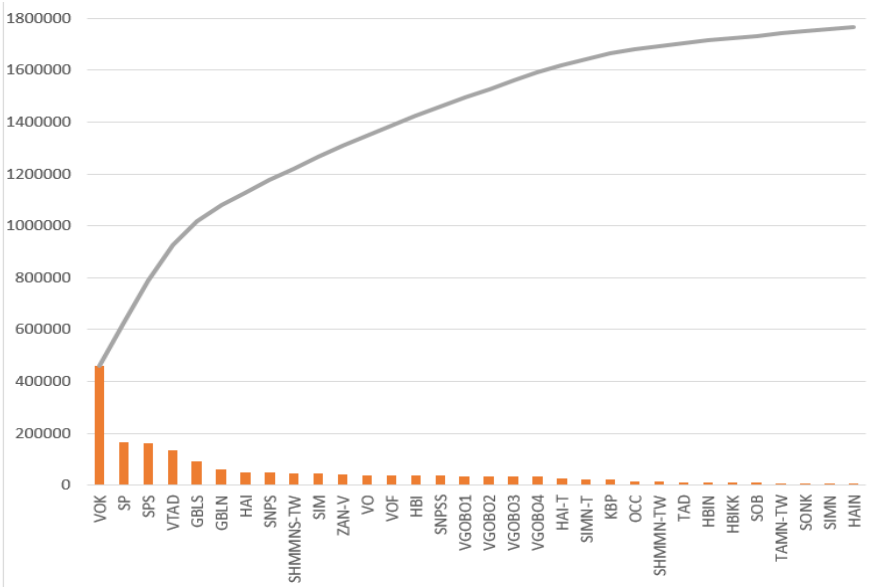
Generating random traffic loads from impact load detector data

Total mass of the trains



Axle mass distribution

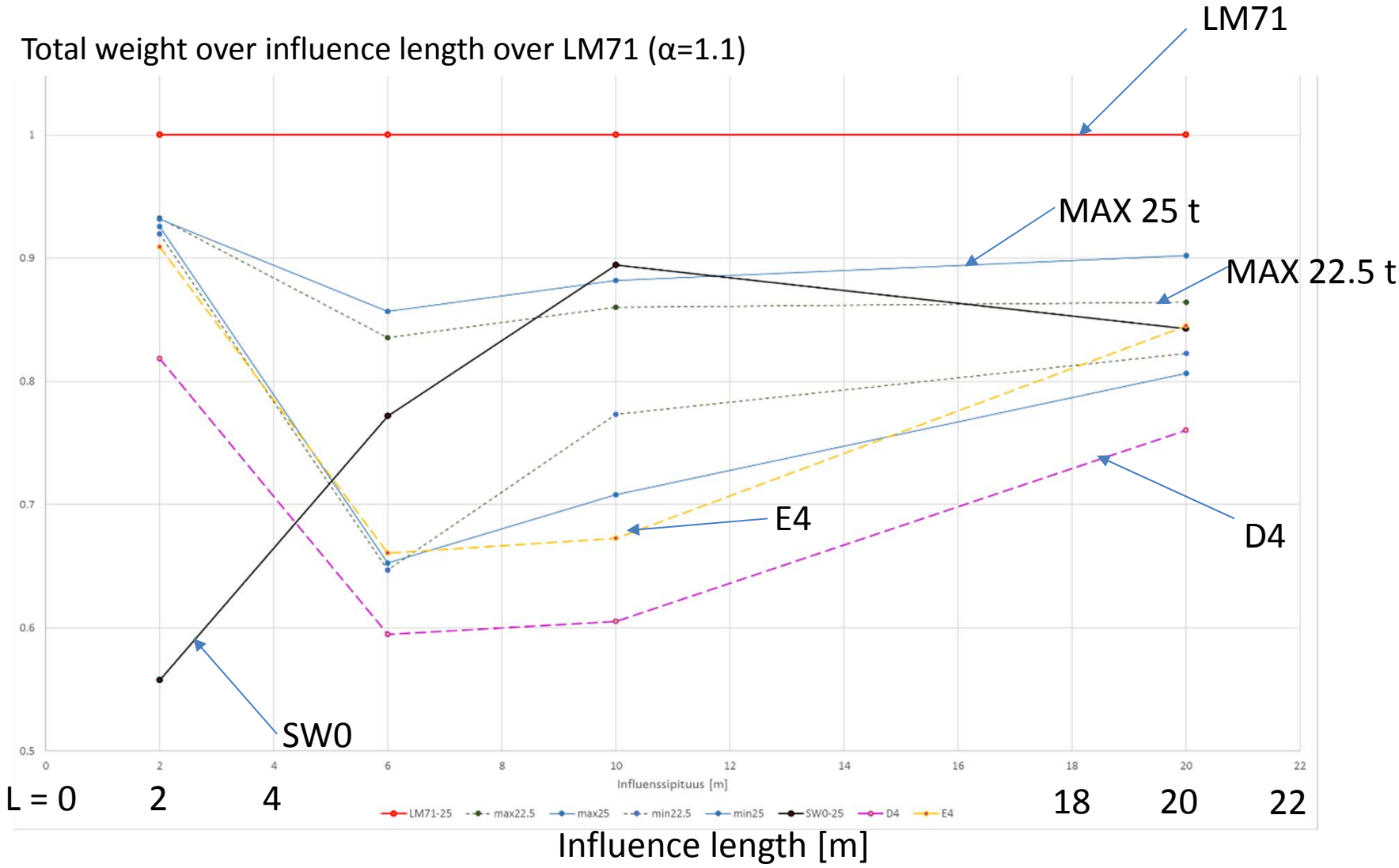




Carriage types

The impact of statistics

Generating random traffic loads from impact load detector data



The impact of statistics

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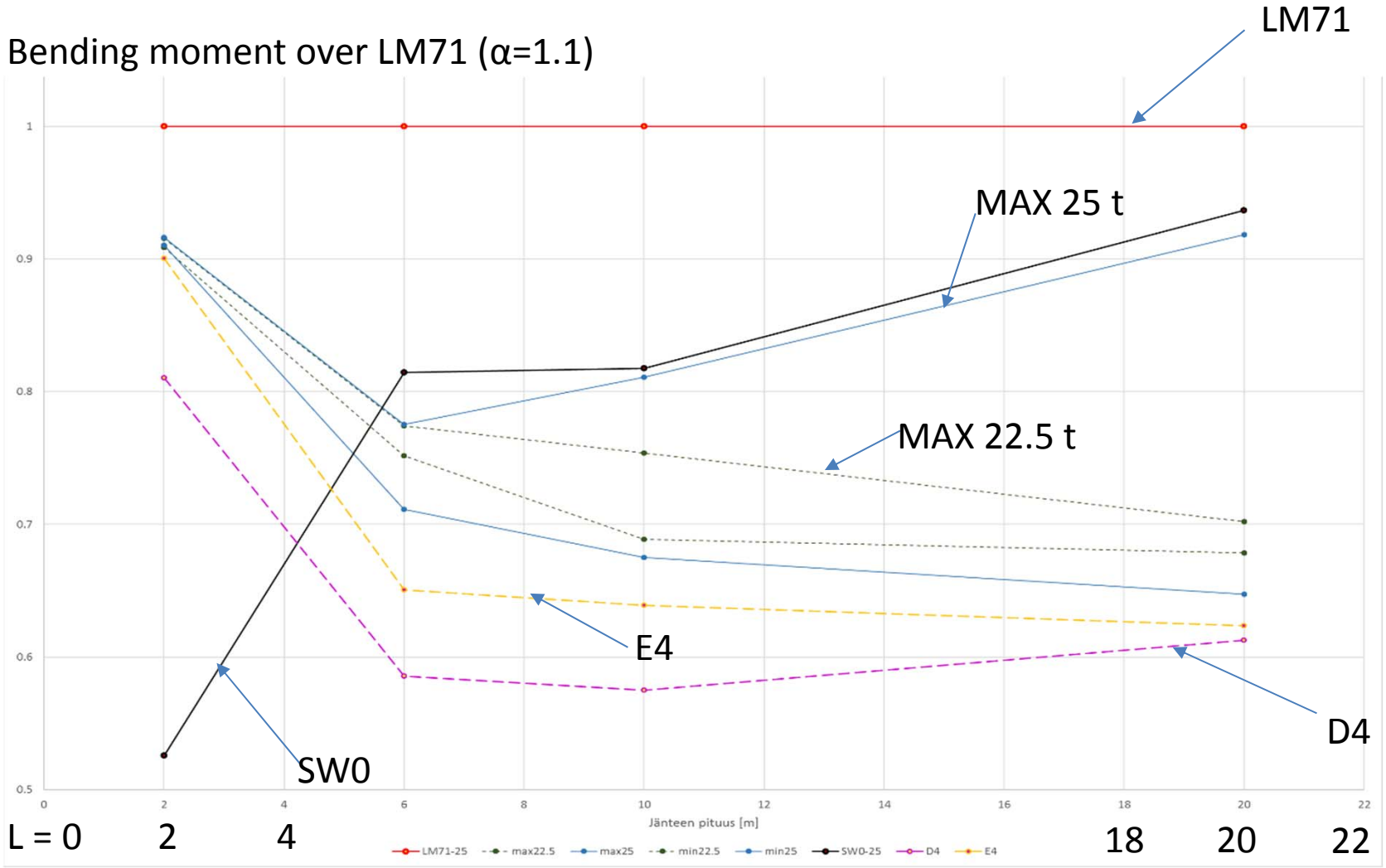

IN2TRACK

Many thanks for your kind attention!

GA H2020 - 730841