# Performance Evaluation of High Recycled Asphalt Surfacing on the Transport for London Road Network

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# CONTENTS

# Introduction

- Increased levels of RAP in surface courses makes better use of high-quality aggregate with high polished stone value (PSV) levels, and reduces resource demand and minimises transportation costs.
- In the UK, 10% RAP has been successfully is incorporated into surface course materials as for a considerable time with the latest standards allowing up to 20%.
- TfL have been instrumental in delivering innovative high RAP content surface course trials and commissioned this research to review their performances to date.

Use of recycled asphalt

Embodied carbon of bitumen

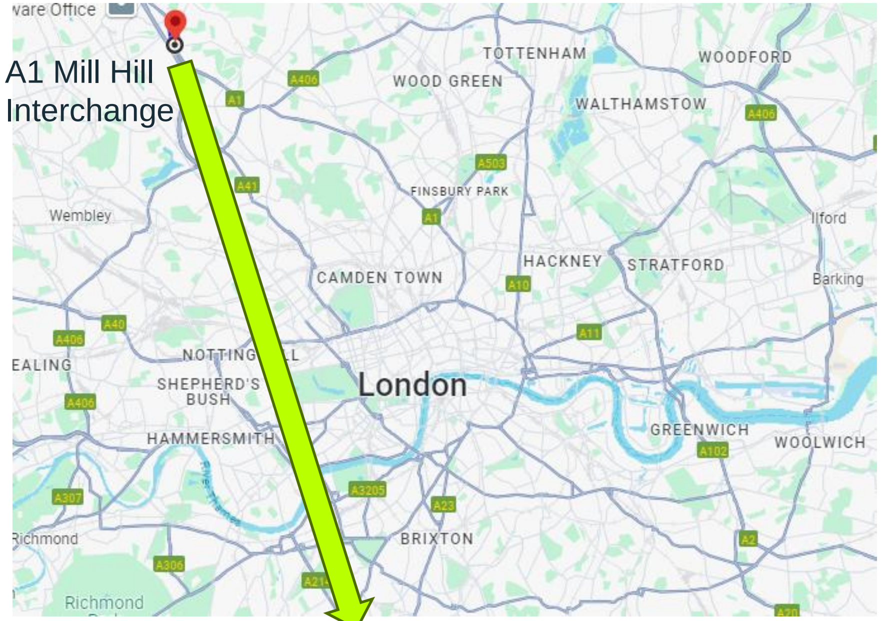
Return haulage of materials

# Project Objectives

- Trials installed in 2016 and 2017 on the A1 Mill Hill Interchange and A40 Westway with control sections installed to compare performance.
- The objective of this project is to investigate how the addition of high proportions of RAP content affects the long-term durability and key performance characteristics of asphalt surfacing mixes.
- These sites have now been in service for at least 7 years and an evaluation of performance at this stage will help evaluate the future viability of such surface courses and their future recyclability.

# A1 Mill Hill

- A1 Mill Hill Interchange trials laid in March 2016
- FM Conway (now Heidelberg Materials) surfacing
  - ❖SMA 14 SurePhalt PMB with 50% RAP
    - 50% RAP + PMB Binder + Sylvaroad rejuvenator
    - Lanes 1-2 ~180m
  - ❖SMA 14 SurePhalt PMB control (No RAP)
    - Lanes 1-3 ~340m

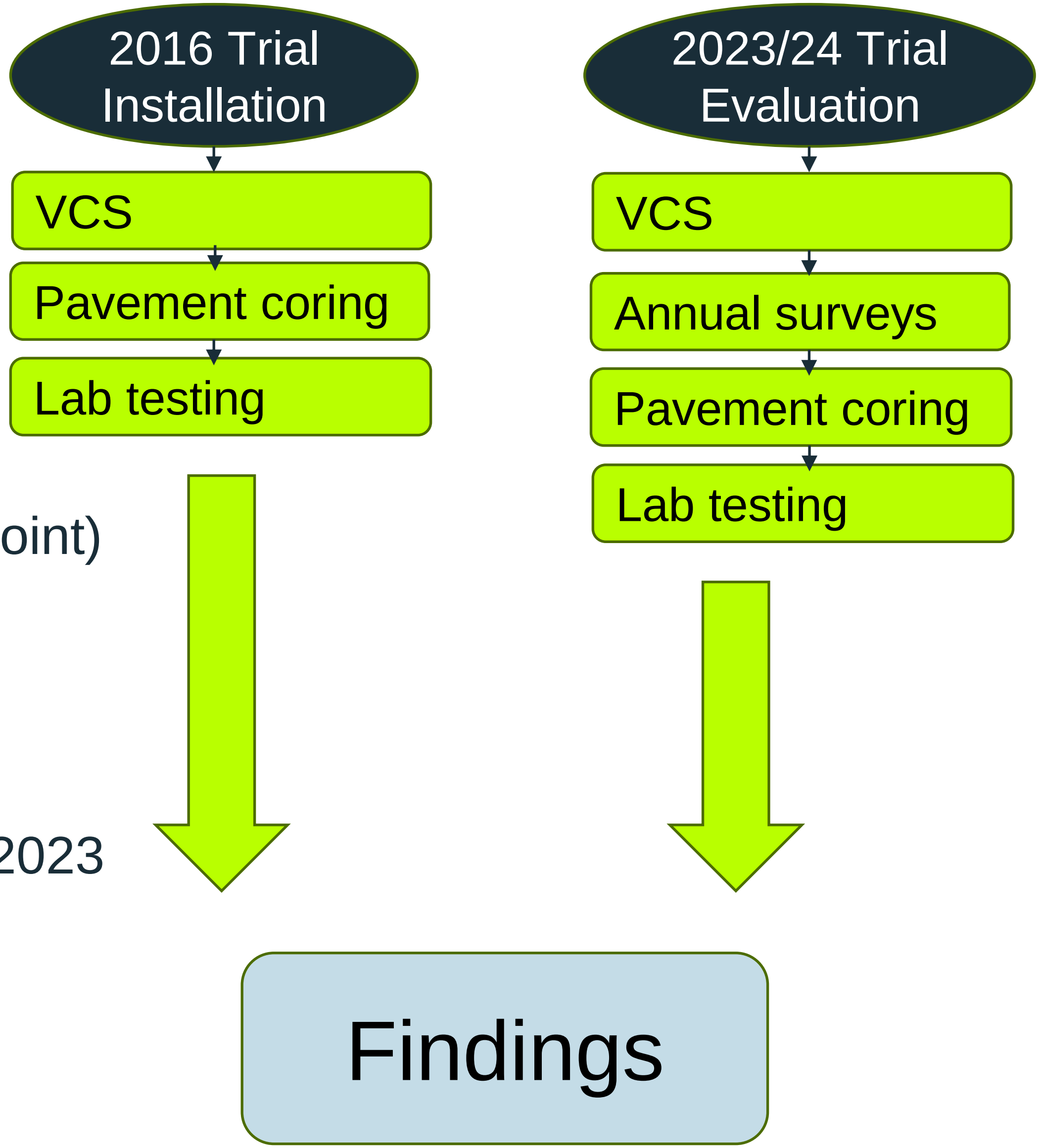



# A40 Westway

- TfL and FM Conway undertook a surface course trial containing 50% RAP in September 2017 on the A40 Westway.
- The trial comprised of FM Conway SMA 14 Surepave with 50% RAP laid in a single layer at a depth of 70mm and a control 50mm SMA 10 with no RAP was also laid.

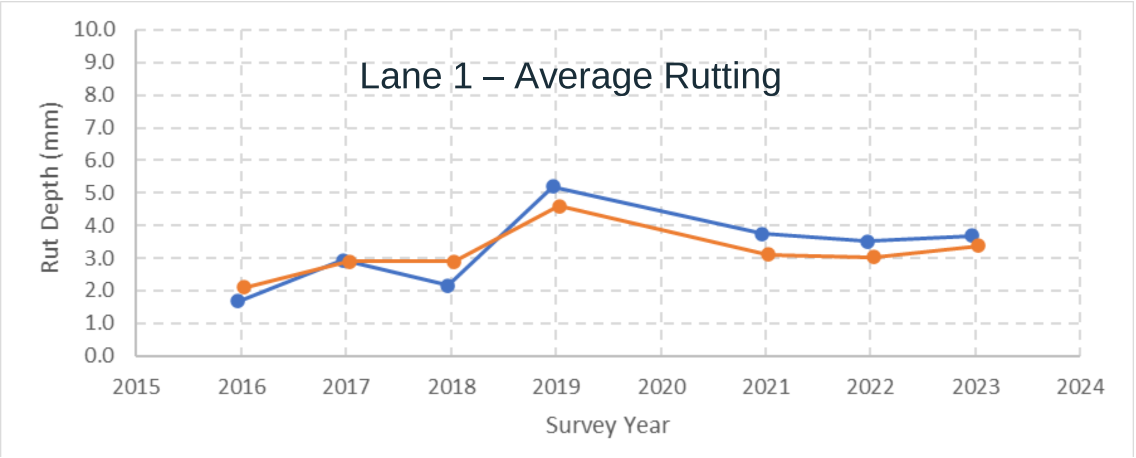

# Technical Methodology

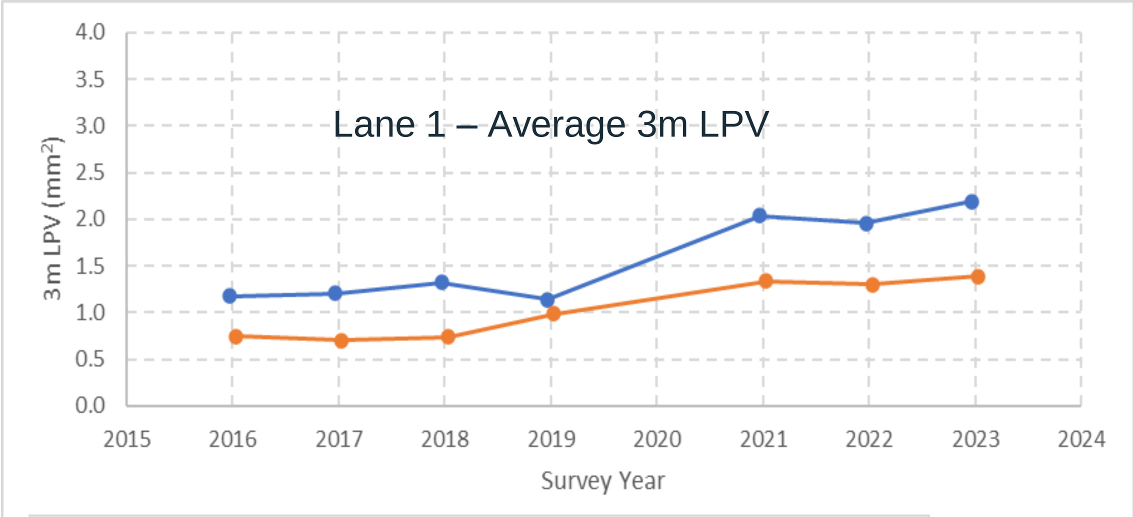
- At installation
  - ❖Visual Condition Survey (VCS)
  - ❖Pavement coring
  - ❖Laboratory testing
    - o Binder content and aggregate grading
    - o Binder Recovery (Penetration & Softening Point)
    - o Dynamic Shear Rheometer (DSR)
- 2023/24
  - ❖VCS
  - ❖Annual traffic speed survey analysis from 2016-2023
    - o SCANNER & SCRIM
  - ❖Pavement coring
  - ❖Laboratory testing

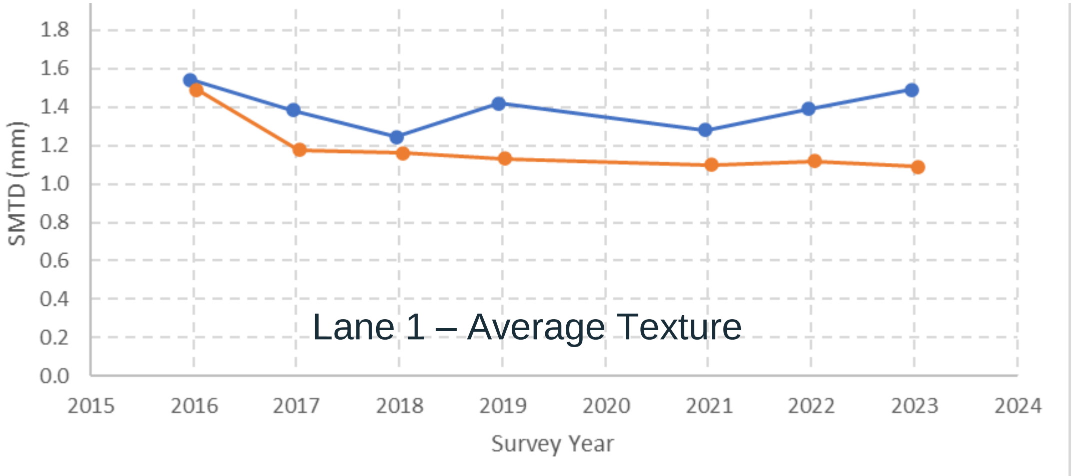


# SCANNER – Annual Survey Data Review

- SCANNER parameters (rutting, texture, longitudinal profile variance (LPV)) – No significant change observed



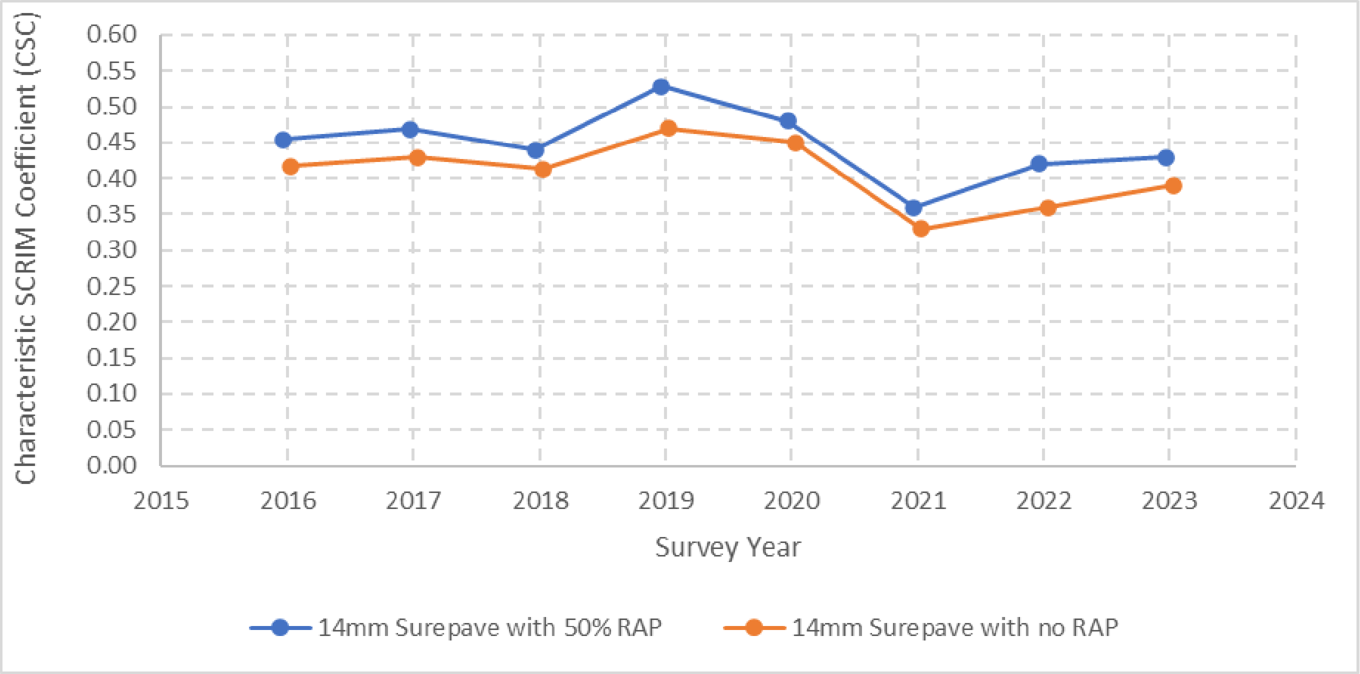


14mm Surepave with 50% RAP
14mm Surepave with no RAP

# SCRIM® – Annual Survey Data Review

- SCRIM
  - Characteristic SCRIM Coefficient (CSC)
  - Mean CSC gradually reduced over time with some variation between years.
  - Mean CSC is currently above the IL (0.40) for the 14mm SurePhalt with 50% RAP (0.43) compared to the control (0.38) in 2023.

Lane 1 – Mean CSC

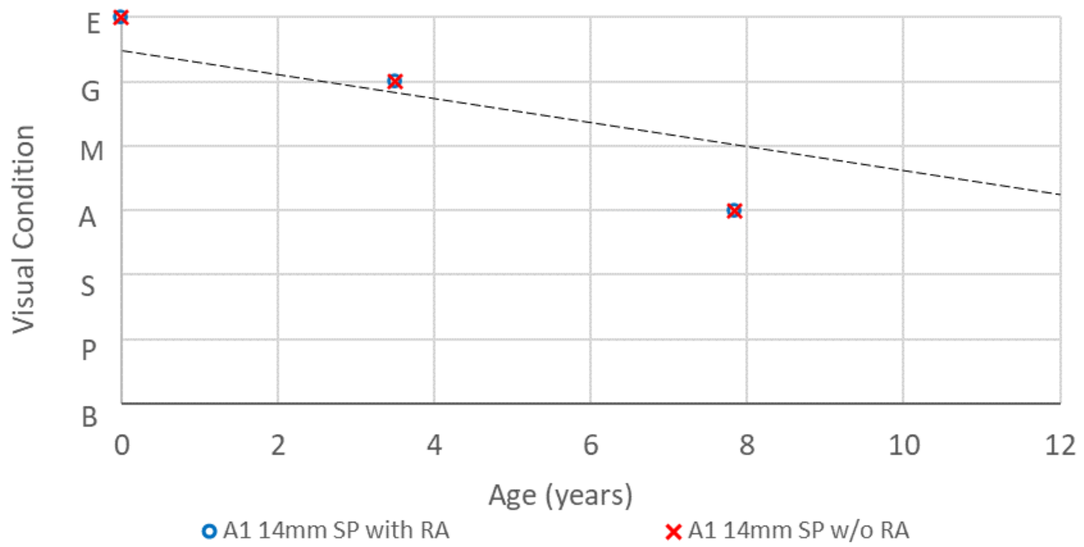


# Visual Condition Survey

- 2019 VCS shows both 50% RAP & Control sites = G (Good)
- Both sites had visibly good texture with no defects associated with the surface course
- Defects observed limited to transverse reflection cracks associated with the underlying hydraulically bound base (HBM)

# Visual Condition Survey

- 2024 Traffic speed VCS using 4k Video survey
  - ❖ Surface condition rating using the 7-point scale (E=Excellent, G=Good, M=Moderate, A=Acceptable, S=Suspect, P=Poor and B=Bad) developed by Carswell et al. (2012)
- VCS shows 50% RAP & Control sites = **A (Acceptable)**
  - ❖ Minor fretting
  - ❖ Longitudinal & transverse cracking present (due to HBM)




# Laboratory Testing – 2018 Study

- Flint & Bailey (2018) documented laboratory testing of samples taken at installation:
  - ❖Binder content and aggregate grading;
  - ❖Blending analysis - Comparison of aged binder using Rolling Thin Film Oven (RTFO) & Pressure Ageing Vessel (PAV)
  - ❖Binder Recovery & Analysis (Pen & SP)
  - ❖DSR

# Laboratory Testing – 2018 Study

- Flint & Bailey (2018) concluded:
- “Results shows that there does not appear to be any adverse ageing effects for the binder recovered from mixture 16-2963 (50% RAP) due to the high percentage of RAP with the softening (rejuvenating) influence of the Sylvaroad additive being maintained for the recovered binder before and after PAV ageing.”
- “Both binders recovered from SurePhalt mixtures show very similar trends in terms of the degree and nature of the change in complex modulus and phase angle during DSR testing suggesting that the addition of high RAP levels with rejuvenator have not had a detrimental effect on the ageing properties of the binder.”

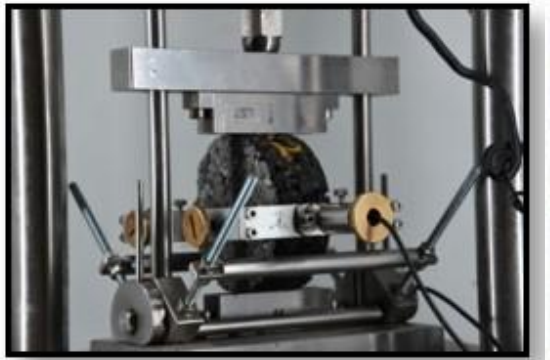
Recovered Binder Properties (Flint and Bailey, 2018)

| Recovered Binder | Ageing | Pen @20˚C (dmm) | SP (˚C) | DSR Predicted Pen (dmm) | DSR Predicted SP (˚C) |
|---|---|---|---|---|---|
| 14mm SurePhalt, 50% RAP, PMB and Sylvaroad | Unaged | 44 | 56.8 | 37 | 60 |
| | After PAV | 32 | 61.4 | 24 | 65 |
| 14mm SurePhalt, Control | Unaged | 37 | 68.4 | 32 | 64 |
| | After PAV | 22 | 68.0 | 20 | 70 |

# 2024 Pavement Investigation & Lab Testing

- Jean LeFebvre UK (JLUK) extracted 18 cores for testing in January 2024.
- Mixture performance testing:
  - ❖ Particle Size Distribution BS EN 12697-2
  - ❖ Binder Content - BS EN 12697-1
  - ❖ Indirect Tensile Stiffness Modulus (ITSM) - BS EN 12697:26
  - ❖ Wheeltracking - BS EN 12697-22 Procedure B @60°C
  - ❖ Water Sensitivity testing - BS EN 12697-12 Method A
  - ❖ Torque bond testing - MCHW Clause 951 (In Situ Test)

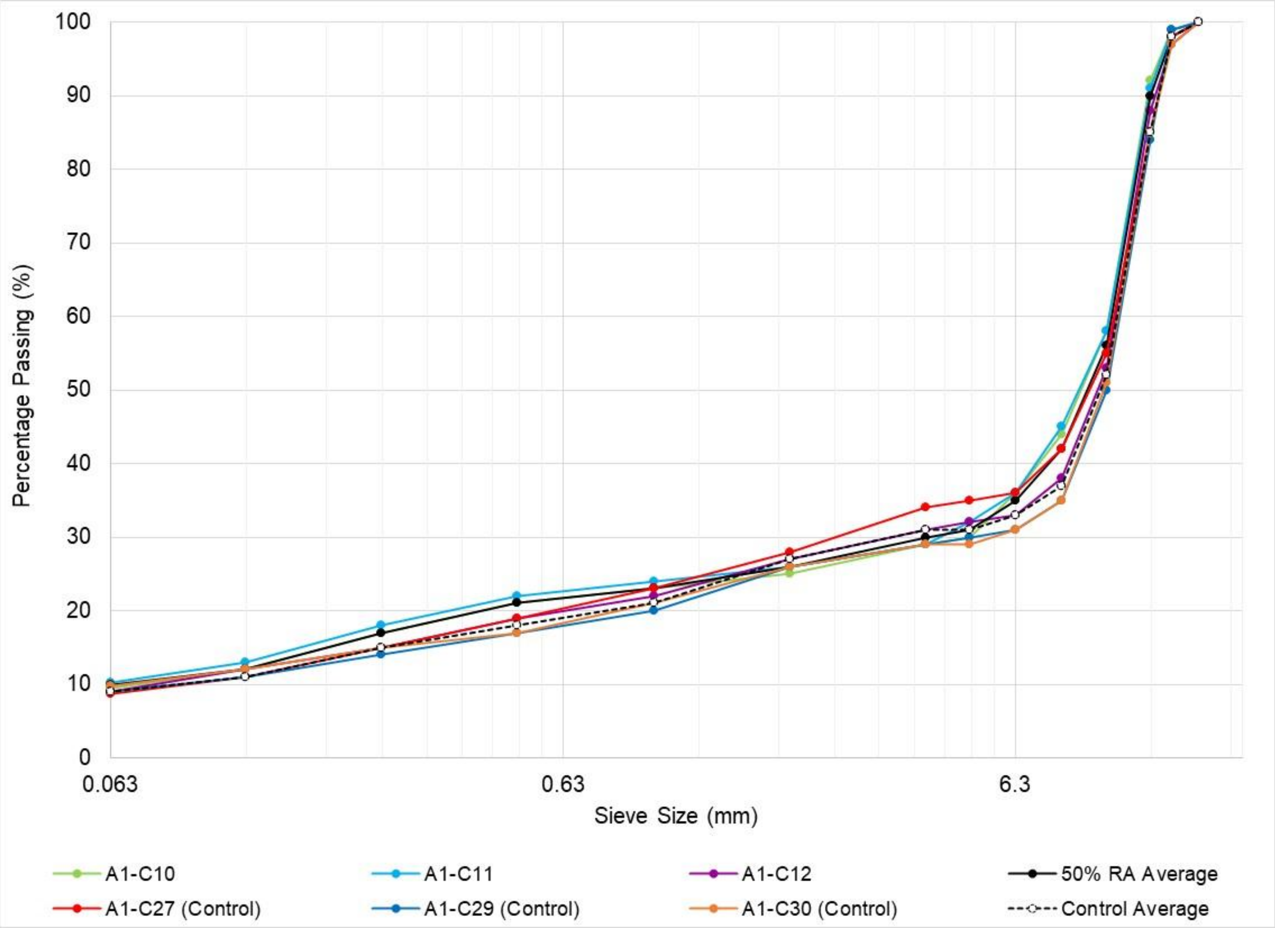

- Recovered binder performance testing:
  - ❖ Binder recovery - BS EN 12697-3
  - ❖ Penetration (Pen) - BS EN 1426
  - ❖ Softening Point (SP) - BS EN 1427
  - ❖ Dynamic Shear Rheometer (DSR)
  - ❖ Linear Amplitude Stress (LAS)



# Bituminous Mixture Testing – 2024

- Particle size distribution results show comparable grading curves
  - ❖ Indicates the supplier protocols for processing and production of the RAP
- Recovered Binder content
  - ❖ 14mm SurePhalt with 50% RAP = Mean 5.1%
  - ❖ Control = Mean 5.7%
  - ❖ Target binder content = 5.5% (±0.5%)

**Particle Size Distribution**




**Soluble Binder Content (%)**

| 14mm SurePhalt with 50% RAP | | | | St. Dev. | 14mm SurePhalt with no RAP (Control) | | | | St. Dev. |
|---|---|---|---|---|---|---|---|---|---|
| C10 | C11 | C12 | Avg. | | C27 | C29 | C30 | Av | |
| 4.8 | 4.7 | 5.9 | 5.1 | 0.67 | 6.1 | 5.9 | 5.1 | 5.7 | 0.53 |

# Bituminous Mixture Testing – 2024

- <u>Water Sensitivity</u> results show all trial sections continue to significantly exceed requirement for Thin Surface Course Systems (TSCS) as defined by MCHW Clause #942, ITSR$_{min70}$

**Water Sensitivity**

| Bituminous Mixture | Air Void Content (%) | Indirect Tensile Strength – Dry Subset (kN) | Indirect Tensile Strength – Wet Subset (kN) | ITSR (%) |
|---|---|---|---|---|
| **14mm SurePhalt with 50% RAP** | 10.3 – Dry<br>9.7 – Wet | 733 | 615 | 83.87 |
| **14mm SurePhalt with no RAP (Control)** | 5.4 – Dry<br>5.9 – Wet | 1,267 | 1,095 | 86.43 |

**Torque Bond Results**

| Bituminous Mixture | Core Ref | Nearside White Line Offset (mm) | Bond Strength/Observation |
|---|---|---|---|
| **14mm SurePhalt with 50% RA** | 13 | 1000 | >400kPa - Pass |
| | 14 | 1150 | >400kPa - Pass |
| | 15 | 1570 | >400kPa - Pass |
| | 16 | 1860 | >400kPa - Pass |
| | 17 | 1950 | >400kPa - Pass |
| | 18 | 2325 | >400kPa - Pass |
| **14mm SurePhalt with no RA (Control)** | 31 | 970 | >400kPa - Pass |
| | 32 | 1220 | >400kPa - Pass |
| | 33 | 1615 | >400kPa - Pass |
| | 34 | 1760 | >400kPa - Pass |
| | 35 | 1900 | >400kPa - Pass |
| | 36 | 2220 | >400kPa - Pass |

- <u>Torque Bond testing</u> (In situ) demonstrate both surfaces exceed the 400kPa requirements defined in MCHW Clause 951

# Bituminous Mixture Testing – 2024

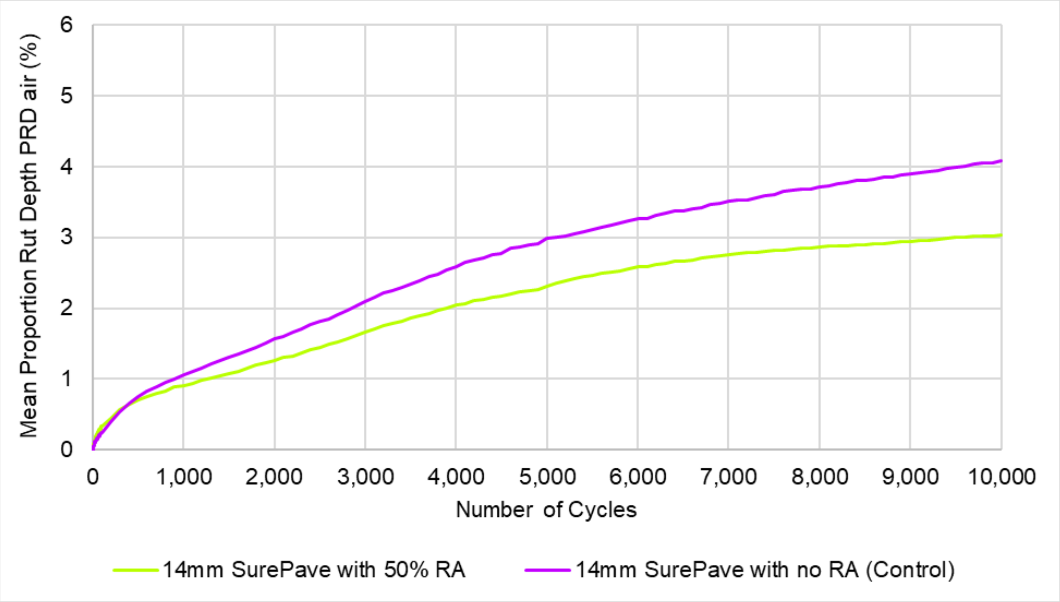
- ITSM results show the Control has a higher stiffness than the 14mm SurePhalt with 50% RAP
  - ❖ Note that the results were based on laboratory prepared specimens
- Wheeltracking
  - ❖ All results complied with PD 6691 Table B.4 requirements for "Very heavily stressed sites requiring very high rut resistance" i.e. $WTS_{AIR}<0.8$

**Indirect Tensile Stiffness Modulus**

| Bituminous Mixture | Air Void Content (%) | Mean Indirect Tensile Stiffness Modulus (MPa) | Standard Deviation |
|---|---|---|---|
| 14mm SurePhalt with 50% RAP | 8.7 – 10.7<br>Average (10.0) | 3,033 | Air voids – 0.8<br>ITSM – 472 |
| 14mm SurePhalt with no RAP (Control) | 4.7 – 6.4<br>Average (5.6) | 4,488 | Air voids – 0.7<br>ITSM – 173 |

| Bituminous Mixture | Air Void Content (%) | Mean wheel track slope ($WTS_{AIR}$ mm per $10^3$ load cycle) | Mean Proportion Rut Depth PRDair (%) | Mean Rut Depth RD at 10,000 Cycles (mm) | Standard Deviation at 10,000 cycles (-) |
|---|---|---|---|---|---|
| 14mm SurePhalt with 50% RAP | 9.0-9.3 | 0.06 | 3.03 | 1.20 | 0.33 |
| 14mm SurePhalt with no RAP (Control) | 3.7-5.0 | 0.09 | 4.07 | 1.60 | 0.75 |

**Wheeltracking**



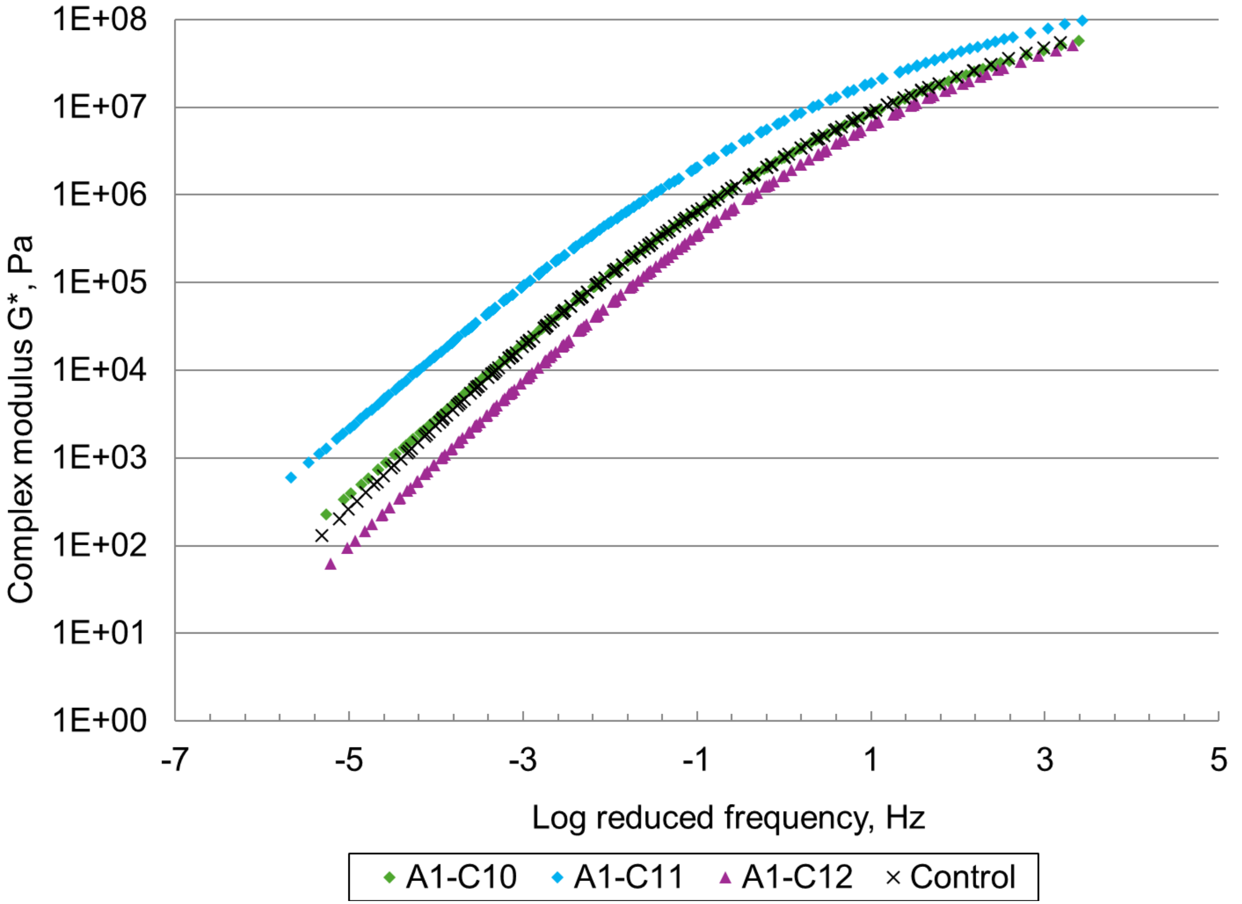
# Recovered Binder Analysis – 2016 vs. 2024

- Pen & SP Results 2016-2024
  - Reduction in average Pen for 50% RAP & Control
  - Increase in average SP for 50% RAP, decrease in Control
    - ❖ Some variability in individual 50% RAP sample results
    - ❖ Overall average 2024 Pen & SP ≈ Control

| Bituminous Mixture | 2016 Pen @20˚C | 2024 Pen. @20˚C | Av Δ Pen. | 2016 SP (˚C) | 2024 SP (˚C) | Av Δ SP (˚C) |
|---|---|---|---|---|---|---|
| **14mm SurePave with 50% RAP** | 44 | 14 – 38<br>Average (**26**) | **-18** | 56.8 | 56.0 - 72.8<br>Average (**64.5**) | **+7.7** |
| **14mm SurePave with no RAP (Control)** | 37 | 21 – 29<br>Average (**25**) | **-12** | 68.0 | 60.0 - 64.6<br>Average (**61.9**) | **-6.1** |

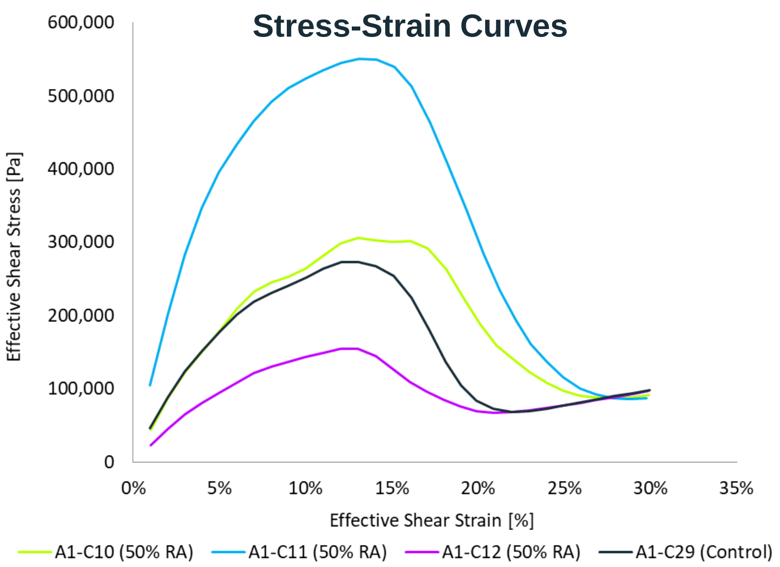
# Recovered Binder Analysis

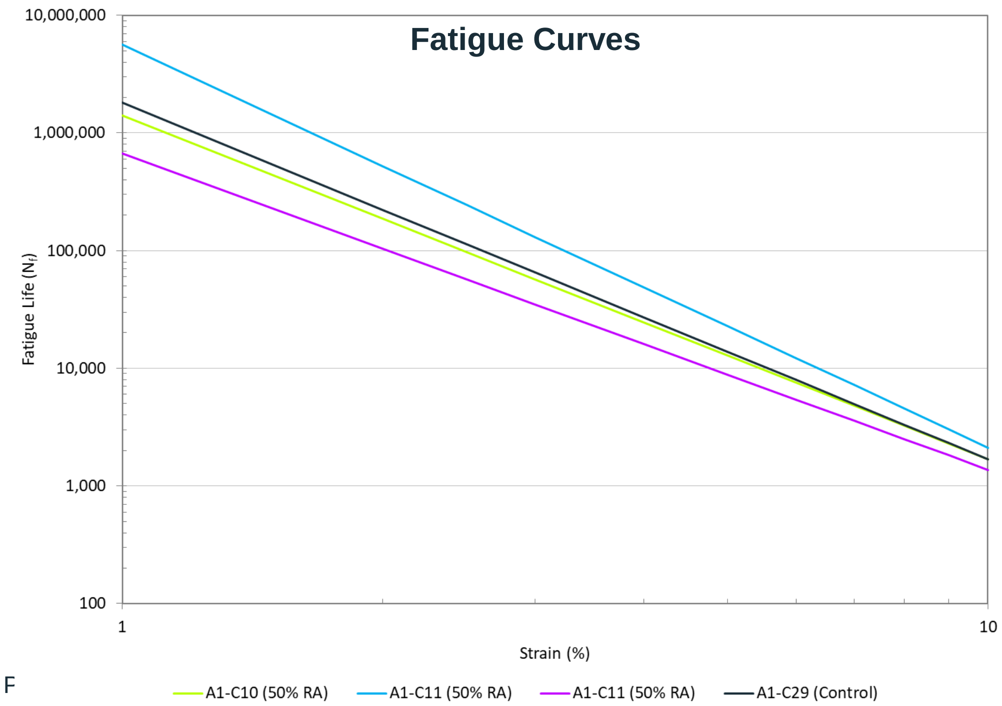
- Dynamic Shear Rheometer (DSR) - 2024
  - Complex modulus master curves
    - C10 & Control G* master curves overlap – Equivalent behaviour
    - C11 shows higher G* at low & high reduced frequencies – potentially better rut resistance (at high temp) and potentially reduced low temperature performance
    - C12 shows lower G* at low & high reduced frequencies

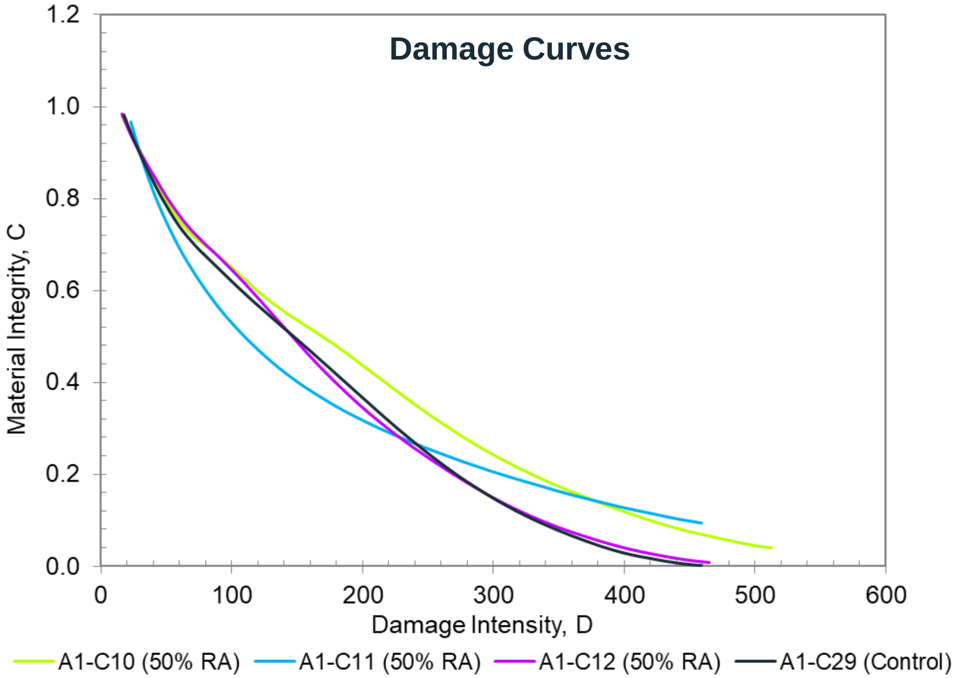


# LAS Analysis

- Fatigue Curves
  - 50% RAP: C10 ≈ Control, C11 & C12 show more variable results
- Damage curves
  - Show accumulated damage intensity at failure (D). Greater the D value, better the fatigue resistance
  - All samples show similar D values (D ≈ 459) except A1-C10 (D=512)



# A1 Performance Evaluation

- As of 2023, trial sections VCS = ‘Acceptable’ condition
- SCANNER & SCRIM show no significant differences in performance parameters for both sections
- Laboratory testing shows:
  - Comparable results for particle size distribution, wheeltracking, water sensitivity and torque bond
  - Similar trends in degree and nature of the change in complex modulus and phase angle, and fatigue performance
  - Slight differences in recovered binder content, air voids, and ITSM
  - A degree of variability in individual samples, which reflects variable nature of high percentage RAP

# Summary of A1 Findings

- In-service surfacing condition for Control & 50% RAP mix: VCS = acceptable condition after 7 years' service
  - 2024 annual traffic speed survey data confirms VCS findings & shows **no significant difference** in surface condition between Control & 50% RAP trial sections
- Laboratory testing showed mostly similar results in terms of materials and binder behaviour
  - Supports the findings from the in-service condition assessment.
  - This is encouraging for the continued application of surfacings with high RAP content when subject to specific quality protocols.
- The site trial will continue to be monitored through annual traffic speed surveys.

# Acknowledgements

- Special thanks to the following organisations for supporting this project

Transport for London — Every Journey Matters
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# thank you