THE FUTURE OF TRANSPORT

Pavement design: future challenges and opportunities

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A changing landscape

Expectation

Increased significance of Asset Data in the new environment due to a better understanding through BIM

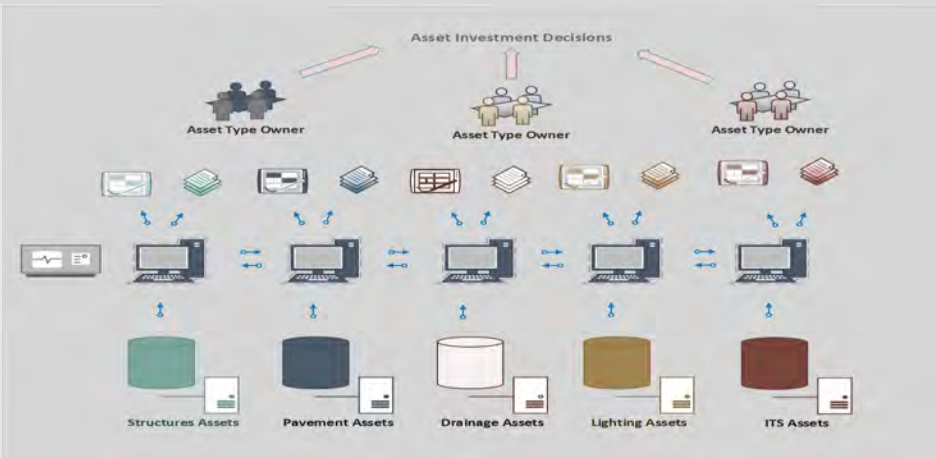
Technology

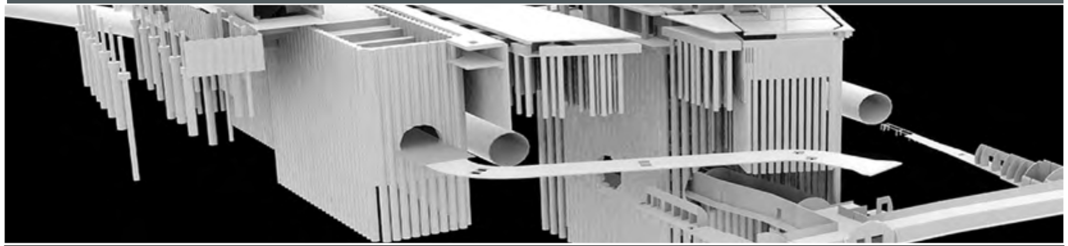
The ‘art of the possible’ has been overtaken by the actual

Industry

The Highways Industry is behind other Infrastructure sectors in embracing the opportunities that intelligent asset data provides and we have been slow to adopt

Best Practice?





Real, tangible benefits available now. The challenge is <u>pace</u>

Lifecycle approach

One, Evolving Data Set, Available to All

Pavement design – Future challenges and opportunities

1. Developing consistent and robust methodology for new design and maintenance design
   - Align the design and maintenance standards

2. Design and build more sustainable pavements
   - Incorporate more recycled materials

3. Effects on pavement design: Future issues
   A. Developments in vehicle technology
   B. More comprehensive monitoring

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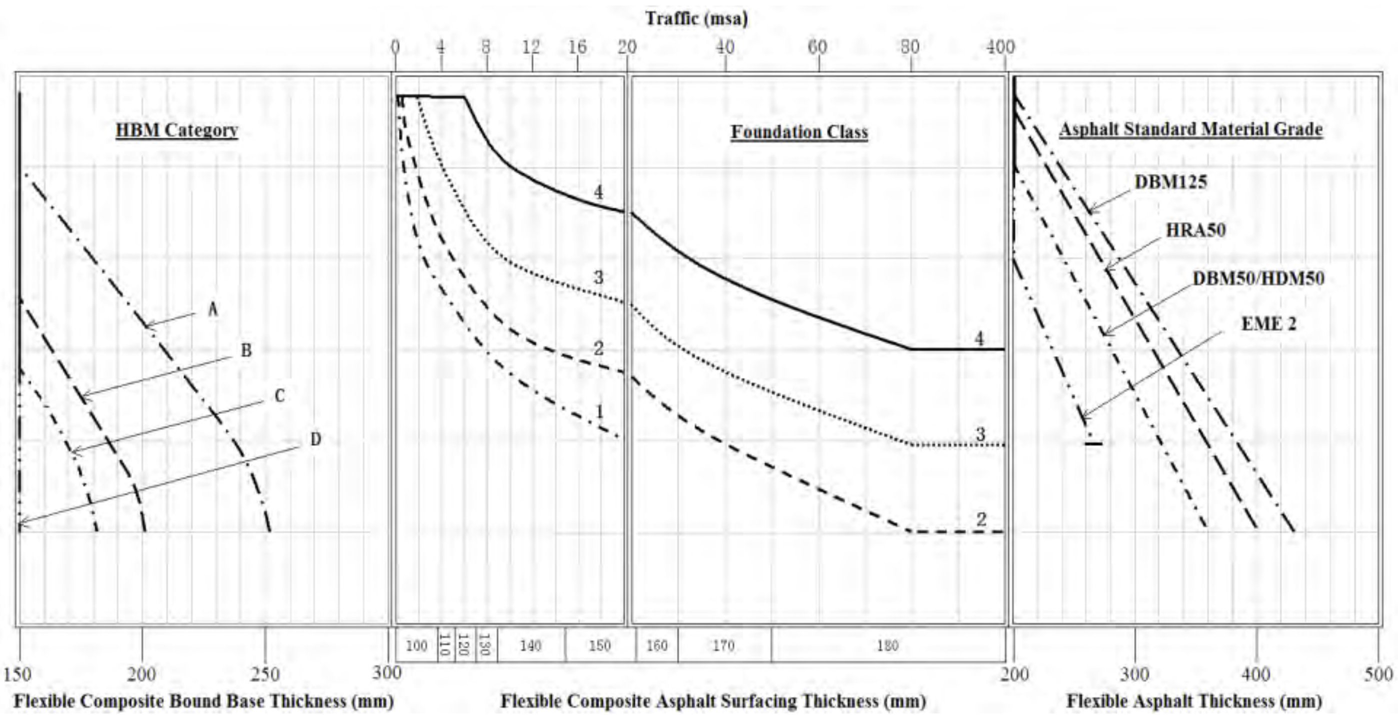
UK Pavement design & maintenance standards

- DMRB Volume 7 HD26
- DMRB Volume 7 HD29/30



Pavement design & maintenance standards

- UK pavement design approach takes into account the critical strains in the subgrade and asphalt layer to prevent structural rutting and fatigue cracking
- Well-constructed thick asphalt pavements typically show surface defects only
- Such pavements are referred to as Long Life Pavements (LLPs)
- Designed to carry ≥ 80 million standard axles (80kN)

Where are we now?

Structural pavement design and maintenance

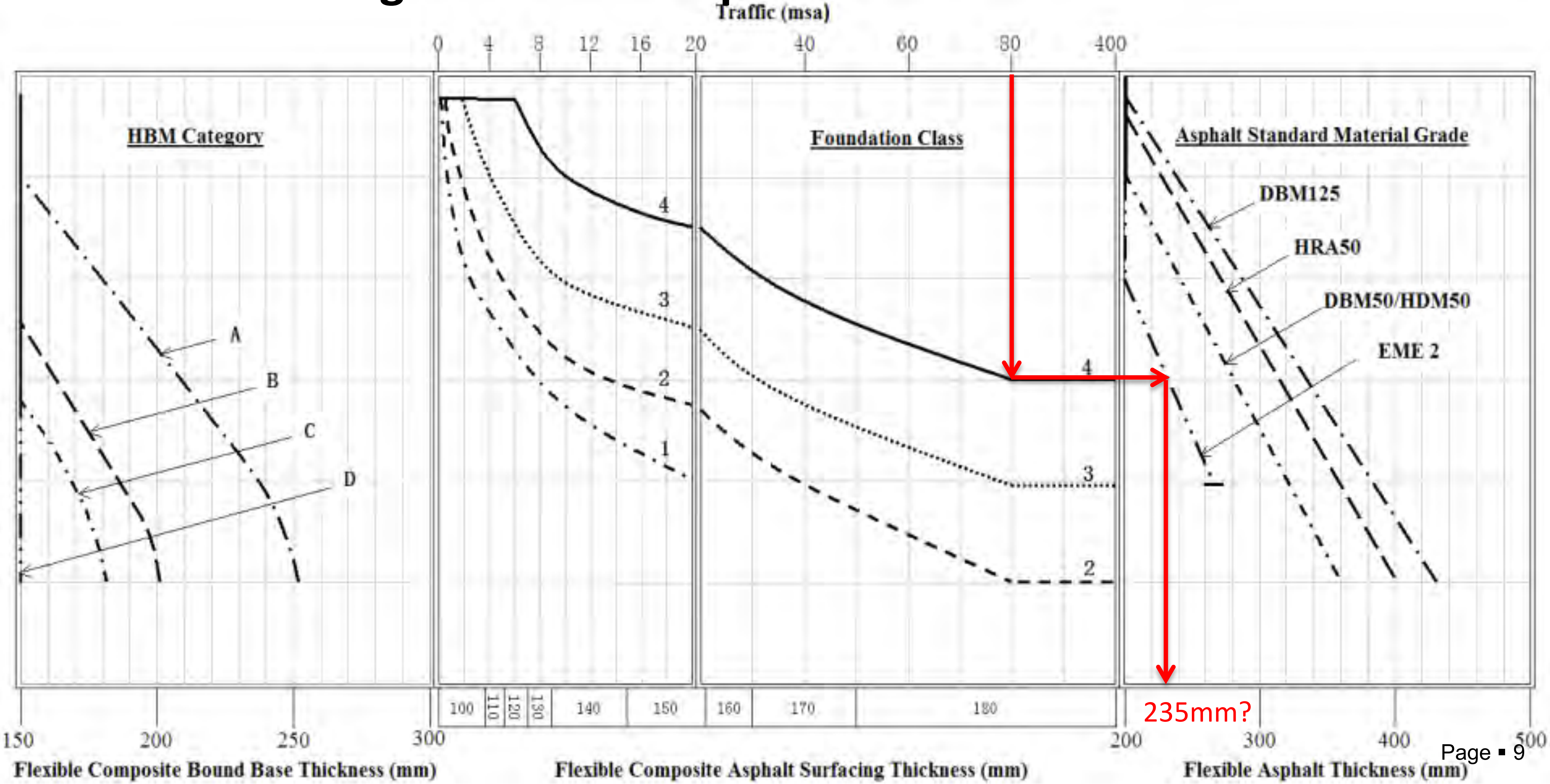
New pavement design

- Thickness varies with traffic up to 80msa
- Limited by critical horizontal and vertical strains i.e. mitigating fatigue and deformation
- Thickness constant above 80msa
- Based on RR250 (and TRL615)

Maintenance design

- Potential LLPs identified by measured deflection and asphalt thickness
  - Minimum 300mm asphalt thickness required for LLP
- For determinate life pavements (DLP)
  - Residual life estimates based on measured deflection and traffic carried
  - Thickness of strengthening overlay determined by measured deflection and future traffic

Pavement design - HD26 example



Where do we want to be?

Focusing on Highways England's Strategic Road Network

Strategic Road Network

- Entirely long life construction?

Structural design

- Based on meeting threshold critical strains whatever traffic level
- Based on minimal necessary design thickness plus risk allowance

New pavement design

- Assume new pavement material properties
- Design thickness so predicted strains meet thresholds
- Add thickness to provided acceptable level of risk

Maintenance design

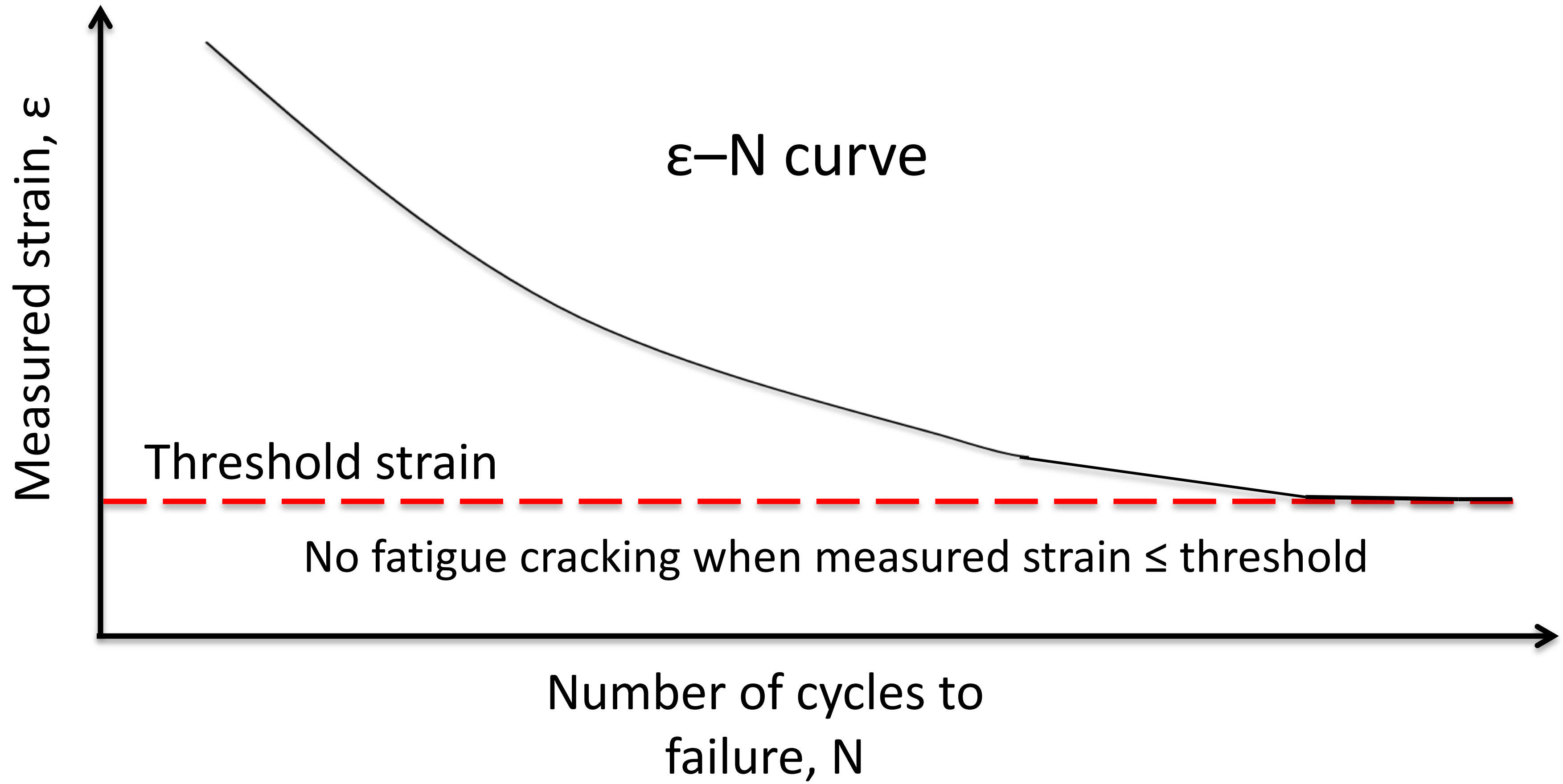
- Measure in-service properties
- Design strengthening or reconstruction so predicted strains meet thresholds
- Add thickness to provide acceptable level of risk

Radical pavement design

What is 'radical pavement design' concept?

1. Design and maintain pavements that takes into account the threshold strain
   - Threshold strain = strain limit within asphalt mixtures below which no fatigue cracking occurs
2. Developing new methodology for new design and maintenance design

Long life pavements - Threshold concept



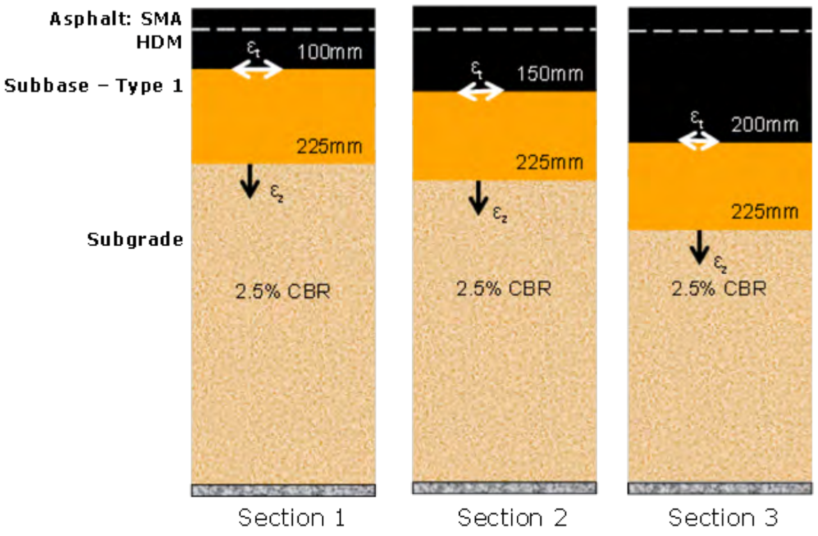
Radical pavement design project

Accelerated testing trials at TRL were designed to demonstrate the threshold concept

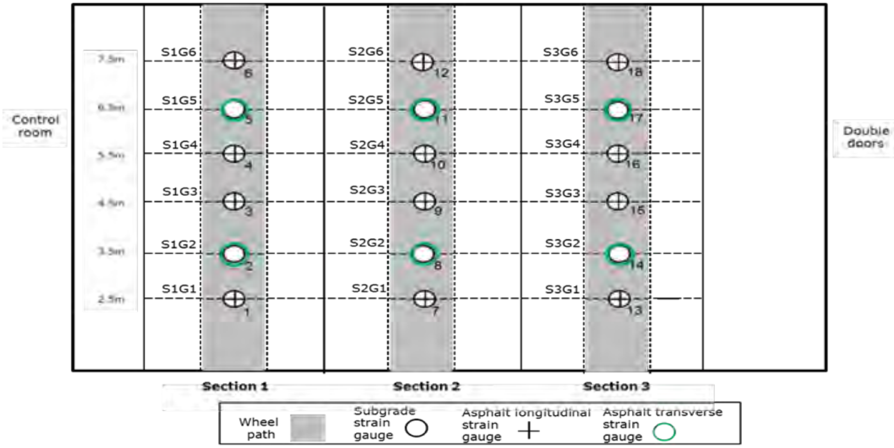
- Three asphalt pavement sections built with different thicknesses ~ 100mm, 130mm, and 180mm thick
- Trial sections were instrumented with strain gauges and monitored before, during and after trafficking
  - Subgrade and asphalt strain data
  - FWD data
  - Rutting measurements

Radical pavement design project – results

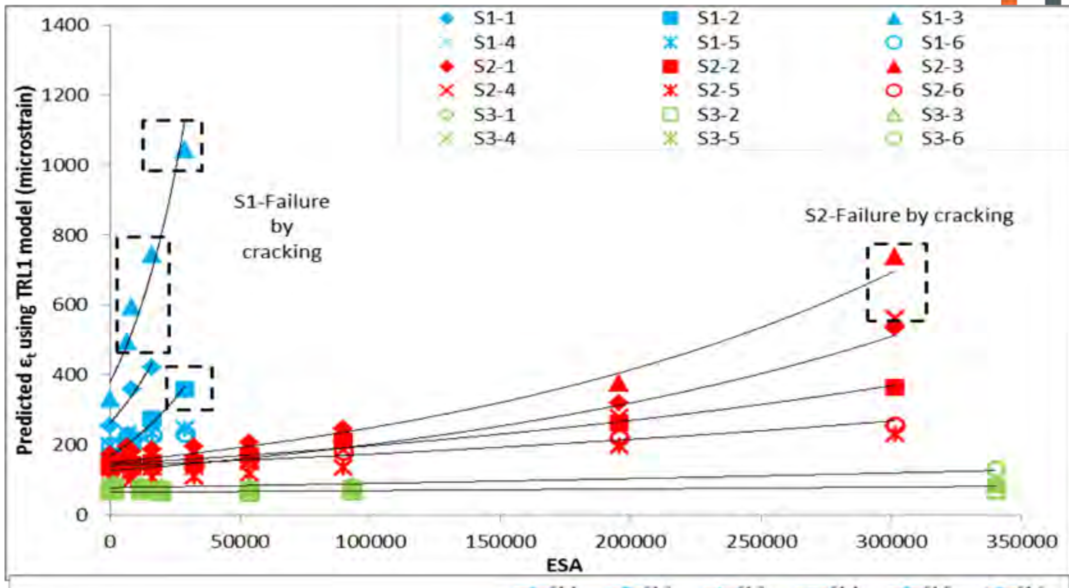
- Two pavement sections failed (100mm & 130mm) from cracking and rutting after 50,000 and 300,000 passes
- Third section showed no signs of failure after 350,000 passes
  - Strain data and FWD data showed no signs of structural deterioration
  - Rutting measurements were <5mm
  - Traffic loading increased to 65kN for the last 50,000 passes!
- A model was developed to enable us to estimate strain from FWD data
  - Allowed us to predict strains at locations where gauges were damaged from trafficking



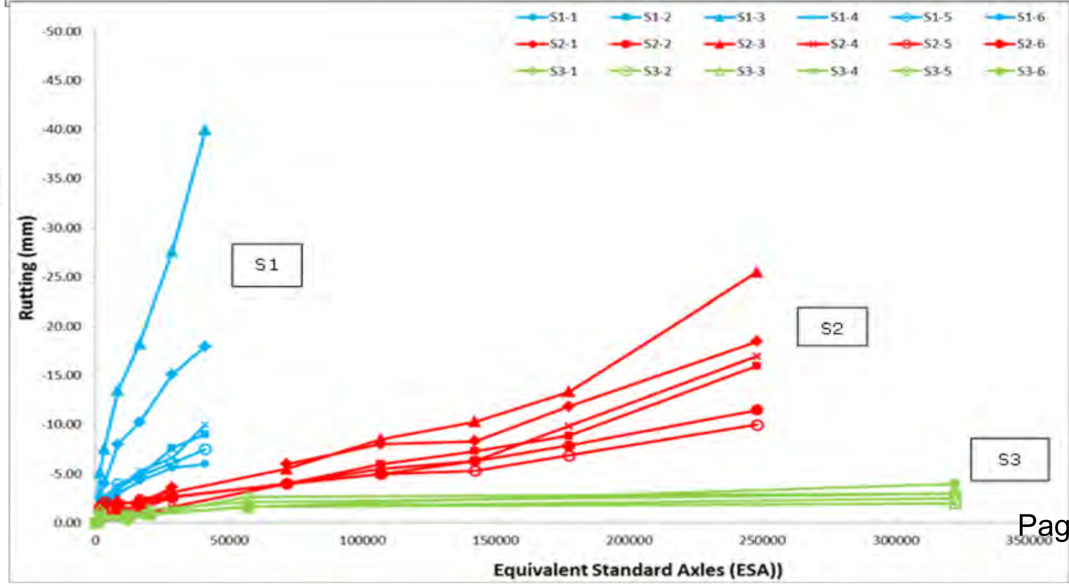
Asphalt: SMA
HDM
Subbase – Type 1
Subgrade
100mm
150mm
200mm
225mm
2.5% CBR
Section 1
Section 2
Section 3



Control room
Double doors
Section 1
Section 2
Section 3
Wheel path
Subgrade strain gauge
Asphalt longitudinal strain gauge
Asphalt transverse strain gauge



Predicted εt using TRL1 model (microstrain)
ESA
S1-Failure by cracking
S2-Failure by cracking



Rutting (mm)
Equivalent Standard Axles (ESA))
S1
S2
S3

Future opportunity: Determine threshold design strains

- Validate robustness of strain prediction models developed from TRL accelerated testing trials
  - Further comparison with FWD-back analysis methodlogy
  - Consider data from other instrumented sites (MIRA, A47 at Postwick, Norfolk)
  - Consider potential for retro-fitted strain gauges at instrumented sites and in-service pavements to provide additonal validation

- Develop a generic temperature correction methodology that accounts for changes in pavement stiffness due to temperature and age

Future opportunity: Determine threshold design strains (contd.)

- Analyse UK motorways to estimate threshold strains of LLPs
  - Review existing datasets
  - Commission additional FWD testing of identified LLP sites

- Compare FWD and TSD data on instrumented sites to further develop model that will allow the TSD to estimate the threshold parameter
  - Use TSD to estimate the threshold parameter on road network where past traffic loading and performance are known

Future opportunity: Develop methodology for new design and maintenance design

Develop minimum design thickness curves for flexible pavements

- Update HD26 and HD29/30
  - Develop risk rationale
- Scope to make improvements in the new DMRB Vol. 7 standards??

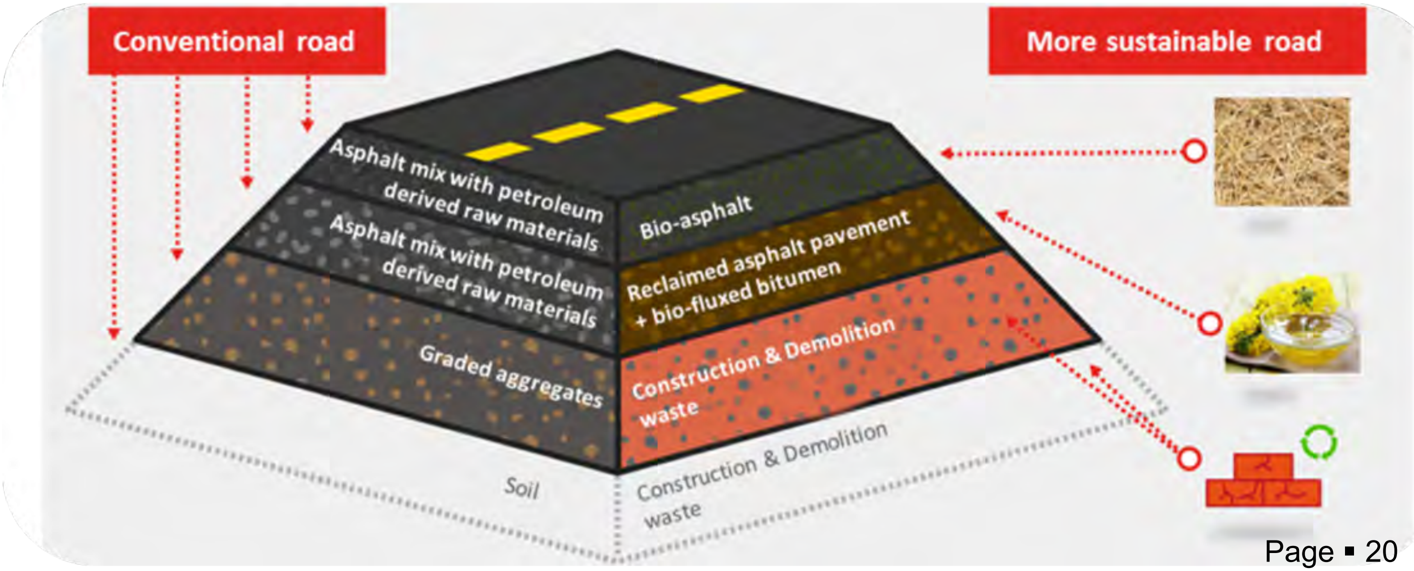
Pavement design – Future challenges and opportunities

1. Developing consistent and robust methodology for new design and maintenance design
   - Align the design and maintenance standards
2. Design and build more sustainable pavements
   - Incorporate more recycled materials
3. Effects on pavement design: Future issues
   A. Developments in vehicle technology
   B. More comprehensive monitoring

Incorporate more recycled materials

Introduction of eco-friendly materials to replace some conventional pavement materials

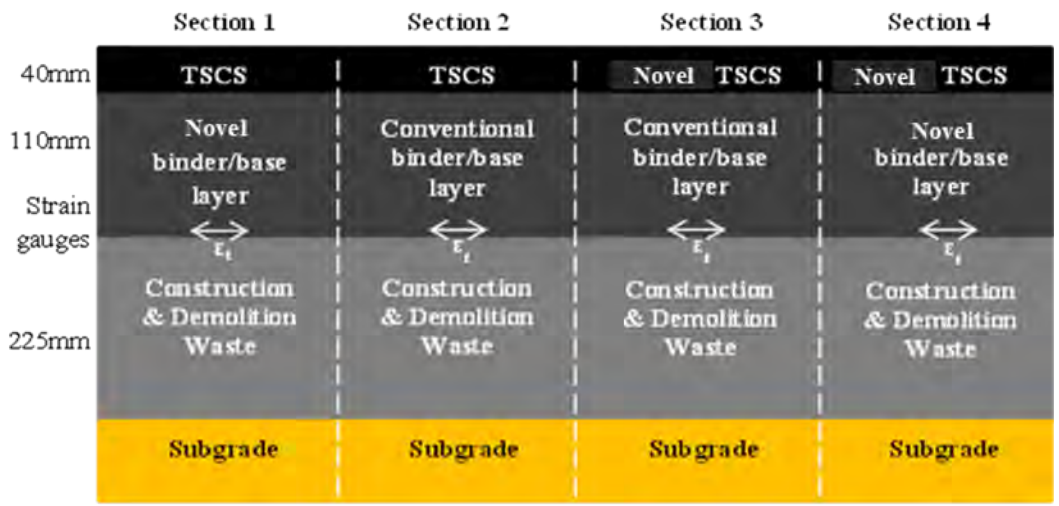
- Accelerated testing trials undertaken at TRL to demonstrate that the novel and recycled materials can perform satisfactorily in road pavements



Sustainable pavement trials – design of trial sections

Design thickness

- 150mm asphalt layer (40mm surface, 110mm binder course and base course layers)
- 225mm subbase Construction & Demolition Waste (C&DW)
- Subgrade CBR 3-3.5%
- Instrumentation



Course	Material type	Date of production	Penetration (0.1 mm)	Softening point (°C)
Novel base-binder	Asphalt concrete 20 mm dense; 40/60 straight-run bitumen; 2.5% bio-flux; 25% RAP	5th July 2016	21	60.2
Conventional base-binder	Asphalt concrete 20 mm dense; 40/60 straight-run bitumen	5th July 2016	19	65.4
Novel surfacing	Asphalt concrete 10 mm close-graded; lignin-modified binder	3rd October 2016	19	70.6

Sustainable pavement trials – construction

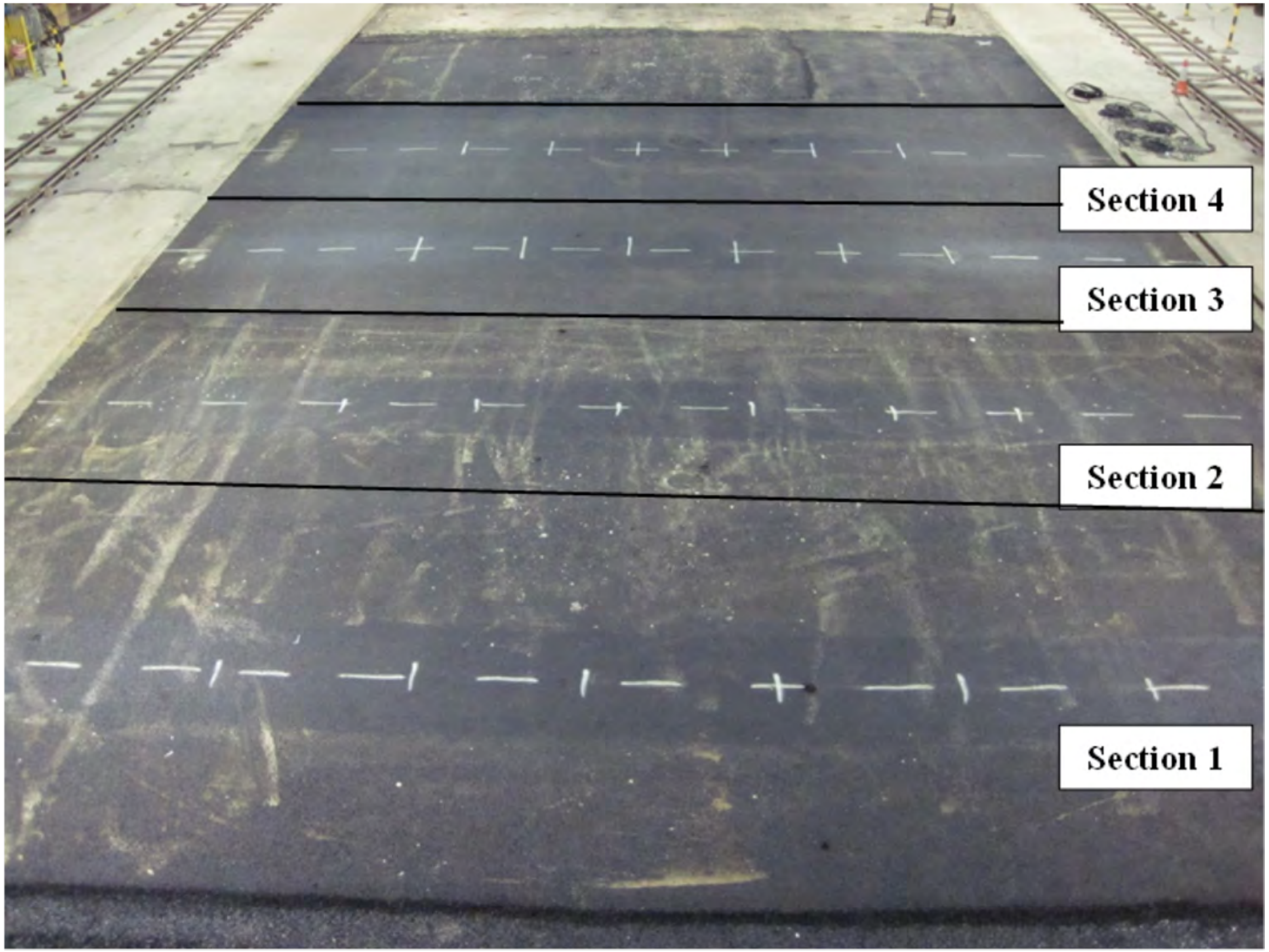
(a) Delivery of asphalt to the PTF

(b) Paving Section 1 base-binder course

(c) Conventional surface course

(d) Novel surface course

Sustainable pavement trials – plan view



Sustainable pavement trials – results

- After 151,032 wheel passes (0.54 million standard axles, msa), no damage observed
- Little or no increase in rutting
- No sign of cracking or surface deterioration
- No significant changes in FWD deflections

Sustainable pavement trials – conclusions

The trials demonstrated that the novel and recycled materials can perform satisfactorily in road pavements provided that:

- they are constructed to specification, and
- laid by experienced site operatives

Pavement design – Future challenges and opportunities

1. Developing consistent and robust methodology for new design and maintenance design
   - Improve HD26 design charts
   - Improve HD29/30 – Inlay design method

2. Improve on design and maintenance
   - Align design and maintenance standards
   - Incorporate more recycled materials

3. Effects on pavement design: Future issues
   A. Developments in vehicle technology
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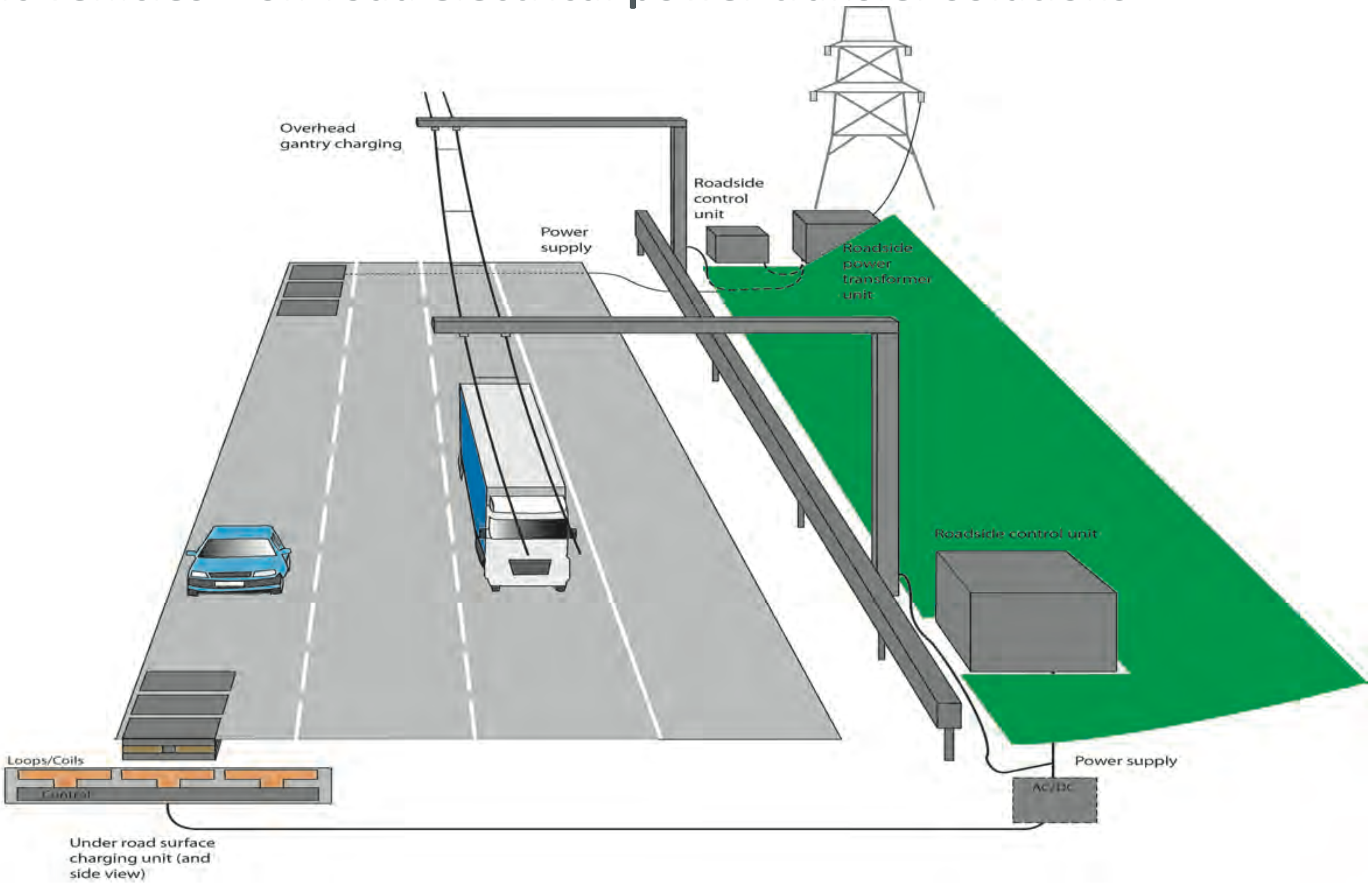
3. Effects on pavement design: Future issues

A. Future developments in vehicle technology
- Electric vehicles and on-road charging systems
- Autonomous vehicles
- Commercial HGV Platooning

B. Comprehensive monitoring of pavements
- During construction – QA/QC
- Throughout service life using traffic speed surveys and smart in-situ instrumentation

A. Future developments in vehicle technology

Electric vehicles – on-road electrical power transfer solutions



A. Future developments in vehicle technology

- Autonomous vehicles (AVs)

- HGV platooning

Summary of AV and platooning challenges

HGV platooning will concentrate loading on road pavements

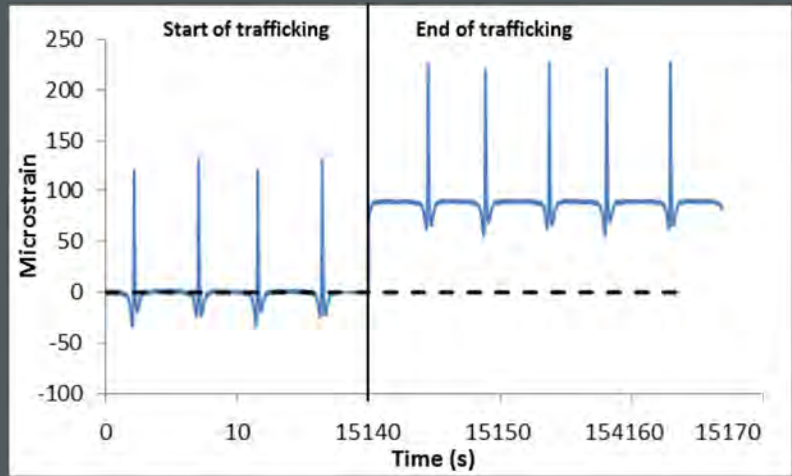
Benefits from platooning

- Improved safety
- Reduced fuel consumption (CO_2)
- Increased network capacity

Challenges

- Loss of skid resistance
- Increased rate of rut formation
- Reduced fatigue resistance

Instrumentation needed to provide the data to assess structural impacts



3. Effects on pavement design: Future issues

A. Future developments in vehicle technology

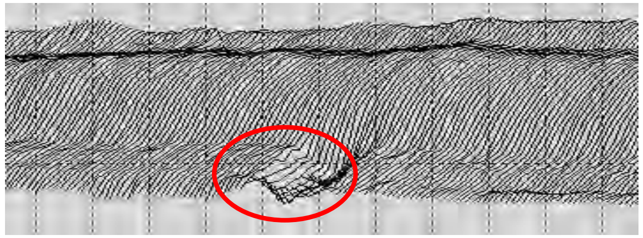
- Electric vehicles and Dynamic Wireless Power Transfer
- Autonomous vehicles
- Commercial HGV Platooning

B. Comprehensive monitoring of pavements

- During construction – QA/QC
- Throughout service life

B. Comprehensive monitoring during construction

- Rapid comprehensive compliance monitoring
  - Material composition (RFID tags)
  - Material temperature up to and including laying (RFID tags and infra-red)
  - Compaction level (instrumented rollers)
  - Layer thicknesses and densities (LIDAR and GPR)
  - 3D surface profiles for ride comfort, wet friction, noise, rolling resistance etc. (LIDAR, laser profilers)
  - Structural strength of all layers (TSD)



B. Comprehensive monitoring during in-service

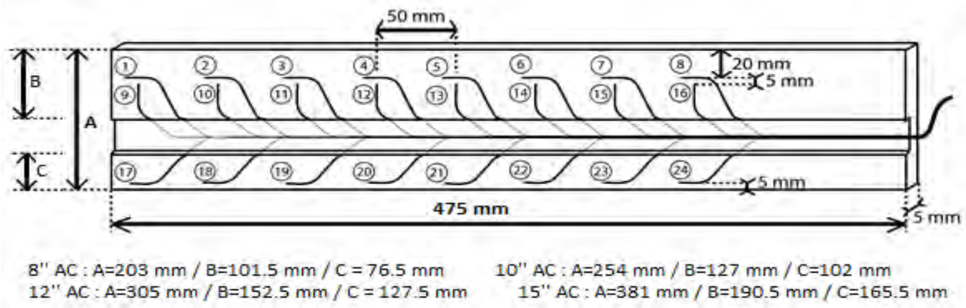
In-situ monitoring – retro-fit gauges

Either:

- Remove core
- Add conventional strain gauges
- Replace core

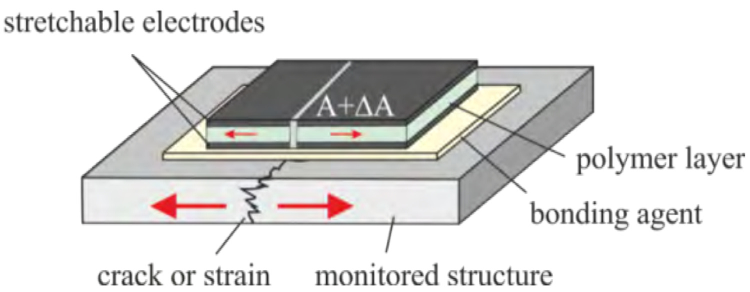
Or:

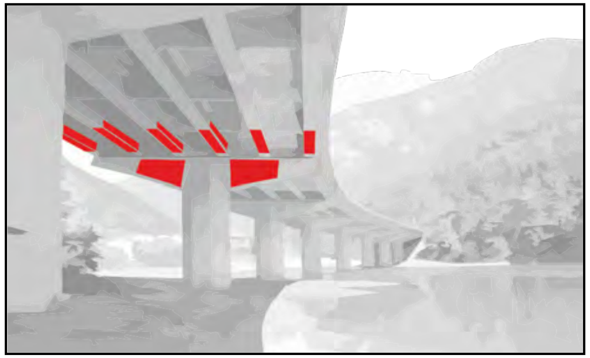
- Remove core or cut slot
- Add fibre optic gauges
- Replace core or fill slot



Towards intelligent infrastructure

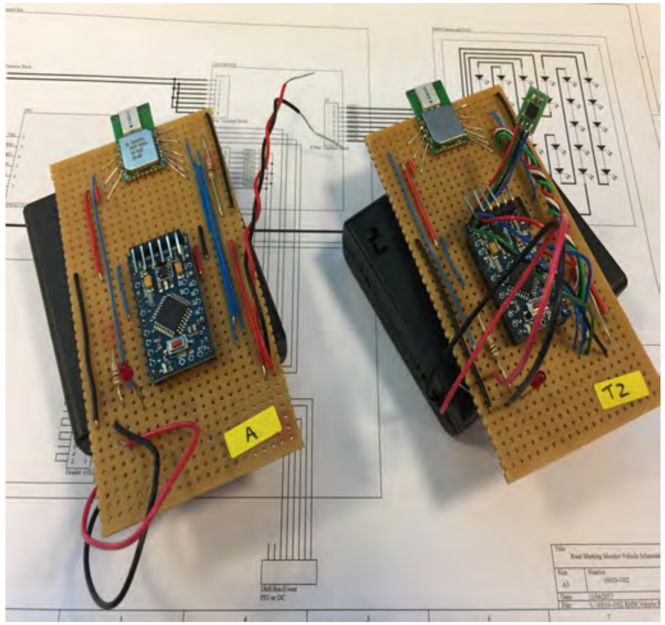
Assets should monitor their own health





Towards real-time alerting using technology that is:

- Robust
- Low cost
- Easy to implement
- Self powered (so low power consumption)
- On board processing
- Connected (central cloud storage / analysis with data delivered to users)

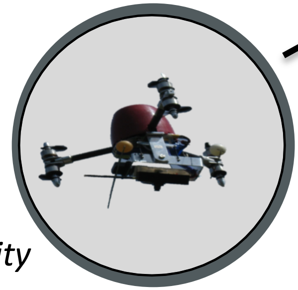


Combination of inputs for enhanced monitoring

Fixed sensors
- *Strain*
- *Scour*
- *Slope stability*
- *Pollutant levels*

Construction record
- *As laid construction*
- *Materials / suppliers*
- *Conditions*

Floating car data
- *Noise*
- *Ride quality*
- *Grip / temperature*
- *Damaged / missing inventory*
- *User information*



Mobile specialist surveys
- *Surface aging*
- *Deflection / structural capacity*
- *Component assessment*

Remote observation
- *Asset inventory*
- *Visual condition*

Comprehensive, real-time asset data

User information
Operational performance
Maintenance planning
Risk assessment

Effective decisions

Overall conclusions

With any challenge there is an opportunity to improve the way we do things

- Recent findings from research studies suggests the way forward
  - Aligned new design and maintenance methodologies will enable a more robust approach
  - Deflection-strain model can be used as a tool to evaluate the UK road network – database of strains associated with LLPs
    - Useful reference to evaluate impact of HGV platooning
- Pavement condition monitoring is good – can it be improved?

Thank you

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