Cold In-Situ Recycling Process – A1 Newton on the Moor

Overview

- Site Selection
- Optioneering report
- Design process
- Compliance testing
- Ongoing testing

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Trial Site

- A1 Newton on the Moor to West Cawledge
- Site length – 5265m, lanes 1 and 2
- Homogeneous Sections – 4 sections, lane 1 0m – 3010m, 3010m – 5265m, lane 2 0 – 3310m, 3310m – 5265m
- Mixes – Two CIR mixes used, same addition %s
- Depths – first sections 200mm, second sections 220mm (after pre-planing 60mm to remove surface course)

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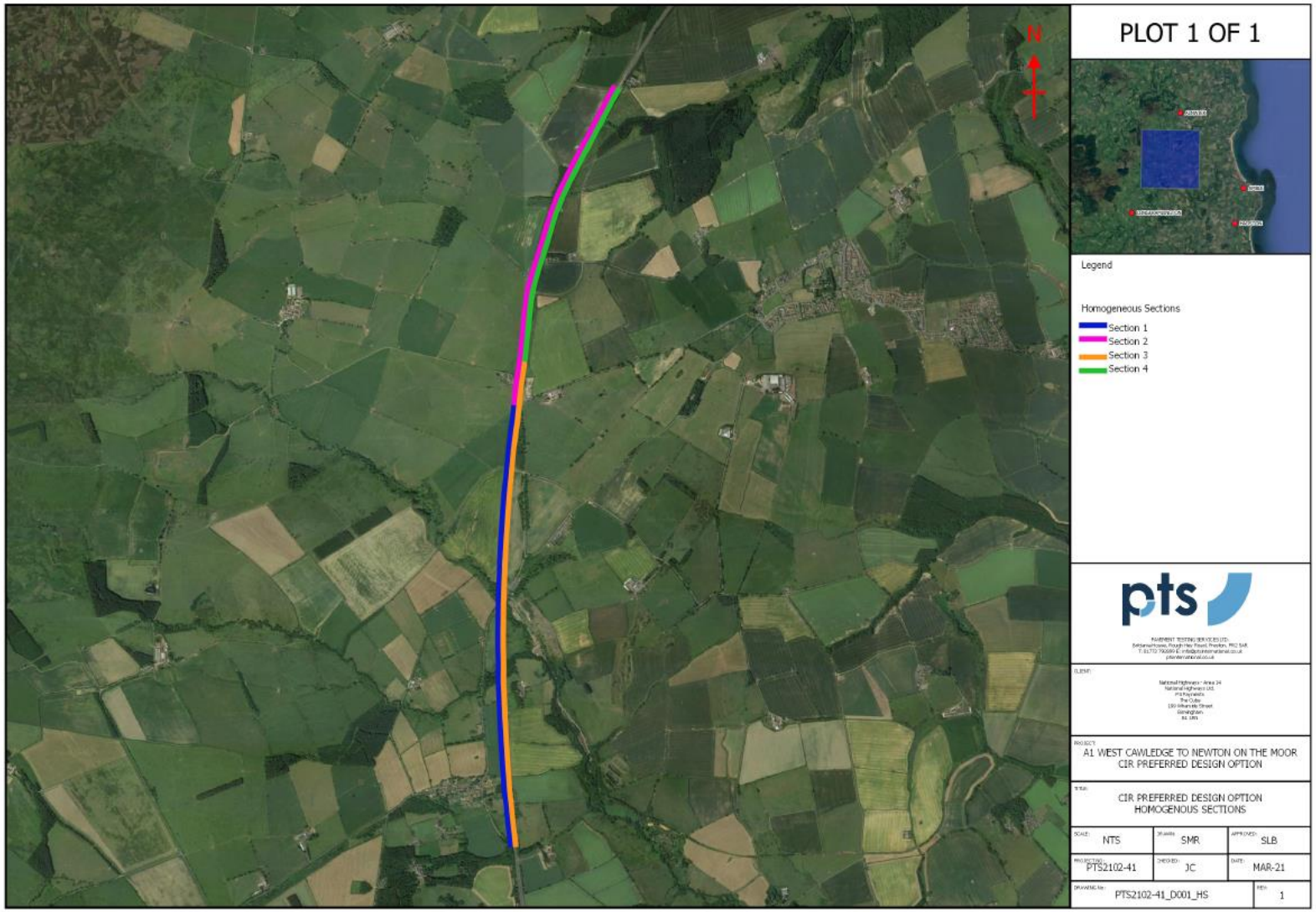
Trial Site

- Homogeneous sections



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Site Selection – Multi Functional Vehicle

- Visual Condition Survey – degradation, depth of structural issues
- Use of MFV – Multi Functional Vehicle, SCANNER and LCMS2 lasers

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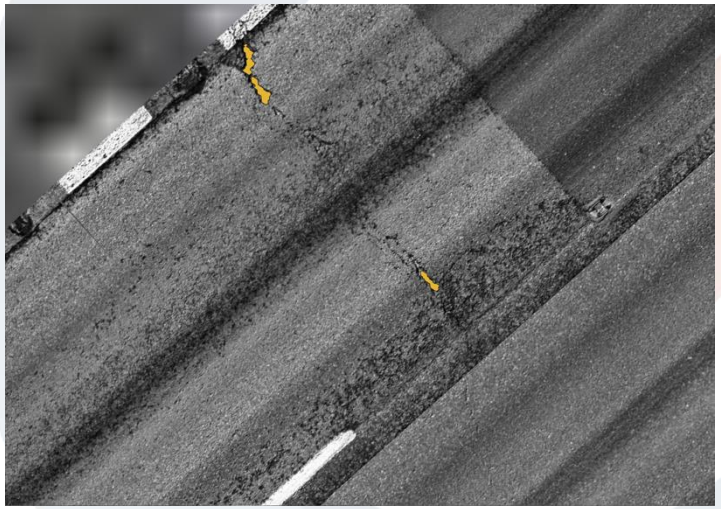
Site Selection – Multi-Functional Vehicle

- Visual Condition Survey – degradation, depth of structural issues
- A1 – Cracking, bumps, swell, potholes, rutting, ravelling all noted on site



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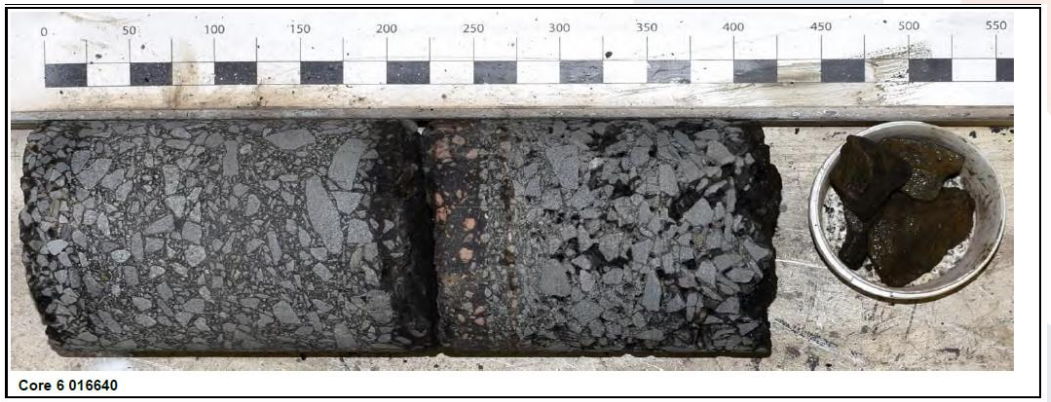
Site Selection - Coring

- Coring – Material depths, material quality, tar content
- A1 - De-bond running throughout at approximately 220mm in both lanes
- Deteriorated material
- Tar bound material at lower depths
- Dynamic Cone Penetrometer (DCP) tests indicate good foundation with high CBR values



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Site Selection – 3D GPR

- Ground Penetrating Radar – Frequency sweep allows range of depths to be clear, full carriageway covered
- 3D GPR – Construction depths, homogenous sections, pavement condition utilities, any unknowns

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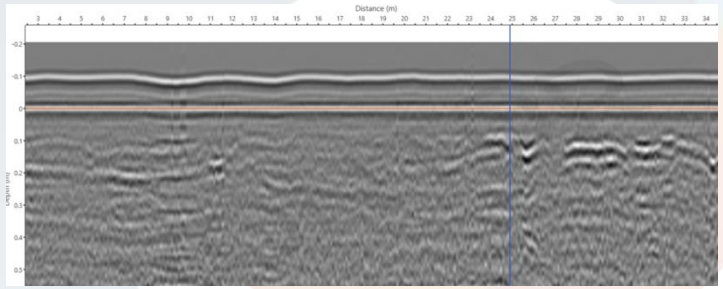
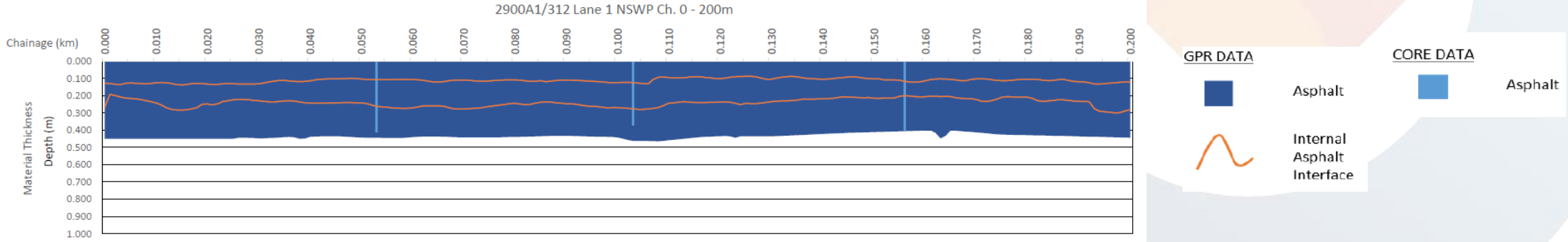
Site Selection – 3D GPR

- 3D GPR – Construction depths, homogenous sections, pavement condition utilities, any unknowns
- A1 – Clear interface at approximately 220mm running the length of the site
- Deteriorated material throughout
- GPR correlates with coring survey
- Gas main running through site





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Site Selection – Falling Weight Deflectometer

- FWD – Material stiffness, pavement load capacity, foundation quality
- Uses known load applied and material depths to produce material stiffnesses

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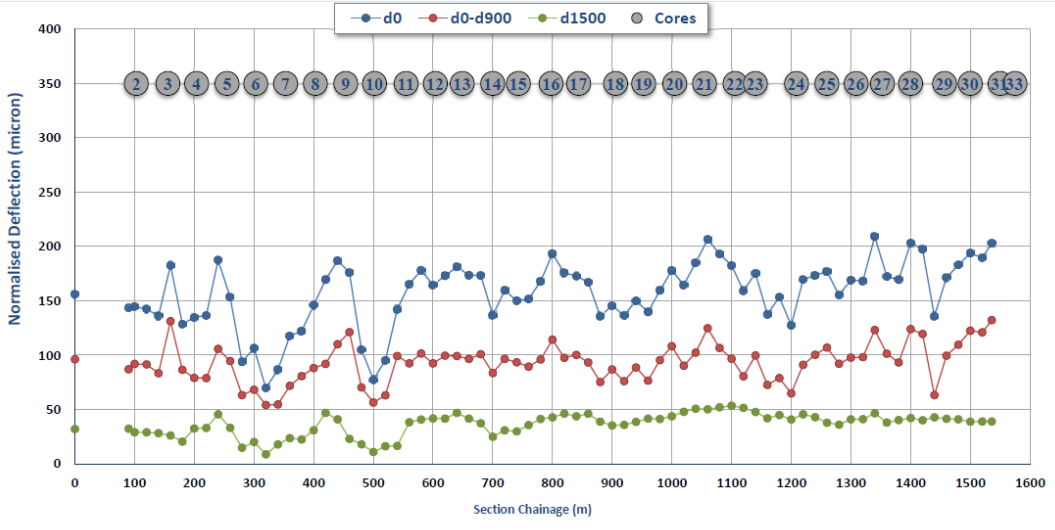
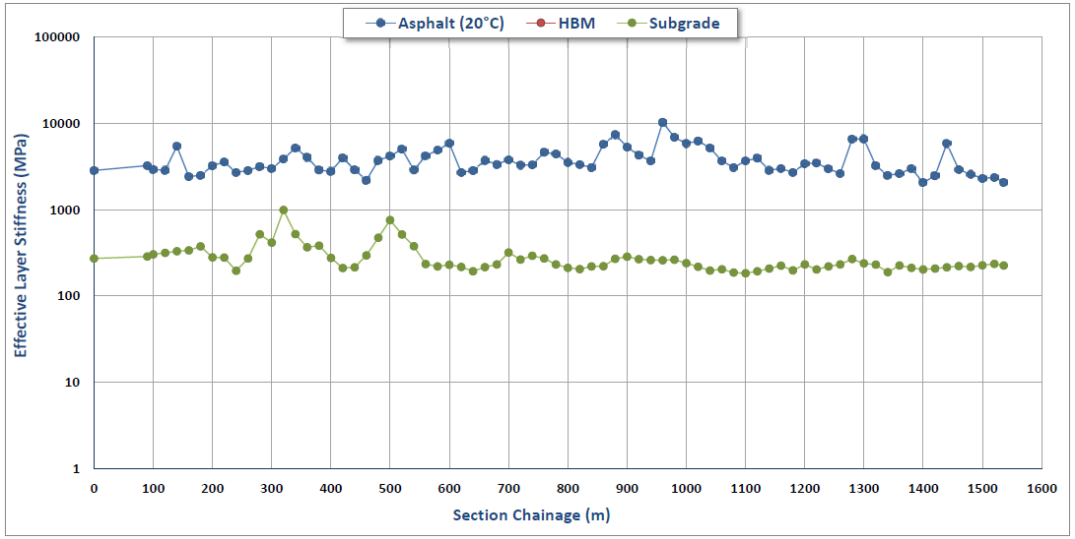
Site Selection – Falling Weight Deflectometer

- FWD – Material stiffness, pavement load capacity, foundation quality
- A1 – Bituminous bound stiffnesses indicate poor integrity through the majority of the site - <3000MPa
- Subgrade stiffnesses >100MPa





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Site Selection – Laboratory Testing

- Lab testing – Condition and consistency of existing pavement materials, tar presence
- A1 – Indirect Tensile Stiffness Modulus testing – stiffnesses suggesting deteriorated material
- Needle penetration and softening point – binder results suggest material has oxidised and hardened
- Binder and grading – consistent material containing mostly hardstone. Comparison with BS 9228 shows filler material required
- Air voids low but many layers untestable due to being disintegrated
- PAH testing – tar present

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Site Selection – General Assessment

- Site assessment – Alignment and drainage
- A1 – No tight bends, steady gradients, nothing that would limit plant on site
- Drainage – No ironworks within proposed area of construction
- No pooling recorded on site

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Theoretical Design

- Design Stage A – Calculate the design layer stiffnesses from the FWD survey

- Design Stage B – Reduce stiffness of remaining existing material using condition factor. Use assumed CIR design stiffness

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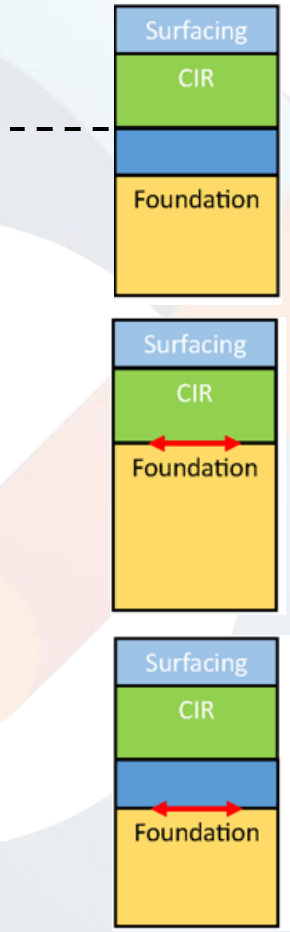
Theoretical Design

- Design Stage C – Calculate the support modulus on top of milled material and the calculate compaction factor of the CIR material
- Design Stage D – Calculate the horizontal strain at the base of the CIR material
- Design Stage E – Calculate the horizontal strain and/or stress ratio at the base of the residual bound material



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Theoretical Design

- The stress/strain values allow the residual life to be calculated
- By varying the design stiffness the design can be optimised to meet the assumed future traffic loading
- Design stiffness can be compared to standard stiffnesses to ensure minimum met in BS 9228

Table 3.1: Section 1 - Recycled Design Inputs

Category	Design Property	Value
Existing Pavement Information	Asphalt Depth	275mm
	Asphalt Modulus	2082MPa
	Foundation Modulus	198MPa
Treatment Details	Depth of Recycled Material	200mm
	Proposed Surfacing Depth	40mm
	Proposed Surfacing Modulus	2000MPa
	Proposed CIR Layer Thickness	160mm
	K_{SAFETY}	0.85

Table 3.2: Section 1 - Recycled Design Results

CIR Material Stiffness Modulus (MPa)	Residual Life (msa)
3100	10.0
3500	10.6
4000	11.5
4500	12.5
5000	13.7
5500	15.0
6000	16.4
6500	17.9

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Theoretical Design

- Carbon calculation using asPECT
- Can model all materials, plant and fuel used in CIR process
- Can compare to conventional inlay treatment to same depth
- Cradle to installation approach used
- Estimate of 48.4% carbon saving compared to conventional inlay treatment

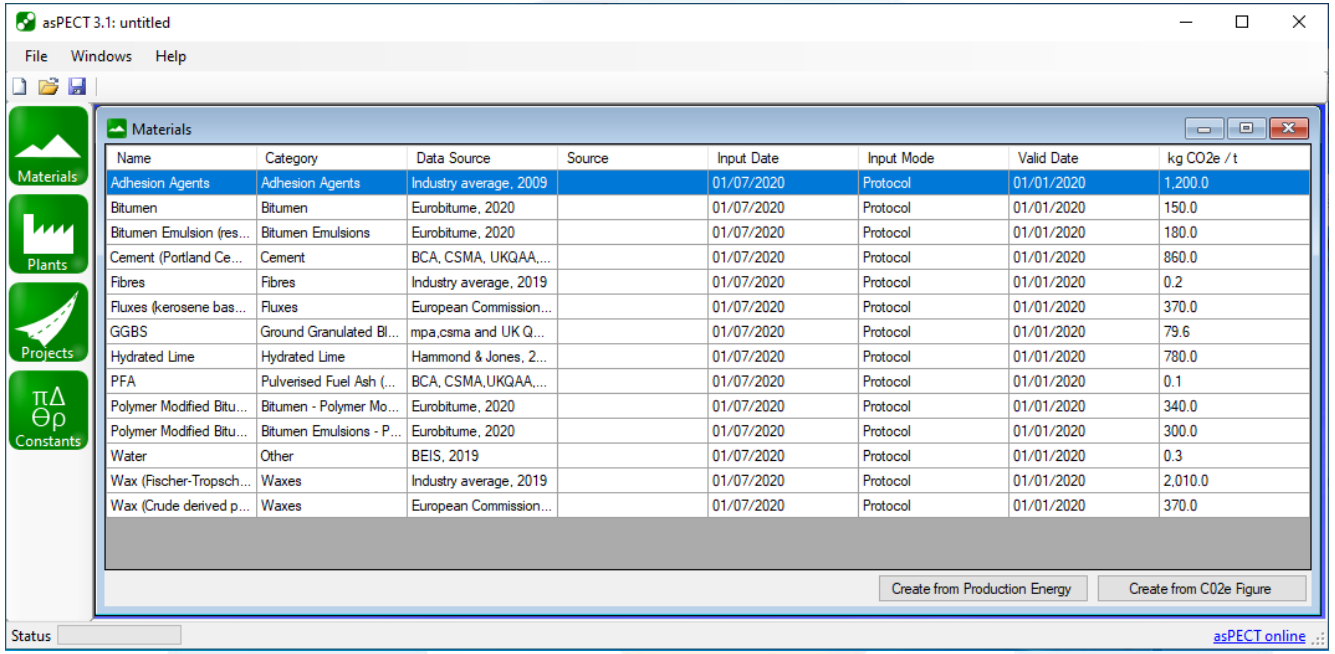

Table 4.1: Carbon Analysis Summary

	Cold In-situ Recycling Treatment (tCO2e)	Conventional Treatment (tCO2e)	Carbon Saving	
			tCO2e	%
Excavation & Removal	47.3	156.2	**108.9**	**69.7**
Transportation	15.5	55.7	**40.2**	**72.2**
Material	644.7	1158.0	**513.4**	**44.3**
Overall Carbon Saving	707.4	1369.9	**662.5**	**48.4**

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Mix Design

- Design process
- Sampling – grading, moisture content – very important for design to work – grading envelope - PFA content

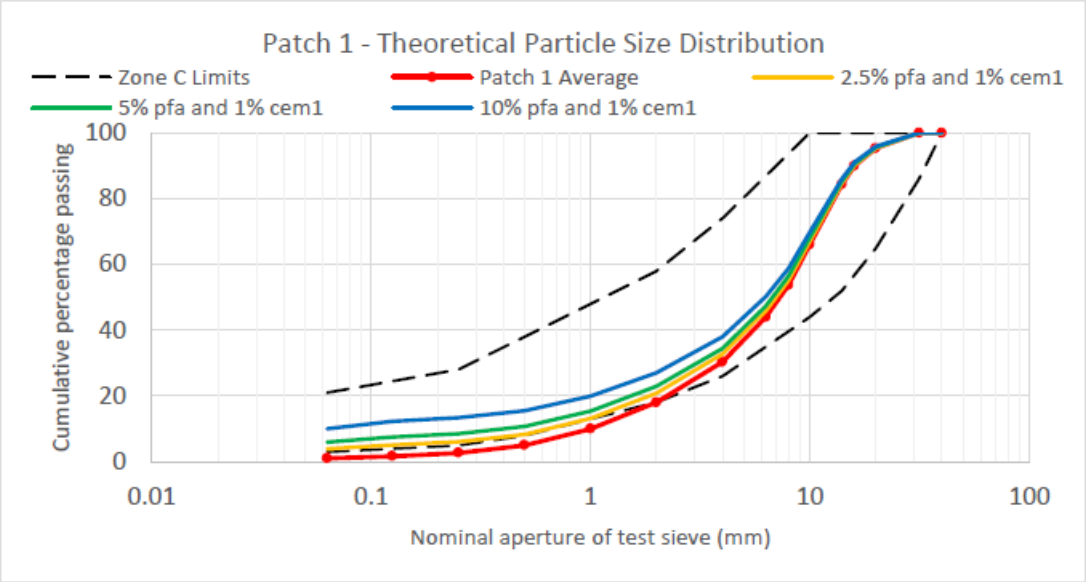

Figure 2.2: Patch 1 Theoretical Particle Size Distribution

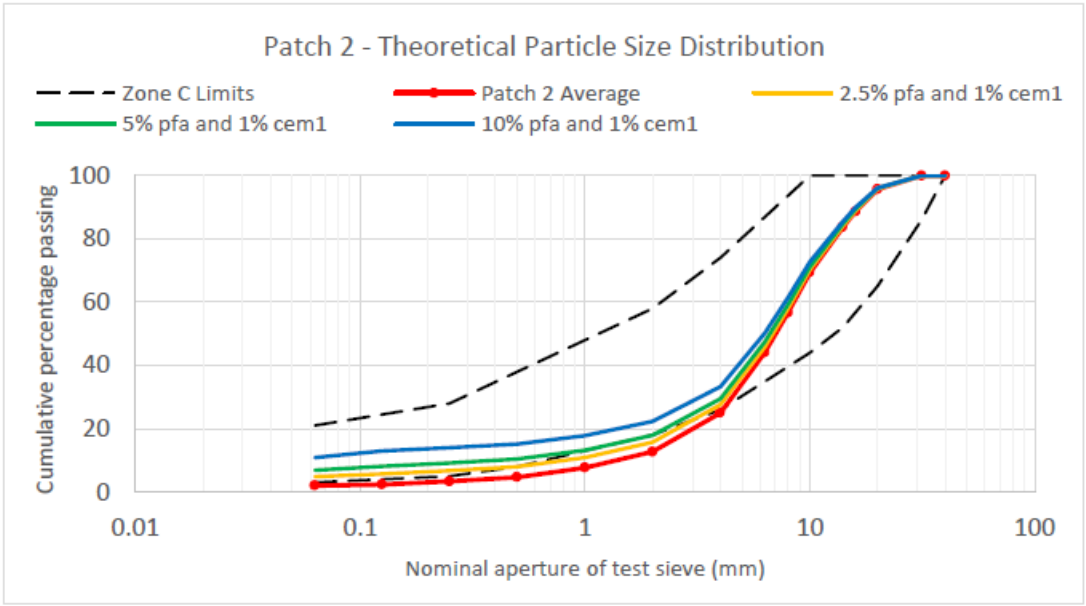

Figure 2.3: Patch 2 Theoretical Particle Size Distribution

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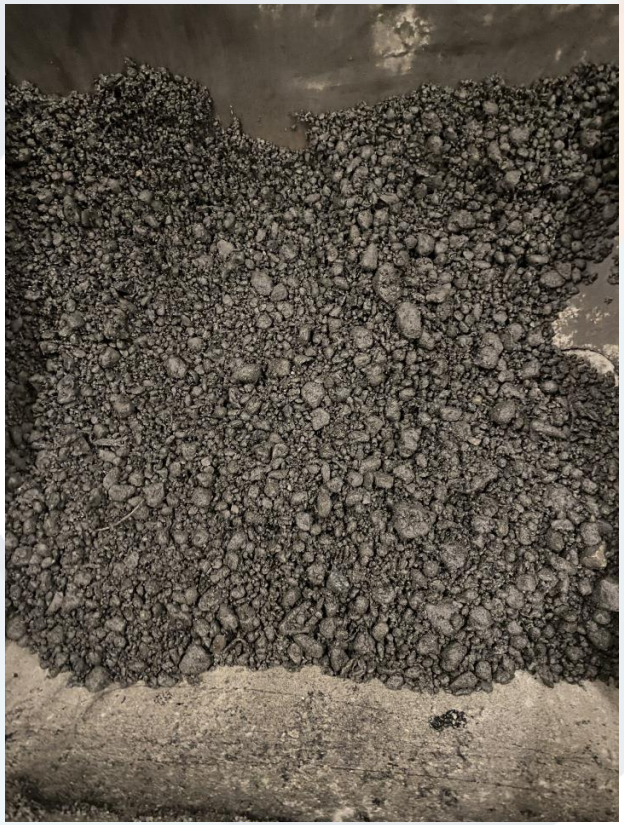
Mix Design

- Optimum moisture content, optimum binder content, optimum cement content – optimising mixes to achieve design stiffness

MIXTURE DESIGN

Calculating material amounts for mixture

Bulk Aggregate Weight	10000.0	g
Target Moisture Content	4.5	%
Cement Content	2.0	%
PFA Content	10.0	%
Binder Content	2.5	%
Aggregate + Powder Weight	11363.6	g
Powder Weight	1363.6	g
Additional Cement Required	**227.3**	g
Additional PFA Required	**1136.4**	g
Wet Mix Weight	12219.0	g
Additional Water Required	**549.9**	g
Additional Binder Required	**305.5**	g



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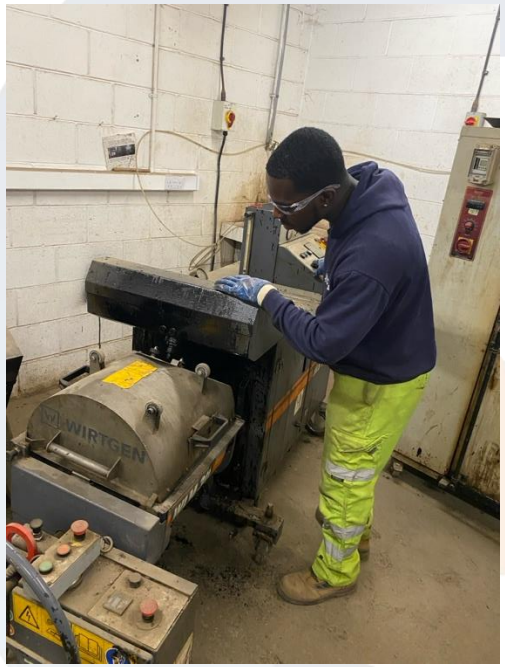
Mix Design

- Foam mix plant in lab to ensure mix is comparable to mix achievable on site



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Mix Design

- Lab testing for each mix – ITSM, ITSMr, voids, densities, optimise mix and ensure standards met
- Results for final mix used as targets for testing of samples from site and for all future testing

Design Information (For all sections):

- Foamed Bituminous Binder – **Total, Azalt 85, Grade 70/100**
- Foamed Bitumen Content - **2.5% - Expansion Ratio - 20 & Half-life - 10 seconds**
- Cement – **Breedon, BS EN 197-1: CEM I – Content 2.0%**
- Pulverised Fuel Ash (PFA) – **Power Minerals, Silicious Fly Ash – Content 5.0%**
- Additional Water – **Content 3.0%**

Target Criteria – Sections 1 & 3:

- Grading – **Zone C**
- Average Bulk Density – **2.381 Kg/m^3**
- Average Maximum Density – **2.521 Kg/m^3**
- Average Void Content – **5.6%**
- Target Moisture Content – **4.9%**
- Average 28 Day Air Cured ITSM Stiffness – **6845MPa**

Target Criteria – Sections 1 & 3:

- Grading – **Zone C**
- Average Bulk Density – **2.381 Kg/m^3 (based upon Section 1 & 3 test results)**
- Average Maximum Density – **2.521 Kg/m^3 (based upon Section 1 & 3 test results)**
- Average Void Content – **5.6% (based upon Section 1 & 3 test results)**
- Target Moisture Content – **4.7%**
- Average 28 Day Air Cured ITSM Stiffness – **5930MPa**

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Site Work - A1 Newton on the Moor to West Cawledge

- Site work from 27/09/2021 – 12/10/2021
- Two days lost to adverse weather
- All work during daytime hours
- Wind and rain affected site in general

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Site Compliance Testing

- Dips – ensure material depths correct
- Paver fitted with profile measurement

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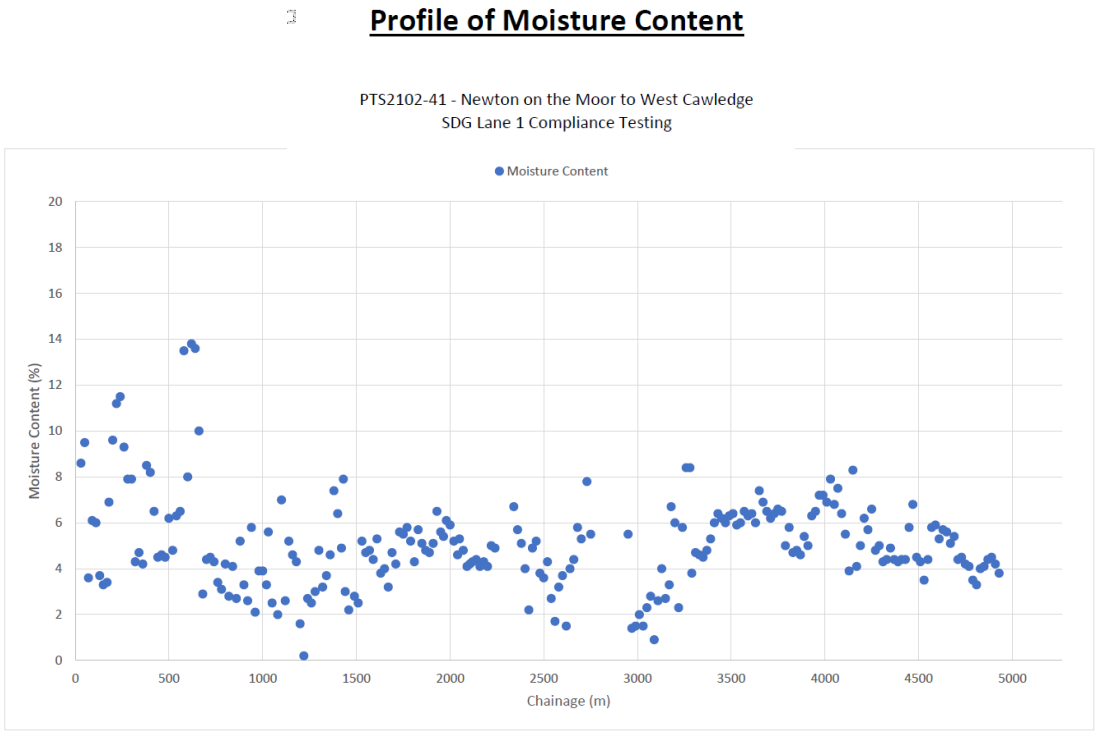
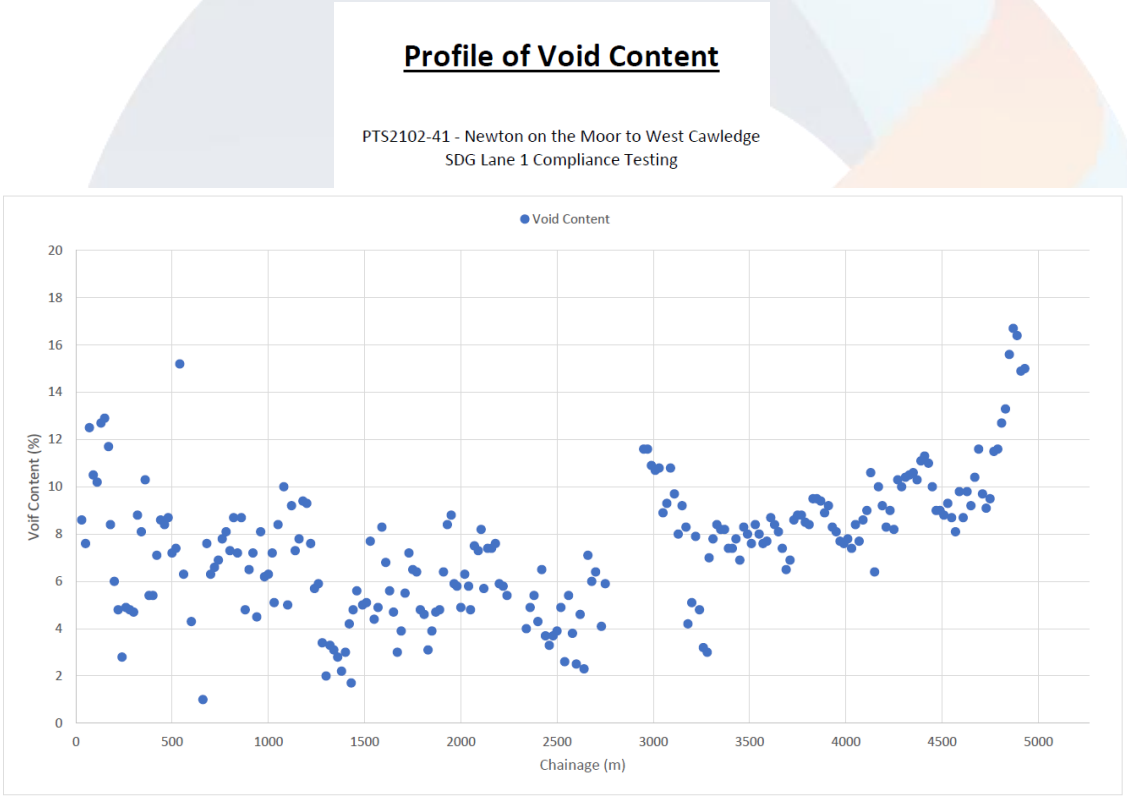
Site Compliance Testing

- In-situ density and moisture content – results show voiding and moisture content varied over site, difficult to achieve design void content





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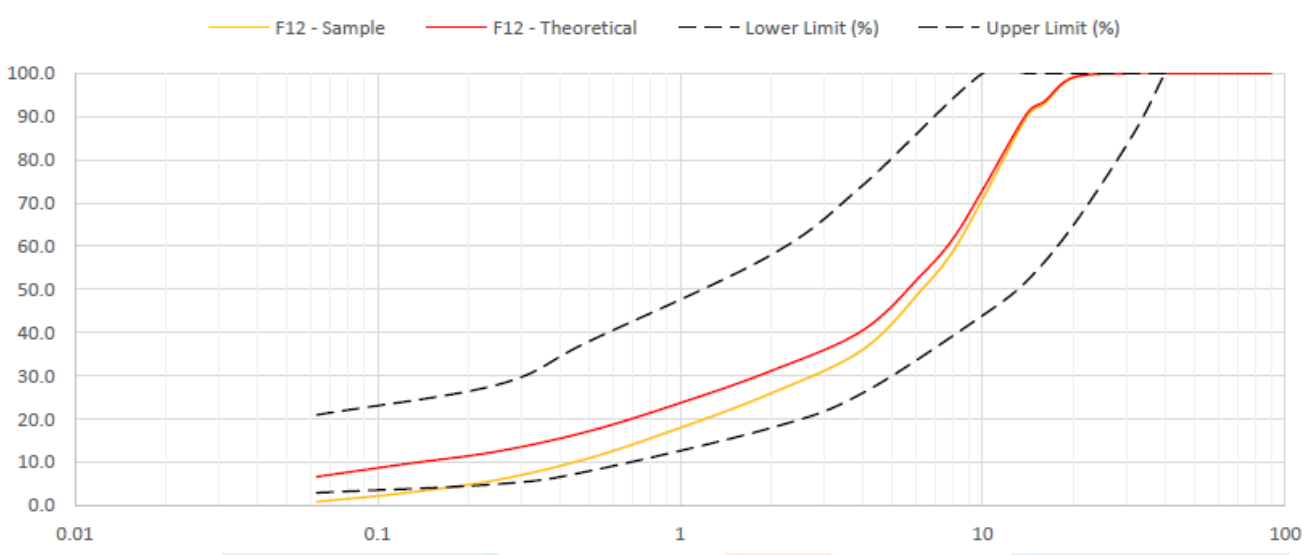
Site Compliance Testing

- Grading from site material – dry material sampled from site, cement and PFA additions theoretically added

SIEVE ANALYSIS

		Sieve (mm)	Passing (%)		Material Specification	
Site	A1 Newton on the Moor to West Cawledge	90	100.0	100.0	100	100
Client	Stabilised Pavements Limited	80	100.0	100.0	100	100
Supplier/Source	N/A CIR - Planed Existing Asphalt (Down Cut)	75	100.0	100.0	100	100
Date Sampled	04/10/2021	63	100.0	100.0	100	100
Sampled By	R.Humphries	40	100.0	100.0	100	100
Sample Location	L1 Ch. 950m NB	31.5	100.0	100.0	100	86
Sample Type	Planed Asphalt (Down Cut)	20	99.0	99.1	100	65
Client Reference	F12 - L1 Ch. 950m NB	16	93.0	93.5	-	-
Sample Certificate	Yes	14	90.0	90.7	100	52
PTS Sample Numer	P21-770	10	71.0	73.0	100	44
Date of Receipt	11/10/2021	8	59.0	61.9	-	-
Date of Test	19/10/2021	6.3	50.0	53.5	-	-
Tested By	A.Wilkinson	4	36.0	40.5	74	26
		2	26.0	31.2	58	18
		1	18.0	23.7	-	-
Remarks	Machine speed at sampling - 5m/min	0.5	11.0	17.2	38	8
		0.25	6.0	12.6	28	5
		0.125	3.0	9.7	-	-
		0.063	0.9	6.7	21	3



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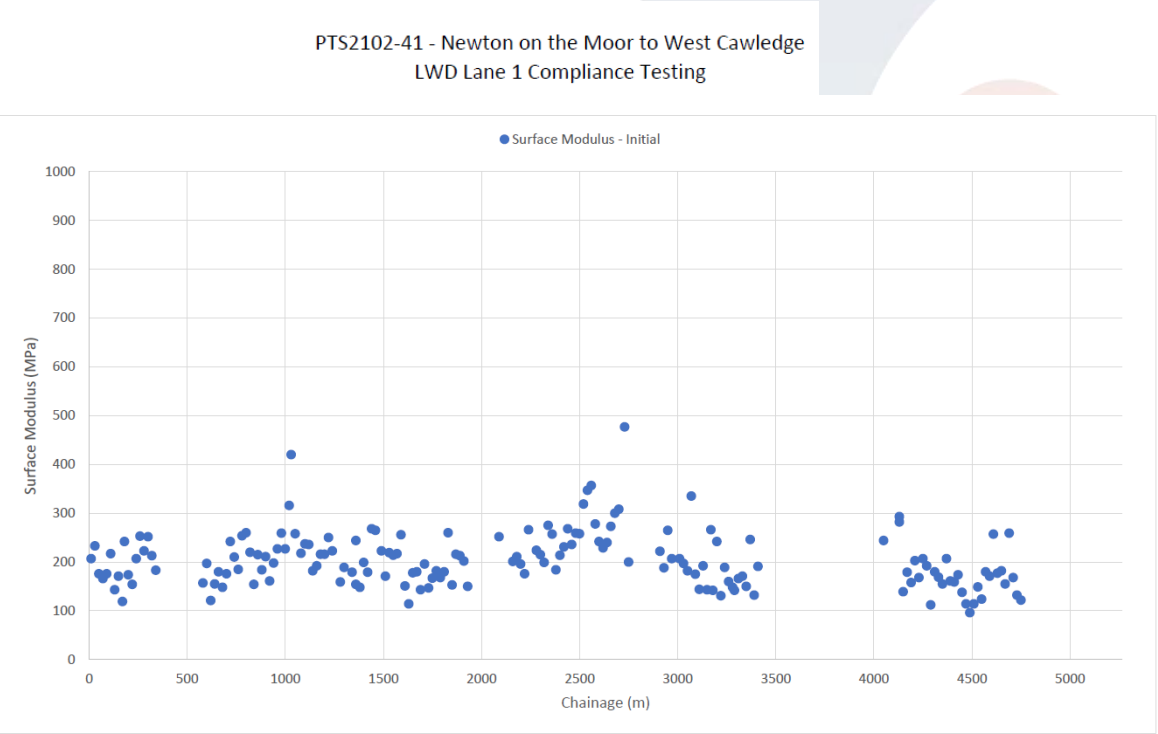
Site Compliance Testing

- Light Weight Deflectometer (LWD) – Undertaken on surface of recycled layer after compaction
- Results were variable but all showed surface moduli would allow laying of surface course material



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Site Compliance Testing

- Lab testing – Test specimens manufactured from sample material taken from site compacted to refusal density
- ITSMs taken at 7, 14 and 28 days, majority met target stiffness after 28 days
- Void content varied through site
- ITSMRs positive

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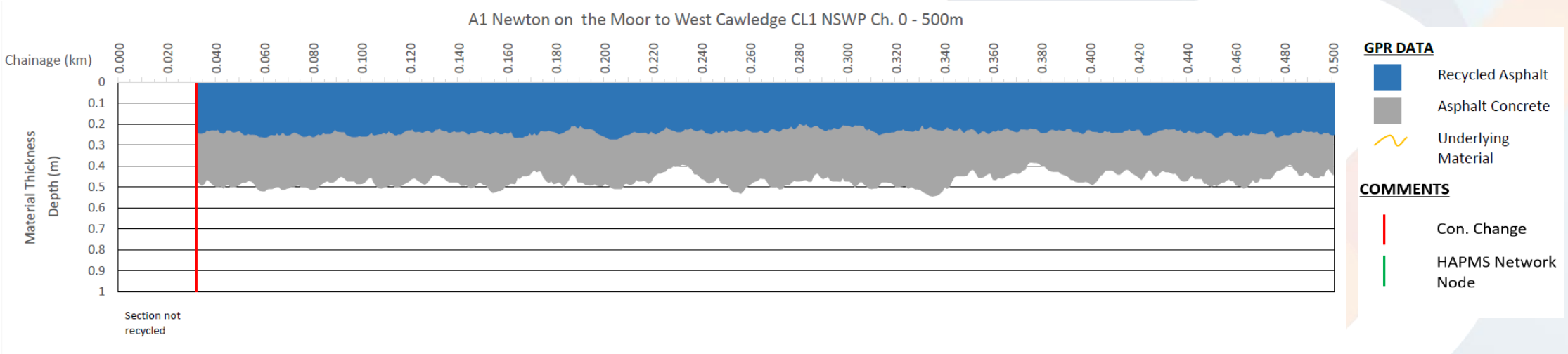
Ongoing Testing – Ground Penetrating Radar

- GPR – monitor material depths, any void/moisture locations



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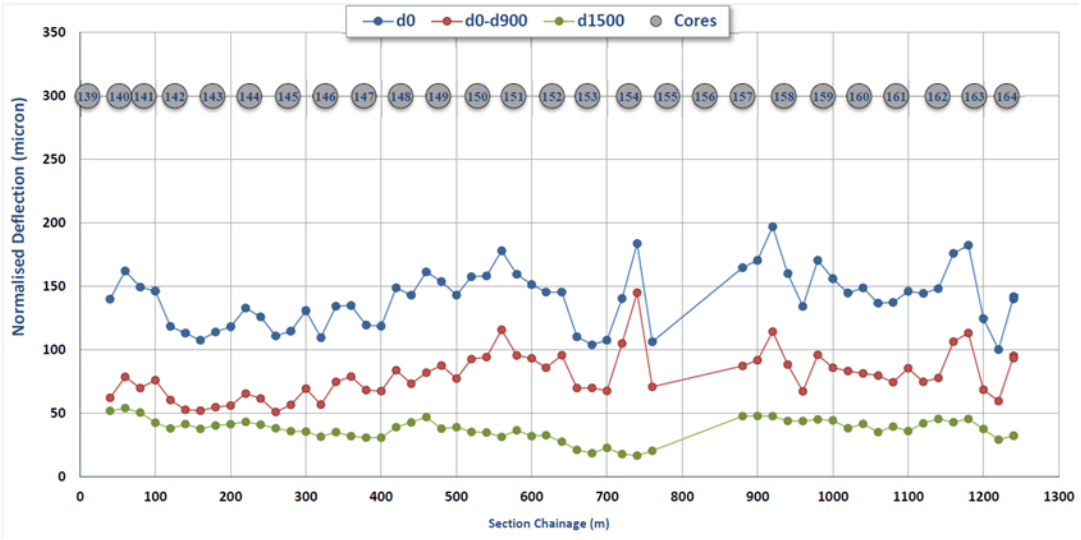
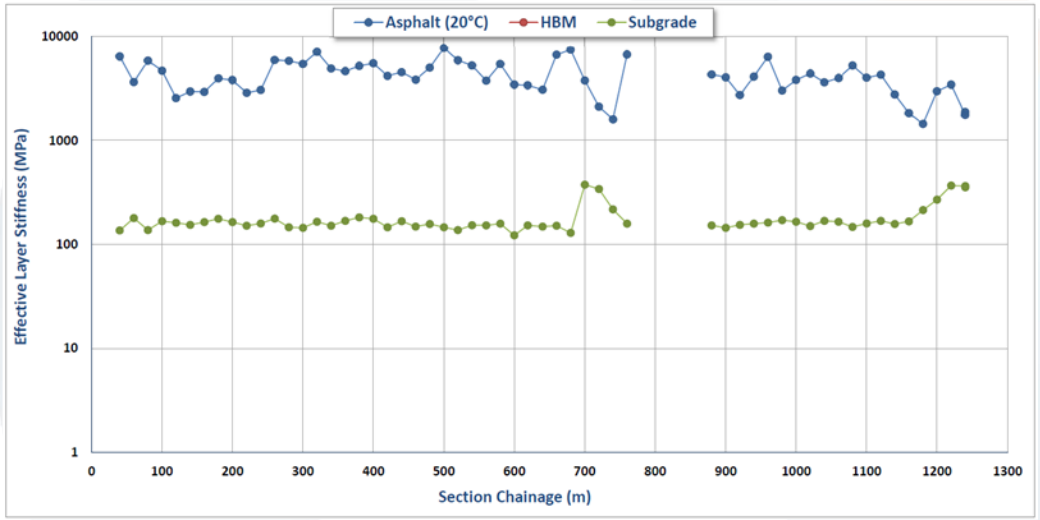
Ongoing Testing – Falling Weight Deflectometer

- FWD – structural capacity – difficult to compare with multi-layer system





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Ongoing Testing – Coring and Laboratory Testing

- Ongoing testing – Coring, lab testing – voids, densities, ITSM, ITSMr
- Core comparison after 24 months

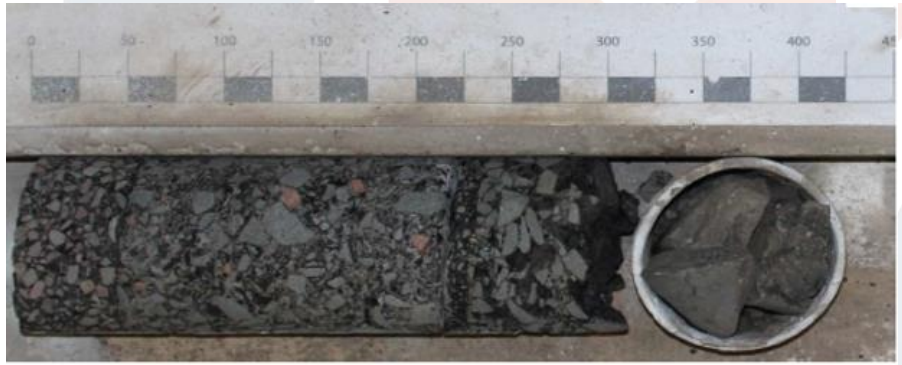
Before

Nearest ITSM		
C18	+200m	
	Layer 3	MPa
ITSM	5020	
Nearest SP & Pen		
C18	+200m	
	Layer 2	
SP	51.6	°C
Pen	39	mm^{-1}
Nearest Air Voids		
N/A		

Core 14 016648

After

Lab Testing	
	C1
Maximum Density	2600
Bulk Density	2267
Air Void Content	12.8
ITSM	8810
$ITSM_w$	8190
$ITSM_R$	93.0



Core 1 50345

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Ongoing Testing

- Ongoing testing – Coring, lab testing – voids, densities, ITSM, ITSMr
- Lab testing – to compare to BS criteria and monitor over time

Table 2.2: ITSM Results Summary

Core Location	XSP	Chainage	Core Numbers	Average Stiffness Modulus (MPa)
1	Lane 1	681m – 687m	C1 – C4	8155
2	Lane 1	4102m – 4108m	C5 – C8	6650
3	Lane 2	994m – 1009m	C9 – C12	1835
4	Lane 2	3556m – 3567m	C13 – C16	5610
5	Lane 2	4003m – 4021m	C17a – C21	7014

Table 2.3: $ITSM_R$ Results Summary

Core Location	XSP	Chainage	Core Numbers	Average $ITSM_D$ (MPa)	Average $ITSM_W$ (MPa)	Average $ITSM_R$ (%)
1	Lane 1	681m – 687m	C1 – C4	7720	6893	89.3
2	Lane 1	4102m – 4108m	C5 – C8	6650	5988	90.0
3	Lane 2	994m – 1009m	C9 – C12	1835	1085	59.1
4	Lane 2	3556m – 3567m	C13 – C16	5930	5253	88.6
5	Lane 2	4003m – 4021m	C17a – C21	7014	4344	79.9

Table 2.4: Density and Air Void Content Results Summary

Core Location	XSP	Chainage	Core Numbers	Bulk Density (kg/m^3)	Maximum Density (kg/m^3)	Air Void Content (%)
1	Lane 1	681m – 687m	C1 – C4	2307	2579	10.5
2	Lane 1	4102m – 4108m	C5 – C8	2202	2520	12.6
3	Lane 2	994m – 1009m	C9 – C12	2075	2421	14.3
4	Lane 2	3556m – 3567m	C13 – C16	2152	2444	11.9
5	Lane 2	4003m – 4021m	C17a – C21	2108	2439	13.6

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Going Forward

- CIR Performing well
- Potential improvements – tack coat
- Positives - homogenous sections, grading, stiffness, ITSMr
- To improve – voiding and density
- Changing standards
- Carbon savings

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Thank you for listening

If you have any further questions, please contact:

steve.brammer@xais-pts.co.uk or
stuart.robinson@xais-pts.co.uk

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