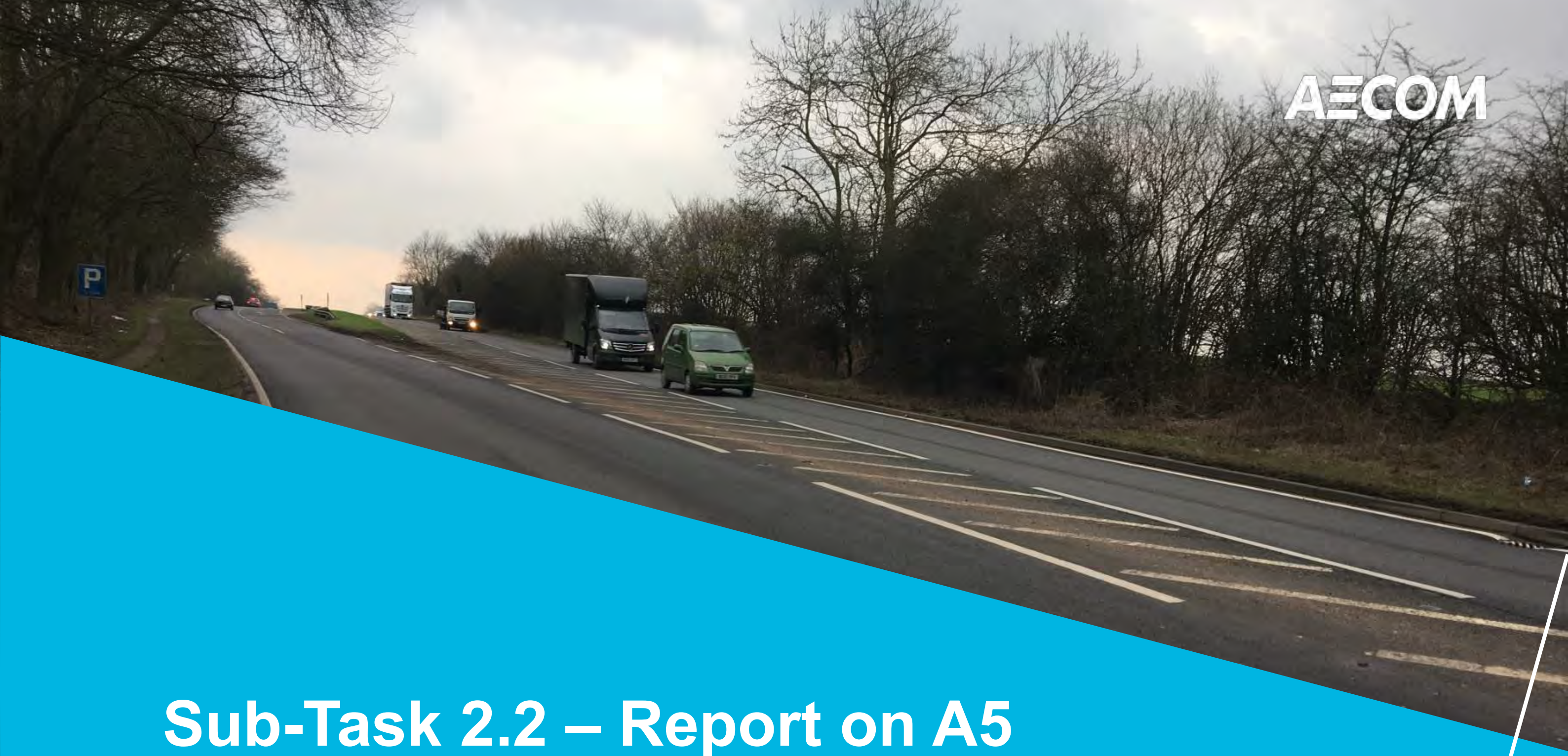

Sub-Task 2.2 – Report on A5 Warm Mix Asphalt

Task 1-111 Collaborative Research Project

Highways England, Mineral Product Association and Eurobitume UK

Project Number: 60523093

November 2017

Quality information

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Revision History

Revision	Revision date	Details	Authorized	Name	Position
0	3rd July 2017	Draft for comment	Y	Daru Widyatmoko	Technical Director
1	3rd August 2017	Comments addressed	Y	Daru Widyatmoko	Technical Director
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Distribution List

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1. Introduction

This collaborative research task has been carried out by AECOM and sponsored by Highways England, Mineral Products Association and Eurobitume UK. The aim of this task is to review and evaluate the mechanical and performance characteristics of the Warm Mix Asphalt (WMA) installed on the Grendon to Mancetter pavement scheme of the A5 in 2014. The site is a stretch of the westbound carriageway approximately 220 m in length installed with proprietary WMA mixtures for the binder and surface course layers with conventional Hot Mix Asphalts (HMA) as control mixtures.

Warm Mix Asphalt (WMA) technology has the potential for reducing carbon emissions associated with road construction. The lower temperatures used to manufacture these materials mean that less energy is required to produce asphalt materials. This results in reduced carbon footprints in the construction of asphalt pavements. The decrease in emissions provides better working conditions and has an influence in reducing impacts to the environment. Some of the potential benefits from using Warm Mix Asphalts are:

- Reduced emissions during manufacturing and road construction.
- Provides a safer working environment for road construction workers.
- No need for new paving equipment as the same pavement and rollers used for HMA can be used.

The main aim of the project is to inform future incorporation of WMA into the standards and specifications.

1.1 Scope

This sub-task investigates, evaluates and analyses the mechanical characteristics and performance properties of the Grendon to Mancetter pavement scheme of the A5 site that incorporated WMA after 3 years in service. AECOM conducted a visual survey on 10th February 2017 and pavement coring investigation on 13th and 14th February 2017. Findings and analysis from this investigation are presented in comparison to the test results reported in TRL PPR742 (Wayman M, Nicholls J.C., Carswell I, 2014, *Use of lower temperature asphalt in pavement construction, Demonstration site construction, in service performance and specification*). PPR742, 2014 testing was carried out on material collected from the asphalt plant during scheme construction.

1.2 Demonstration site

1.2.1 Site location

The demonstration site is located within a 1.1 km maintenance scheme on the A5 between Grendon and Mancetter in North Warwickshire, United Kingdom. A section of the westbound carriageway of the A5, approximately 220 m in length (Chainage: 2960-3180 m) was inlaid with 110 m length of WMA binder and surface courses and 110 m length of conventional HMA binder and surface courses acting as a control mixture. The production and application of both binder and surface course layers were closely monitored and the laboratory properties of the asphalt mixtures tested to ascertain mechanical and performance properties (PPR742, 2014).

A picture of the site and approximate location are shown in Figure 1 and Figure 2 respectively.

Figure 1: Demonstration Site within the A5 Grendon to Mancetter Maintenance Scheme (Google maps, 2017)

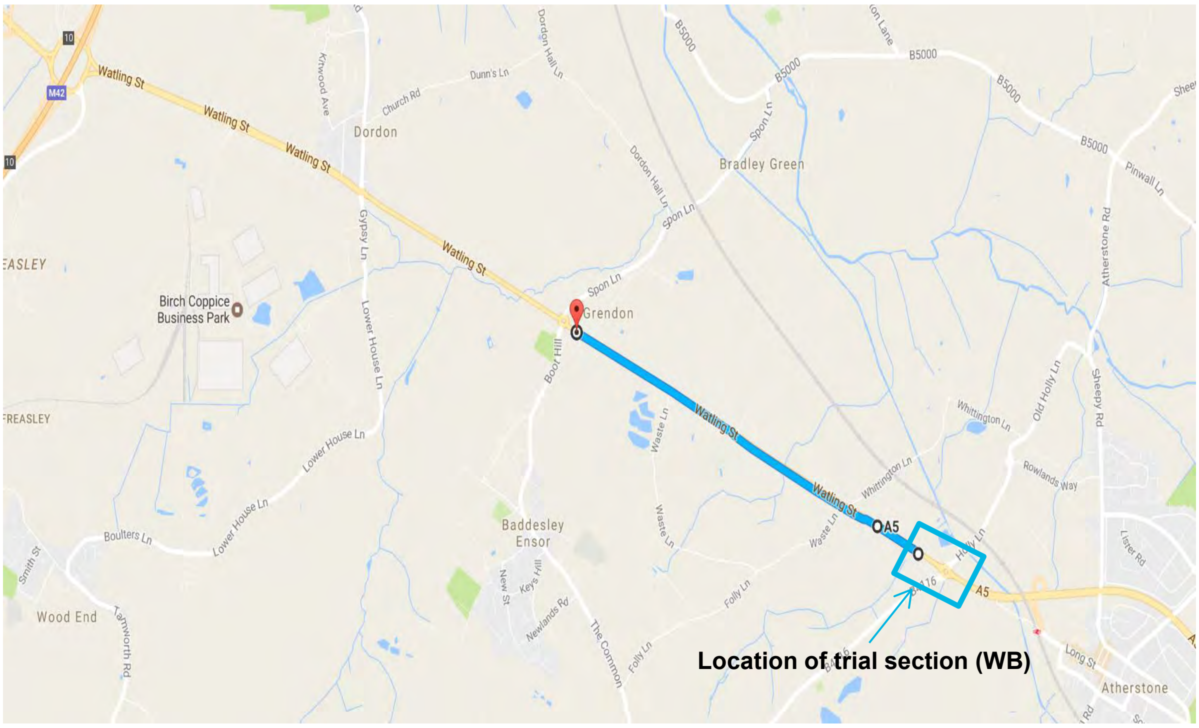

Figure 2: Approximate Location of the A5 Grendon to Mancetter Maintenance Scheme

1.2.2 Materials used in the demonstration site

The mixtures used for the construction of the demonstration site are:

I.	Mixture 1	WMA	Binder Course	AC 20 HDM bin 40/60 design
II.	Mixture 2	WMA	Surface Course	AC 14 surface PMB PSV 65
III.	Mixture 3	HMA	Binder Course	AC 20 HDM bin 40/60 design
IV.	Mixture 4	HMA	Surface Course	AC 14 surface PMB PSV 65

There are two broad approaches to manufacturing WMA; foaming processes and additive technologies. The demonstration trials used WMA produced using foaming technology.

Foaming processes create micro bubbles of air within the bitumen that increases mixture workability at lower temperatures compared with HMA. Bitumen foaming can be produced using an injection 'foaming bar' on the asphalt plant, where a controlled quantity of air and water is introduced to the bitumen under pressure. The bitumen surrounds the air/water bubbles which increase the volume of the bitumen thus reducing surface tension. This bitumen foam is sprayed through fine nozzles into the asphalt mixer. Alternatively, water releasing mineral additives such as zeolites may be added to the asphalt mixer, providing a controlled release of moisture which again produces tiny bubbles in the bitumen causing the bitumen to 'foam' and expand. At times, the moisture is added to the aggregates in a controlled manner and delivered to the asphalt mixer box via a cold feed (i.e. no drying takes place). Again, when bitumen is added the water turns to steam and creates foamed bitumen. The WMA foaming process is shown below in Figure 3.

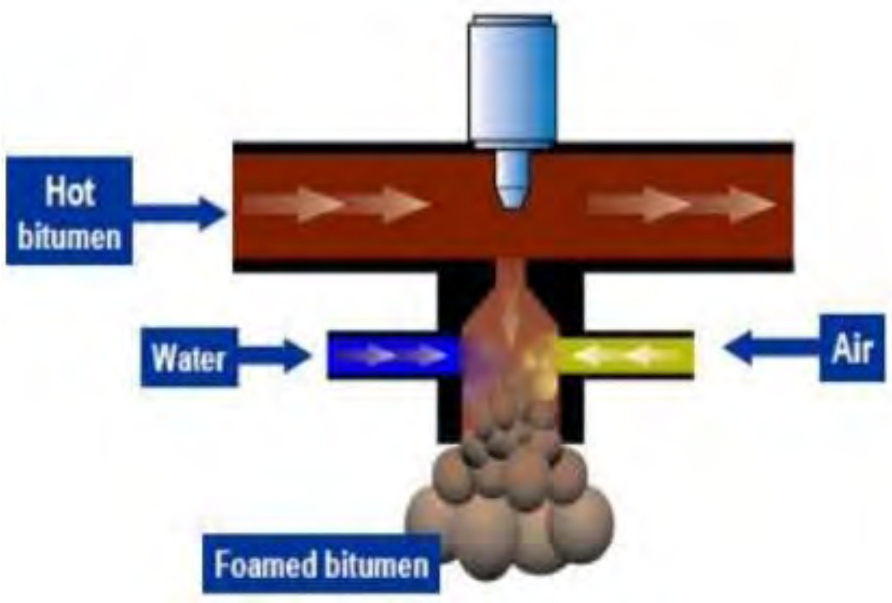

Figure 3: Warm Mix Asphalt Foaming Process

Additive systems generally involve the addition of a low dosage of liquid or solid WMA chemical to the bitumen line or asphalt mixer. A large range of WMA additives are available on the market and include chemical additives (waxes, amides and sulphur) and surfactant based chemical additives. In general, chemical additives function by either reducing the viscosity of the bitumen or by acting as surfactants that work at the interface between the aggregate and bitumen to improve the ability of the bitumen to coat the aggregate and enhance compaction at a lower temperature. Chemical additives may also offer adhesion benefits between bitumen and aggregate. Bitumen suppliers are able to offer bespoke warm mix asphalt bitumen which may have chemical additives pre-blended within the bitumen.

For the demonstration site, the HMA mixtures were manufactured conventionally and the WMA mixtures were manufactured using a patented 'injection foaming' technique. The target binder content for both binder course mixtures was 4.3% and the target binder content of both surface courses was 5.1% (PPR742, 2014). Production temperatures (as reported in PPR742, 2014) are presented in Table 1.

Table 1: Production Temperatures

Mixture No.	Type	Course	Mixing Temperature (°C)	
			Mean	Range
1	WMA	Binder	92	88 – 95
2	WMA	Surface	107	92 – 119
3	HMA	Binder	171	149 – 182
4	HMA	Surface	169	141 – 182

Reclaimed asphalt was incorporated in each of the asphalt mixtures. The WMA binder course targeted 25% reclaimed asphalt. HMA binder course also targeted 25% reclaimed asphalt, however, the actual proportion was 6% which is reportedly thought to be due to a combination of grading and high moisture content of the feedstock reclaimed asphalt which would have required some superheating of the aggregates (required to dry the reclaimed asphalt) to temperatures beyond acceptable production plant tolerances. HMA and WMA surface course mixtures included approximately 16% reclaimed asphalt (PPR742, 2014). The proportions of reclaimed asphalt incorporated into the mixtures are shown in Table 2 (PPR742, 2014).

Table 2: Reclaimed Asphalt Content

Mixture No.	Type	Course	% Reclaimed Asphalt Mean	% Reclaimed Asphalt Range
1	WMA	Binder	25.9	24.4 – 27.2
2	WMA	Surface	15.6	14.9 – 17.1
3	HMA	Binder	5.9	0.0 – 13.0
4	HMA	Surface	15.6	15.2 – 16.4

PPR 742, 2014 reports the site condition in advance of works, details of the construction and material production. PPR 742 also presents an overview of observations and general condition after installation of the demonstration section.

2. Methodology

The proposed methodology and approach for the project comprised of site investigations and laboratory testing to determine material and performance properties in order to establish the condition of the pavement and performance of the asphalt materials. The site surveys and laboratory tests conducted are detailed below in Table 3.

AECOM aimed to replicate the testing undertaken by TRL in 2014. The following points are important to note:

- TRL testing was carried out on bulk material sampled from the works which were compacted in the laboratory. AECOM 2017 investigation and testing are based on the cored material. As such a direct comparison of 2014 and 2017 test results is not possible due to the differences in sample preparation.
- The following testing reported by TRL does not form part of this study:
  - Four point bending stiffness test to BS EN 12697-26 Annex B
  - Fatigue resistance to BS EN 12697-24 Annex D
  - Large scale wheel tracking to BS EN 12697-22

Table 3: Summary of Investigations and Testing

Investigation	Standard
Visual Condition Survey (VCS)	Site Survey
Coring Survey	Site Survey
Volumetrics (Maximum Density and Air Voids)	BS EN 12697-5, BS EN 12697-6 and BS EN 12697-8
Compositional Analysis	BS EN 12697-3
Penetration Index	BS EN 1426
Softening Point	BS EN 1427
Dynamic Shear Rheometer (DSR)	BS EN 14770
Water Sensitivity	BS EN 12697-12
Wheel Tracking	BS EN 12697-22 (Small Scale)
Indirect Tensile Stiffness Modulus (ITSM)	BS EN 12697-26

3. Site Surveys

3.1 Visual Condition Survey (VCS)

The Visual Condition Survey (VCS) covering the demonstration site was conducted in daylight on 10th February 2017 from the footpath. The aim was to identify and record the type, level and severity of visible distress on the surface of the road. Findings from the VCS are discussed here and the full VCS report is presented in Appendix A.

3.1.1 General observations

Table 4 presents general views of the scheme from TRL survey in 2014 which was conducted 8 hours after opening to traffic, alongside the corresponding view taken during AECOM's VCS in 2017.

Table 4: Photographs of demonstration site, taken in 2014 and 2017

Images were taken in 2014 (8 hours after completion of the scheme) (taken from TRL PPR742, 2014)	Images were taken during Feb 2017 AECOM VCS
	
2014 WMA section (looking in EB direction)	2017 WMA section (looking in WB direction)

2014 Boundary between WMA and existing surface

2017 Boundary between WMA and existing surface

2014 Boundary between WMA (right) and HMA (left)

2017 Boundary between WMA (bottom) and HMA (top)

2014 Boundary between HMA & existing surface (looking in Eastbound direction)

2017 Boundary between HMA & existing surface (looking in Westbound direction)

Observed defects include surface cracking, rutting, crazing and loss of aggregates (fretting). An image of the 2017 VCS (see Appendix A for full report) is shown in Figure 4. Summary of observed defects detailed in Table 5.

The VCS found areas of distress in the form of crazing and possible subsidence which is suspected to be a result of underlying issues in the pavement foundation and/or substrate.

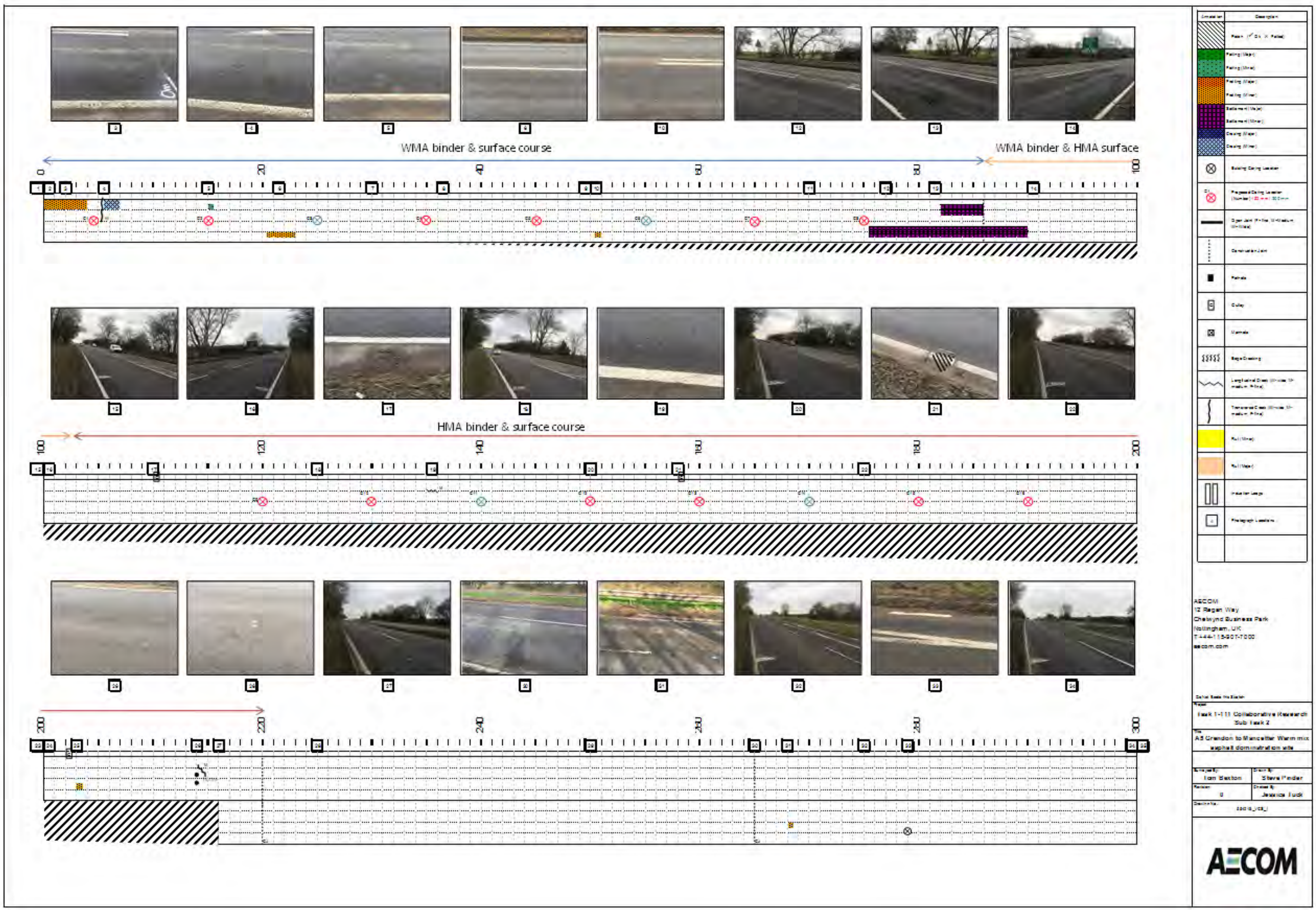

Figure 4: Image of 2017 Demonstration Site VCS report (See Appendix A)

Table 5: Summary of VCS Observed Defects

Section	Chainage	Observation	Photograph
Warm Mix Asphalt	0-92	General observations: Fretting and/or 'open' texture was evident in areas throughout the section. Cracking and crazing were observed with areas of settlement. In some areas there appeared to be some bitumen bleeding in the wheel tracks.	
	0-5m	Possible segregation and/or fretting of the surface course material at the start of the demonstration section.	Picture 3
	5-7m	Extended minor crazing on the pavement surface with wide transverse cracks and block cracking. Similar defects were observed during the VCS conducted by TRL in 2014 pre-works.	Picture 4
	16m	A fatty patch on the surface was observed. There is also evidence of bitumen-rich areas in the wheel tracks.	Picture 5
	21-23m	This section had signs of visible fretting and loss of fine materials on the surface course.	Picture 6
	51m	This section had signs of visible fretting and loss of fine materials on the surface course.	Picture 10
	75-90m	Major rutting and extended crocodile crack defects were observed. In some spots, there was a loss of surface course materials causing potholes. Similar defects were observed in this location in the VCS conducted by TRL in 2014 pre-works.	Picture 13
Hot Mix Asphalt	92-223m	General observations: Some local fretting was observed along with cracking. In some areas there appeared to be some bitumen bleeding in the wheel tracks.	
	135-136m	Minor longitudinal cracks. Visible signs of excessive bitumen on the surface of the road synonymous with fatting/bleeding.	Picture 19
	203m	Visible signs of fretting observed	Picture 25
	204-205m	Medium transverse and longitudinal cracks were observed. Rutting and crazing were recorded in this location as in the TRL 2014 VCS pre-works.	Picture 26

AECOM 2017 VCS Photo log


Picture 3: WMA


Picture 4: WMA


Picture 5: WMA


Picture 6: WMA


Picture 10: WMA


Picture 13: WMA


Picture 19: HMA


Picture 25: HMA


Picture 26: HMA

There is evidence of underlying issues (possible subsidence) in certain areas of the demonstration scheme which is observed in the form of rutting, cracking and crazing. It was observed that the recorded defects were located in close proximity to defective areas as identified by TRL in surveys conducted in 2014. This strongly suggests fundamental underlying issues which may be related to the condition of the foundation and/or substrate. Further testing and analysis are required to ascertain pavement condition of the underlying layers. This falls outside the scope of this project.

Fretting of the surface course materials was also observed in some areas which were noted to a greater extent in the WMA section. It is noted that photographs of the WMA section taken 12 hours after completion of the works in 2014 (shown in Table 4) appear to have a variable surface finish with some areas appearing more open in texture than others.

3.2 Coring Survey

A coring survey is an intrusive survey test performed typically by using a rotary coring rig at preselected locations across the site (after all utility drawings provided have been reviewed and a permit to dig issued). Core logs provide information on the pavement material type, layer thickness, presence of crack and material condition. In addition to this, the retrieved cores provide samples for subsequent laboratory testing to confirm material properties and condition. The cores were extracted at 10 m intervals from the lane centre, with the exception of cores 15 and 16 which were taken from the nearside wheel path due to the location of buried services.

A total of 16 cores were extracted, comprising of 12 x 150 mm cores (shown as red ⊗ on the VCS plan) and 4 x 200 mm cores (shown as blue ⊗ on the VCS plan) as shown in Appendix A.

Table 6: Core locations

	Core Ref	Dir.	Lane	Ch. (m)	X-Pos	Core Dia. (mm)	Material
Warm Mix Asphalt	1	WB	CL1	5	LC	150	WMA
	2	WB	CL1	15	LC	150	WMA
	3	WB	CL1	25	LC	200	WMA
	4	WB	CL1	35	LC	150	WMA
	5	WB	CL1	45	LC	150	WMA
	6	WB	CL1	55	LC	200	WMA
	7	WB	CL1	65	LC	150	WMA
	8	WB	CL1	75	LC	150	WMA
Hot Mix Asphalt	9	WB	CL1	120	LC	150	HMA
	10	WB	CL1	130	LC	150	HMA
	11	WB	CL1	140	LC	200	HMA
	12	WB	CL1	150	LC	150	HMA
	13	WB	CL1	160	LC	150	HMA
	14	WB	CL1	170	LC	200	HMA
	15	WB	CL1	180	NSWP	150	HMA
	16	WB	CL1	190	NSWP	150	HMA

LC denotes Lane Centre

NSWP denotes near side wheel path

Table 7 summarises the core log information. The Tar Spray Test for Poly Aromatic Compounds (PAC) was conducted to check for the possible presence of tar on the cores. It was observed that cores 9, 10, 11 and 13 showed the possible presence of tar on Layer 3 of the cores.

It was observed that the surface and binder courses were bonded together. However, the lower layers were not well bonded, especially at the interface between the asphalt and concrete layers. In addition, there were visible signs of loss of material mostly between the asphalt and cement bound layers.

Appendix B presents the core log information.

Table 7: Summary of Core Log Information

Summary of Core Log Information

Nominal Core Diameter [mm]	Core Number	Total Asphalt Thickness [mm]	Description
General observations			In general, three asphalt layers were observed with layers 1 and 2 comprising the trial materials, layer 3 was largely de-bonded and broken up and the cement bound layers (referred to in the core logs as concrete) was found to be broken up in some locations.
150	1	140	3 asphalt layers identified. No bond between the asphalt and concrete layers (Layers 3 and 4). 3rd layer broken with the loss of material. Visible longitudinal cracks on the concrete layer (Layer 4).
150	2	140	3 asphalt layers identified. No bond between asphalt and concrete layers. 3rd asphalt layer broken with the loss of material on both layers.
200	3	130	3 asphalt layers identified. No bond between asphalt and concrete layers. 3rd layer broken with the loss of material.
150	4	110	3 asphalt layers identified. No bond between asphalt and concrete layers. 3rd layer broken with the loss of material.
150	5	135	3 asphalt layers identified. No bond between asphalt and concrete layers (Layers 3 and 4). 3rd layer broken with the loss of material. Concrete layer is broken up.
200	6	170	3 asphalt layers identified. No bond between asphalt and concrete layers. 3rd layer broken with the loss of material.
150	7	120	3 asphalt layers identified. No bond between both Layers 2 and 3, and Layers 3 and 4. 3rd layer broken with the loss of material.
150	8	154	3 asphalt layers identified. No bond between both Layers 2 and 3, and Layers 3 and 4. 3rd layer broken up with the loss of material.
150	9*	205	3 asphalt layers identified. No bond between asphalt and concrete layers (Layers 3 and 4). 3rd layer broken up with the loss of material.
150	10*	175	3 asphalt layers identified. No bond between both Layers 2 and 3, and Layers 3 and 4. 3rd layer broken and 4th layer disintegrated with the loss of material.
200	11*	135	3 asphalt layers identified. 3rd layer damaged to face.
150	12	150	3 asphalt layers identified. No bond between asphalt and concrete layers (Layers 3 and 4). 3rd layer damaged to face and delaminated.
150	13*	150	3 asphalt layers identified. No bond between asphalt and concrete layers (Layers 3 and 4). 3rd layer broken up with the loss of material.
200	14	170	3 asphalt layers identified. No bond between both Layers 2 and 3, and Layers 3 and 4. 3rd layer disintegrated with the loss of material.
150	15	175	3 asphalt layers identified. No bond between both Layers 2 and 3, and Layers 3 and 4. 3rd layer broken. 3rd layer disintegrated with the loss of material.
150	16	170	3 asphalt layers identified. No bond between both Layers 2 and 3, and Layers 3 and 4. 3rd layer broken and 3rd layer disintegrated with the loss of material.

*PAK marker indicates compounds indicative of the presence of tar.

Appendix B presents the detailed core log information.

4. Laboratory Test Results and Analysis

Figure 5 summarises laboratory tests carried out on cores obtained from the sampling and site investigation of the A5 between Grendon and Mancetter demonstration sections.

AECOM — **LABORATORY TEST INSTRUCTION**

Project Title : **Task 1-111 A5 Warm mix Testing**	Prepared By : **NAL**
Job Number : **60523093**	Checked By : **JT**
Cost Code : **Warm mix cost code**	Date of Issue : **03 March 2017**
Location of Creation : **AECOM Nottingham, NG9 6RZ**	Project Deadline : **22 March 2017**

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Core	Layer	2. Bulk Density Using Density Method B & C	10. ITSM @ 20°C	17. WTT BS @ 60°C	Water sensitivity BS EN 12697-12 Method A	5. Binder Recover BS EN 12697-3, Followed by Empirical Pen and SP		11. Maximum Density		1. Air Voids Using Density Method B & C	Full Sweep DSR
		26	22	4	4	4		4		26	2
1	WMA Surface	x	x			x				x	x
1	WMA Binder	x	x		x		x			x	
2	WMA Surface	x	x			x Combine				x	x Combine
2	WMA Binder				Dry						
4	WMA Surface	x	x			x				x	x
4	WMA Binder	x	x		x		x Combine			x	
5	WMA Surface	x	x					x		x	
5	WMA Binder	x	x		x		x			x	
7	WMA Surface	x	x					x Combine		x	
7	WMA Binder	x	x		x Wet				x Combine	x	
8	WMA Surface	x	x					x		x	
8	WMA Binder	x	x		x				x	x	
9	HMA Surface	x	x			x				x	x
9	HMA Binder	x	x		x Dry		x			x	
10	HMA Surface	x	x			x Combine				x	x Combine
10	HMA Binder	x	x		x		x Combine			x	
12	HMA Surface	x	x			x				x	x
12	HMA Binder	x	x		x		x			x	
13	HMA Surface	x	x					x		x	
13	HMA Binder	x	x		x Wet				x	x	
15	HMA Surface	x	x					x Combine		x	
15	HMA Binder	x	x		x				x Combine	x	
16	HMA Surface	x	x					x		x	
16	HMA Binder										
3	WMA Binder	x		x						x	
6	WMA Binder	x		x						x	
11	HMA Binder	x		x						x	
14	HMA Binder	x		x						x	
	Site location: A5 between Grendon & Mancetter (WB)					Note: please ensure there's enough bitumen for tests					

Figure 5: Laboratory Test Instruction

*Samples were combined as indicated to produce sufficient sample size for testing.

4.1 Mixture Volumetrics

The bulk and maximum densities including the air void content test results are presented in Appendix C. The maximum densities of samples were measured in accordance with BS EN 12697-5. The bulk densities of the samples were measured in accordance with BS EN 12697-6 to Procedures B (Saturated Surface Dry – SSD) and Procedure C (Sealed).

As a guide, Annex A of the BS EN 12697-6 states that Procedure B – SSD method is most suited for continuously graded materials such as asphalt concrete (with relatively small pores) having void contents up to approximately 5%. For materials which give rise to large diameter voids in the specimen (e g. stone mastic asphalt) up to approximately 4%, the method is also applicable”. “Procedure C is more suitable for measuring the bulk density of bituminous specimens with air void levels up to 15%”.

The mixture volumetrics was obtained for both the surface and binder courses using an average of six cylindrical specimens cored from the site. The test results for both Procedures B and C are presented in Appendix C. Comparisons between the mixture volumetrics following testing of samples by AECOM in 2017 and TRL in 2014 (reported in PPR 742, 2014) is shown below in Figure 6.

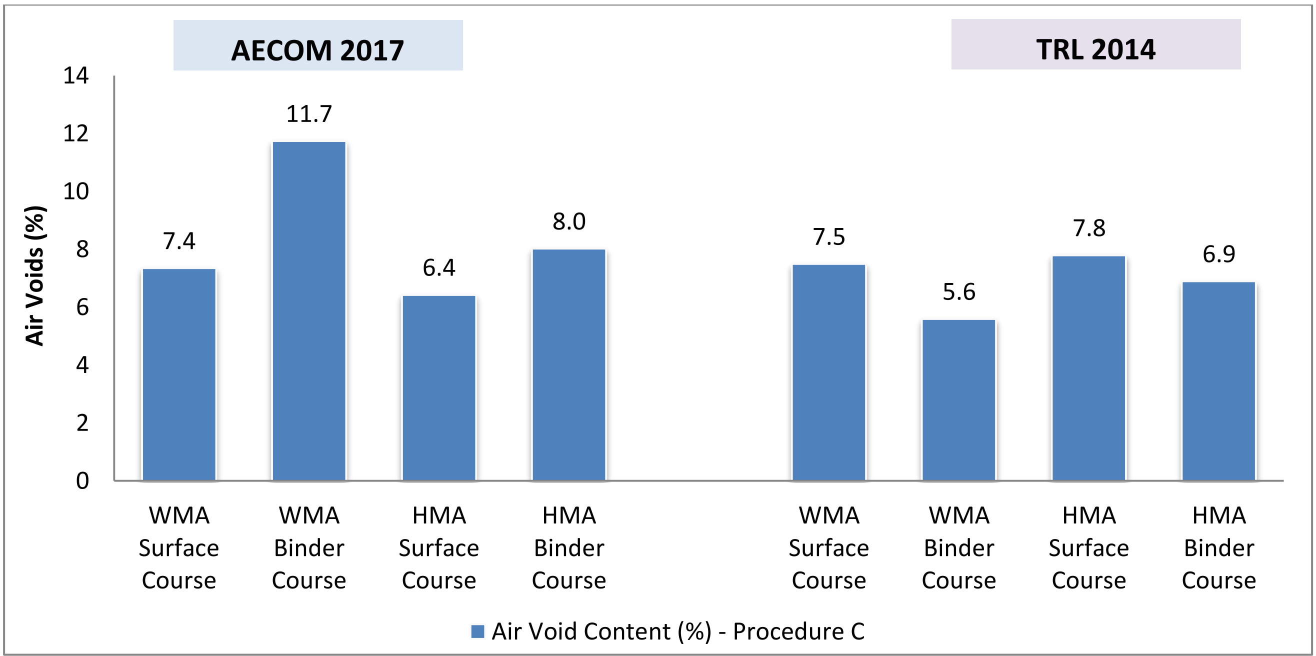

Figure 6: Air Voids Procedure C for AECOM 2017 and TRL 2014

It should be noted that TRL in 2014 analysed the same number of specimens but made use of laboratory manufactured slabs cored and tested in accordance with BS EN 12697-6 using three procedures: Procedure A (Dry), Procedure C (Sealed) and Procedure D (Dimensions) (Wayman et al., 2015). On this basis, the measured results are not directly comparable and the 2014 testing is not considered to accurately represent the material air voids in service. The air voids for WMA and HMA are higher than would be expected for AC 20 binder course materials. WMA binder course contains 25% recycled asphalt which could contribute to variation in density. This is because the specific gravity of the recycled material may vary to a greater extent than virgin material. PPR742, 2014 reports the average in-situ density measurements as 9.5% and 7.6% for WMA and HMA binder courses respectively. Air voids measured on binder course during this 2017 survey are higher than those recorded in situ.

4.2 Indirect Tensile Stiffness Modulus Test Results

The Indirect Tensile Stiffness Modulus (ITSM) test was conducted in accordance with BS EN 12697-26 at 20°C. The test results are presented in Appendix D. The test results are analysed and summarised below in Figure 7.

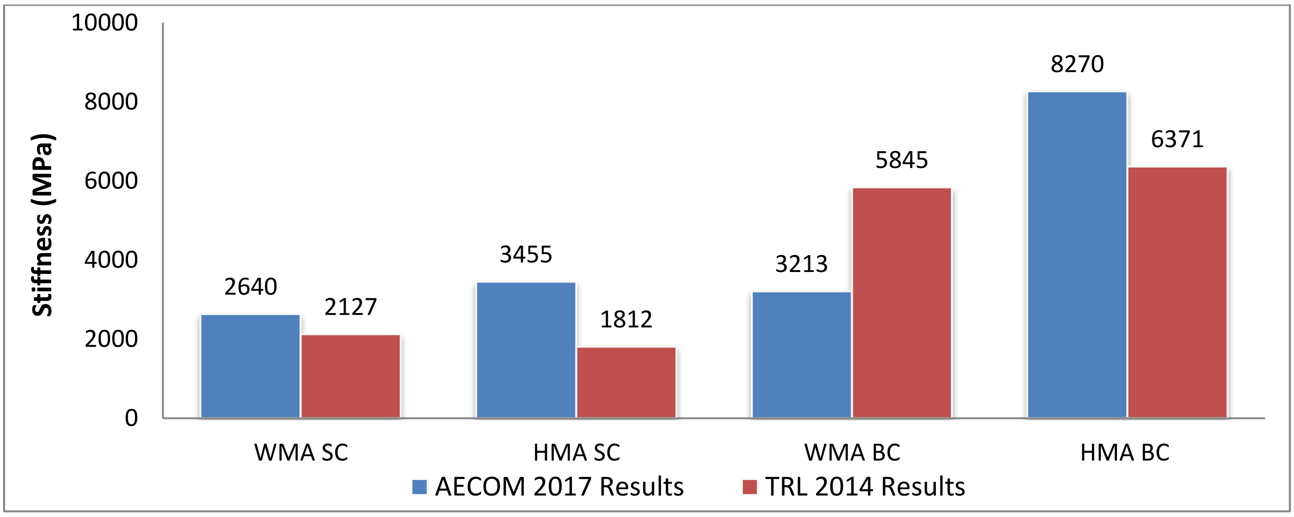

Figure 7: ITSM Test Results

The test results as conducted in 2017 by AECOM show that the HMA mixtures have higher stiffness values in comparison to the WMA mixtures for Surface Course (SC) and Binder Course (BC). AECOM 2017 stiffness results would be expected to be higher than testing conducted by TRL in 2014 due to binder ageing. However, TRL testing is based on laboratory manufactured samples whilst AECOM results are based on cores and therefore, results are not directly comparable.

4.3 Resistance to Permanent Deformation

Wheel Tracking Tests were conducted to ascertain the resistance of the asphalt mixtures to permanent deformation. The test was conducted in accordance with BS EN 12697-22, Procedure B in Air at 60°C. Two Binder Course (BC) samples were used in ascertaining resistance to permanent deformation of the WMA and HMA. Appendix E presents the wheel tracking test results. The mean rut profiles are shown below in Figure 8.

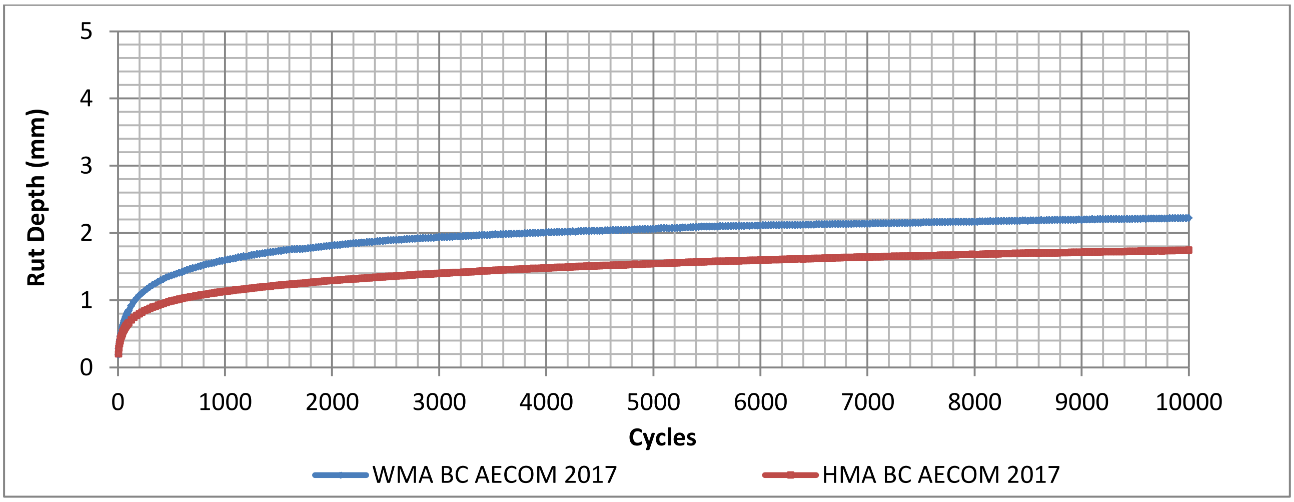

Figure 8: Rut Profile - AECOM 2017

Table 8 presents wheel track slope and proportional rut depth results from AECOM 2017 survey. These results were not available in the TRL report.

Table 8: Wheel tracking results with small scale device

	AECOM 2017	
Material	**Mean wheel track slope (WTS_{AIR} mm/1000cycles)**	**Mean Proportional Rut Depth (PRD %)**
WMA BC	0.03	5.8
HMA BC	0.04	4.2

Figure 9 shows that the rut depth profile of the WMA and HMA materials with rut depths < 3 mm after 10,000 cycles at 60°C (Procedure B).

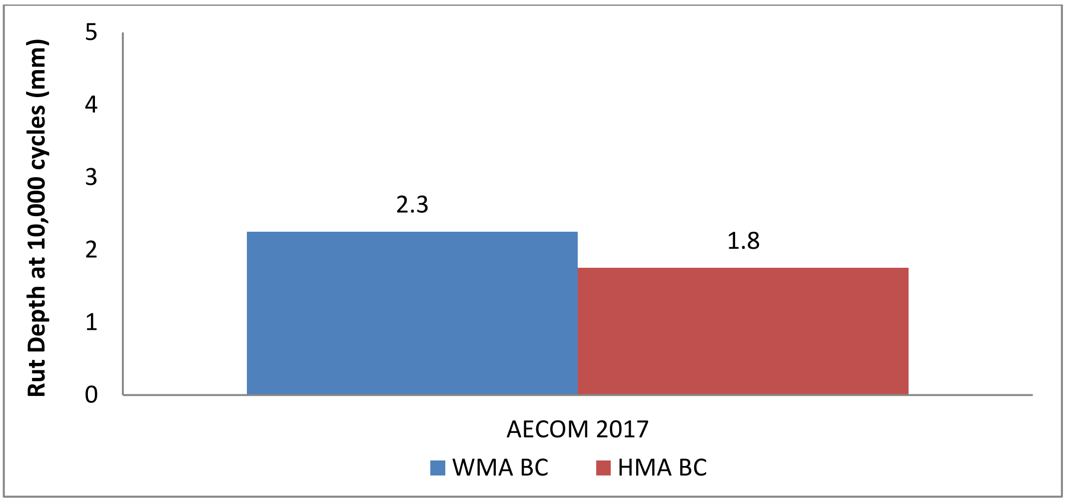

Figure 9: Rut Depth at 10,000 Cycles - AECOM 2017

Figure 10 shows the rut depth at 1,000 cycles (Procedure A) used in comparing the resistance to permanent deformation of the AECOM 2017 samples WMA and HMA BC mix. Both rut depths were found to be < 3 mm.

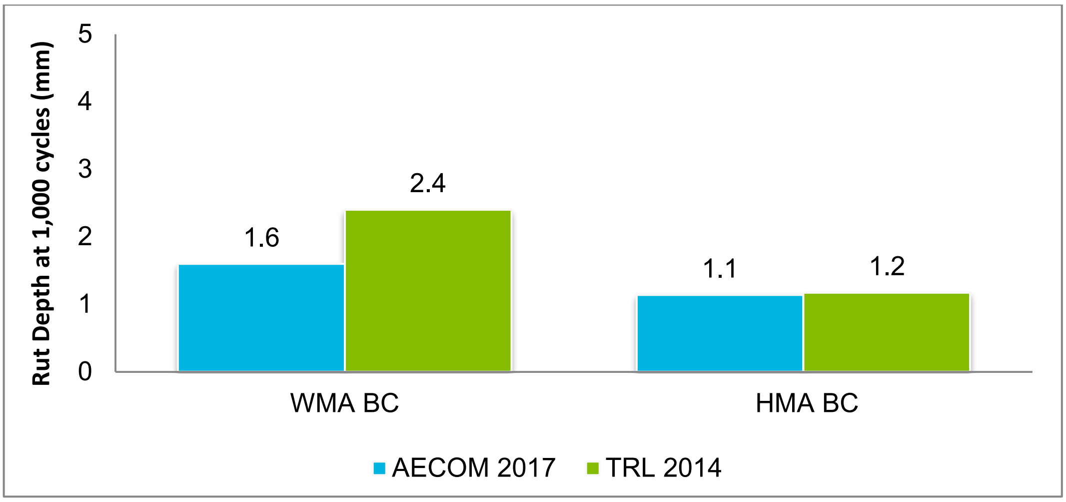

Figure 10: Comparing Rut Depths at 1,000 cycles for AECOM 2017 and TRL 2014

Note for Figure 10: TRL results are based on laboratory compacted samples and not cored samples from the site. Further to this, BS EN 12697-22 Procedure A was followed in ascertaining the rut depth profile.

4.4 Water Sensitivity

Moisture damage can be defined as the loss of strength of asphalt mixtures due to the presence of water. Moisture damage accelerates as moisture permeates and weakens the mastic, making it more susceptible to damage following cyclic loading.

Resistance to moisture damage is evaluated by means of the water sensitivity test in accordance with BS EN 12697- 12 using Method A for the Indirect Tensile Stiffness Ratio, ITSR. Ten cylindrical cored specimens, extracted from the site were split into two subsets. Each one is tested for tensile strength at 20°C.

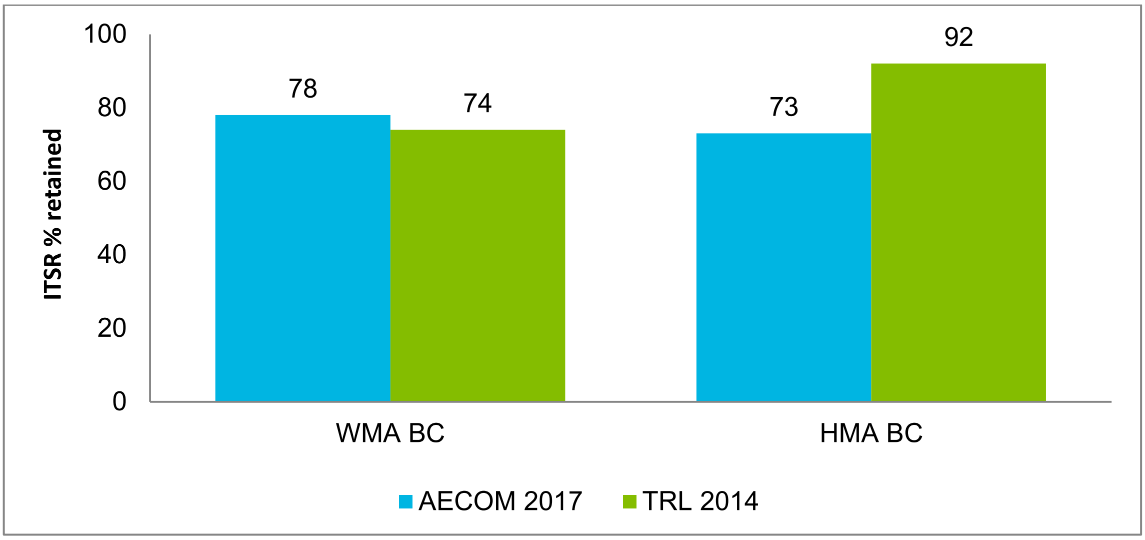

Figure 11: Water Sensitivity Test Results at 20°C

Figure 11 shows that the ITSR values for all the binder course mixtures are above 70% which suggests good resistance to water damage. The WMA BC showed similar test results between the AECOM and TRL samples. The HMA had variable test results with values of 92% for the TRL sample in comparison to 73%. It must be noted that samples used for testing by TRL were laboratory manufactured as opposed to samples obtained from the site. Similar ITSR values are obtained from WMA and HMA mixtures (AECOM and TRL).

4.5 Binder Analysis

The original binder properties used in producing the WMA and HMA are detailed below:

I.	Mixture 1	WMA	Binder Course	AC 20 HDM bin 40/60 design
II.	Mixture 2	WMA	Surface Course	AC 14 surface PMB PSV 65
III.	Mixture 3	HMA	Binder Course	AC 20 HDM bin 40/60 design
IV.	Mixture 4	HMA	Surface Course	AC 14 surface PMB PSV 65

The Dynamic Shear Rheometer (DSR) was used to evaluate and provide insight into the rheological properties of the recovered bitumen from the Grendon to Mancetter pavement scheme. The binder was recovered using the rotatory evaporator in accordance with BS EN 12697-3 (CEN, 2005a). Following recovery of the binder, the penetration and a softening point of the binders were obtained in accordance with BS EN 1426 (CEN, 2007a) and BS EN 1427 (CEN, 2007b) respectively. These result sheets are presented in Appendix F.

Table 9 summarises the penetration and softening point test results for the samples recovered from the site by AECOM.

Table 9: Recovered Binder Properties – AECOM 2017

	2017 Site Review		
	Layer	Penetration [dmm]	Softening Point [°C]
Warm Mix Asphalt	Surface Course	87	49.0
	Binder Course	42	63.8
Hot Mix Asphalt	Surface Course	82	50.4
	Binder Course	50	55.2

The test results show that the recovered binder for the binder course has not aged significantly taking into account the fact that a 40/60 paving grade bitumen was used in producing the asphalt mixtures. To check these properties, the HMA binder course recovered bitumen was placed in the oven at 70^{o}C overnight, then had further time on the rotary evaporator and were retested. The penetration grade did not change significantly following this process. To check these properties, the HMA binder course recovered bitumen was placed in the oven at 70^{o}C overnight, then had further time on the rotary evaporator and were retested. The penetration grade did not change significantly following this process.

Evaluating test results provided by TRL in 2014, it was observed that the penetration and softening point test results were completed only for the binder course. The penetration and softening point test results are shown in Table 10.

Table 10: Recovered Binder Properties – TRL 2014 (PPR742, 2014)

	TRL 2014		
	Layer	Penetration (dmm)	Softening Point (°C)
Warm Mix Asphalt	Surface Course	-	-
	Binder Course	28	60.2
Hot Mix Asphalt	Surface Course	-	-
	Binder Course	22	64.2

The major observation taking into account test results as presented in Table 10 was in the reported penetration values which show significantly lower penetration values (28 dmm and 22 dmm) for the new binder course asphalt mixtures than would be expected for the relatively unaged 40/60 penetration grade bitumen.

The binder rheological properties were tested in accordance with BS EN 14770. The complex modulus as a function of the temperature is presented below in Figure 12. The test was conducted for the surface course WMA and HMA mixtures.

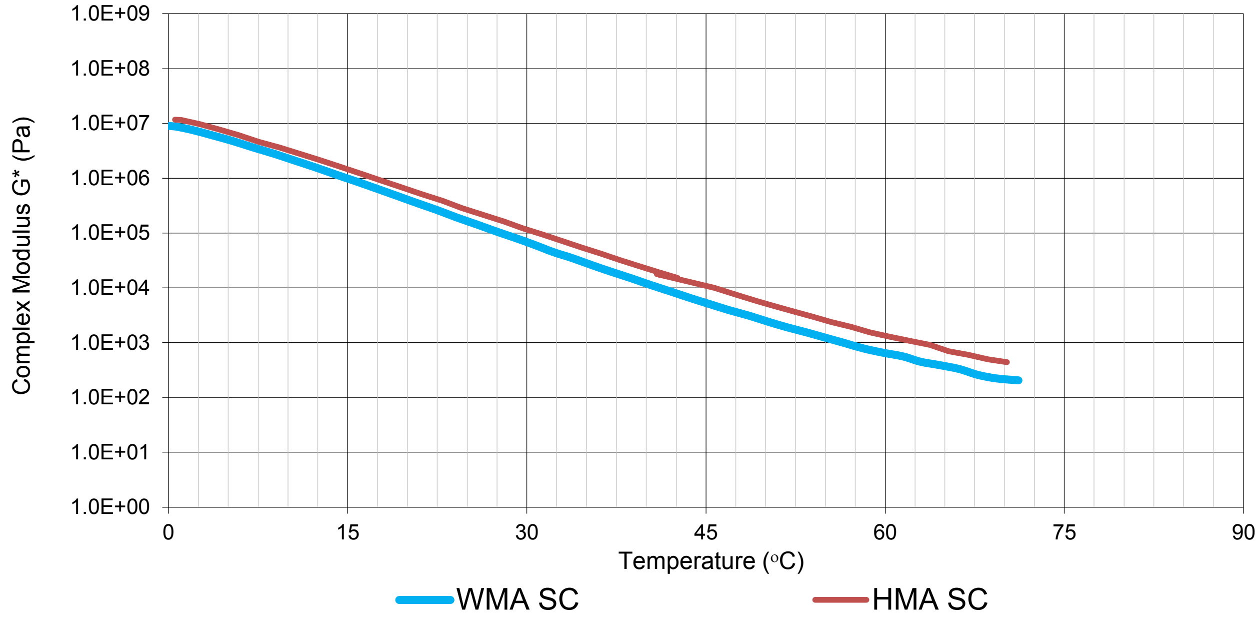

Figure 12: Complex Modulus vs Temperature

Figure 13 presents a plot of the phase angle as a function of temperature. The result shows that at increasing temperatures, the phase angles increase to a more viscous state.

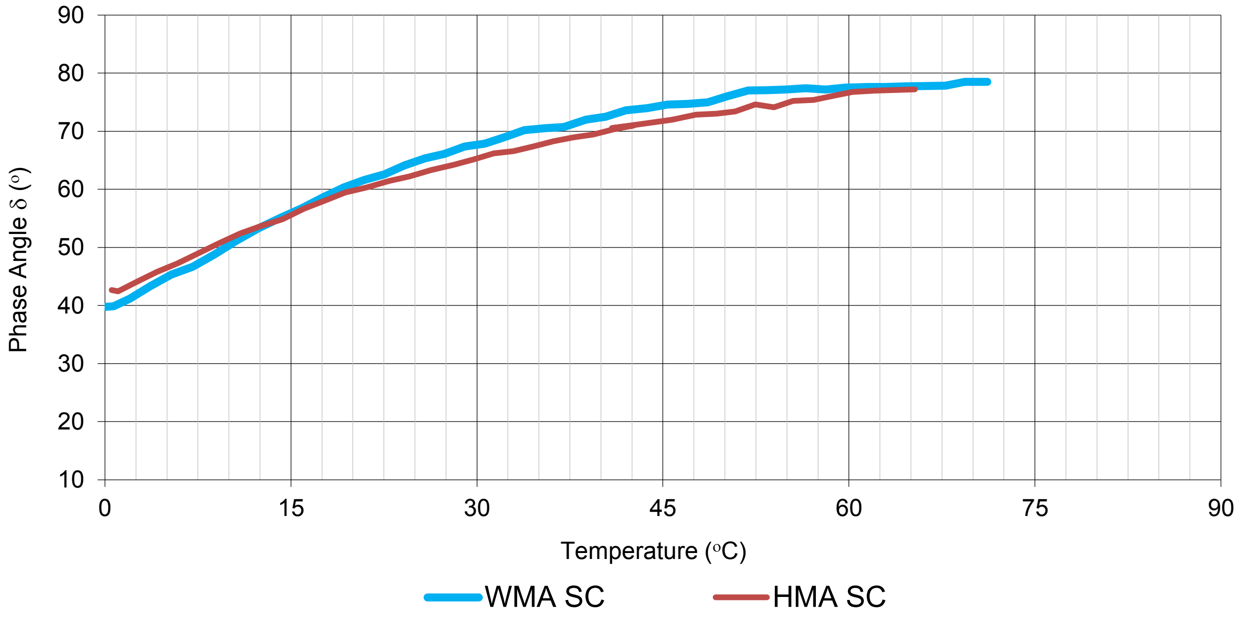

Figure 13: Phase Angle vs Temperature

Figure 12 and Figure 13 shows similar binder rheological properties between the WMA and the HMA Surface Course (SC). This indicates that most probably, the same PMB was used in the production of the asphalt mixtures. The initial/original rheological properties of the PMB were not available to facilitate further comparative analysis.

5. Conclusions

The demonstration site on the Grendon to Mancetter pavement scheme of the A5 provides the comparative performance of WMA manufactured using foaming technology and HMA binder and surface courses. The scope of the work was to review and evaluate the mechanical and performance characteristics of the Warm Mix Asphalt (WMA) installed on the Grendon to Mancetter pavement scheme of the A5 in 2014 and provide a detailed report on findings from the investigation. The surveys and tests undertaken comprised of Visual Condition Survey (VCS), Coring Survey, Mixture Volumetrics, Indirect Tensile Stiffness Modulus (ITSM) tests, Resistance to Permanent Deformation, Moisture Susceptibility Tests and Binder Rheology using the Dynamic Shear Rheometer (DSR).

The VCS and cores suggest that the underlying site conditions may have had a significant influence on its suitability as a trial site. Given the deterioration of the underlying base course, and lack of bond between layers, this seems to have influenced the performance of both the HMA and WMA and as such it may not be advisable to draw weighty conclusions on the performance of WMA on the basis of this demonstration site alone. It would be difficult to conclude that WMA (or HMA) on this site has performed "better (or worse)" or in excess of reasonable expectations. TRL PPR742, 2014 also indicates challenges experienced in performing the trial which may have additionally adversely influenced the general outcome.

The VCS showed that the most common defects include longitudinal and traverse surface cracking, depressions or signs of rutting on certain sections of the road surface, crazing of the surface and loss of aggregate (fretting). In general, the WMA section exhibited more signs of deterioration than HMA. However, many of the defects are suspected to be attributed to issues in the underlying layers and possible subsidence and as such the support provided by the pavement foundation may not be uniform across the sections. A visual survey was undertaken by TRL before the demonstration scheme took place (reported in PPR742, 2014) exhibited similar defects in the same locations. The coring information showed a significant lack of bond between the asphalt and concrete layers irrespective of the section in which the cores were obtained from and the 3rd asphalt layer (existing material not replaced as part of the demonstration works) was in poor condition and deteriorated during the coring operation.

The air void contents reported varied significantly and were found to be higher than expected. Higher air void contents may indicate that these asphalt materials could be susceptible to increased oxidation and permeability. WMA air voids were found to be higher than HMA. High air voids may result in increased susceptibility to the ingress of water into the pavement structure.

The mean rut depths for the WMA and HMA binder course were < 3 mm after 10,000 cycles (tested at 60°C in accordance with BS EN 12697-22). WMA rut depth was found to be slightly higher than HMA which could be attributed to higher air voids, the difference in grading which may be associated with the recycled content, or possibly the binder properties. The proportional rut depth and wheel track slope fall within specified limits outlined in PD 9961:2015 Table B4 for asphalt concrete for very heavily stressed sites requiring very high rut resistance.

The samples tested for moisture susceptibility showed ITSR values for all the binder course mixtures exceeded 70% indicating adequate resistance to water damage of the mixtures. The binder test results recovered from AECOM in 2017 show penetration grade values of 42 dmm and 50 dmm. The penetration grades measured for the WMA and HMA binder course materials are higher than expected for material which has gone through the installation process and has been in service for three years.

The recycled content of the mixtures may have an effect on the recovered binder properties and it is noted that the WMA binder course had a higher proportion of reclaimed asphalt than the HMA. It is not known whether the virgin bitumen added was of a softer grade than 40/60 pen to enable the overall penetration grade to fall within the required range. In addition, the recovered binder properties were higher than those measured by TRL in 2014. This may be due to a difference in sample preparation (recovered from cores vs bulk plant material) or it could be attributed to variation in the recycled components. Details of the PMB used for the surface course were not provided. The WMA and HMA PMB penetration grades were found to be similar with WMA having slightly higher penetration grade and lower softening point than HMA surface course which agrees with the hypothesis that WMA undergoes less heating and ageing during installation.

Findings related to the bitumen properties did not present a clear benefit in performance or ageing of the WMA in comparison to the HMA materials. However, visual condition along with air void content suggests that the HMA is in a better condition than the WMA.

6. Recommendations

It is understood that maintenance of the trial site was undertaken in June 2017 to address the defects associated with underlying issues at the site. As such the trial site is no longer available for further monitoring.

Track record on the use of WMA in the UK and overseas suggested many benefits including good in service performance. WMA is used as standard in a number of Local Authorities, for example Norfolk CC and Staffordshire CC. In addition, WMA has been used on the Strategic Road Network on major roads with Departures having been approved for schemes with short possession to enable a shorter period prior to overlay and opening to traffic. It is therefore recommended to further explore the potential benefits from using WMA by monitoring other existing WMA asphalt sites in the UK and carrying out further trials involving different types of WMA to monitor their performance in service. This will allow developing best practice guide for design, selection and installation of WMA to meet performance requirements for use on strategic road network.

References

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British Standards Institution, "Bituminous mixtures – Test methods for hot mix asphalt. Part 1: Soluble Binder Content", BS EN 12697-1: 2012.

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British Standards Institution, "Bituminous mixtures – Test methods for hot mix asphalt. Part 5: Determination of maximum density of bituminous specimens", BS EN 12697-5: 2009.

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Appendix A - Visual Condition Survey

Appendix A – Visual Condition Surveys

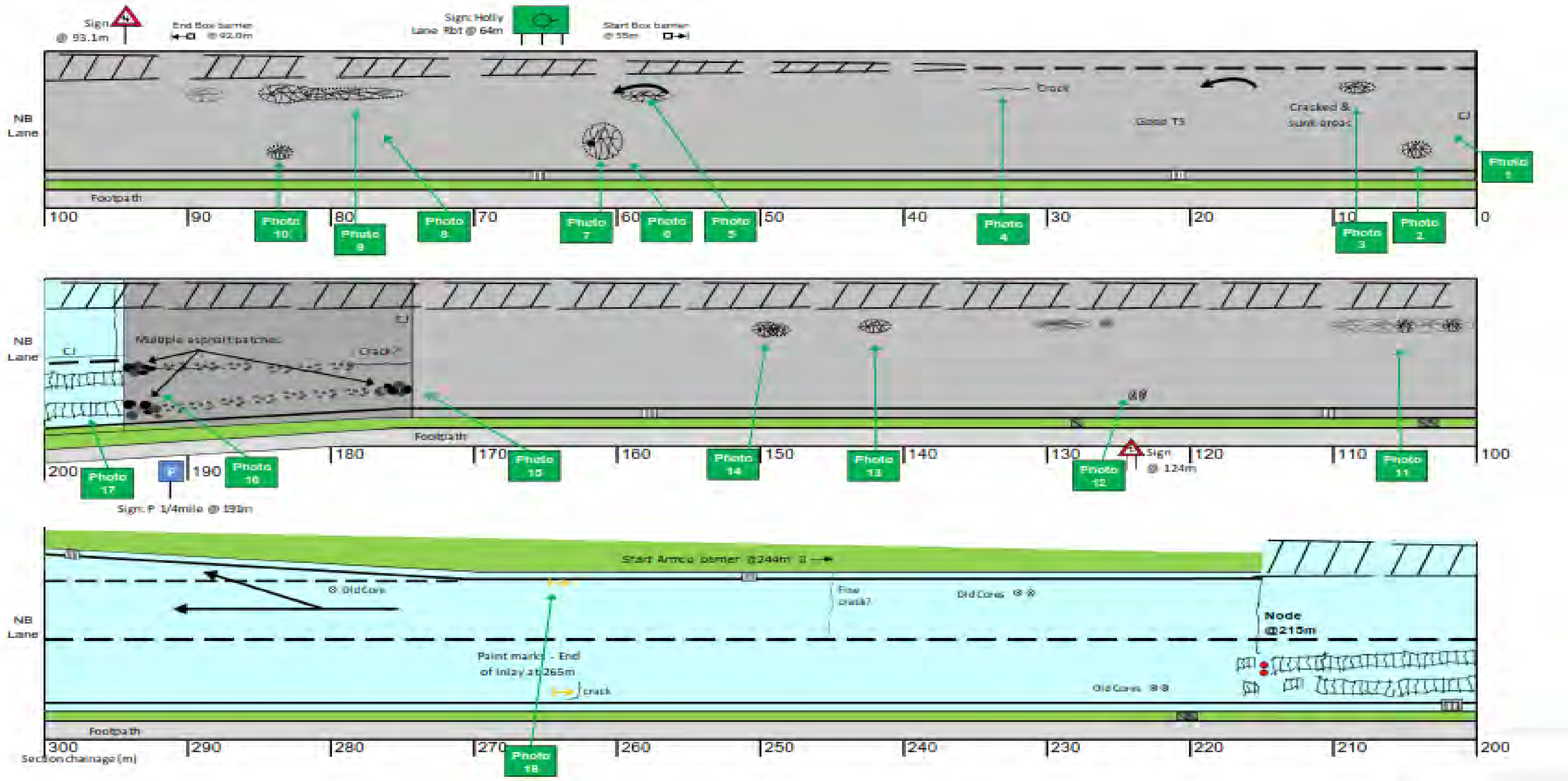


Figure A.1-1: Visual Condition Surveys Conducted by TRL in 2014

Annotation	Description
	Patch (✓ Ok, X Failed)
	Fatting (Major)
	Fatting (Minor)
	Fretting (Major)
	Fretting (Minor)
	Settlement (Major)
	Settlement (Minor)
	Crazing (Major)
	Crazing (Minor)
	Existing Coring Location
C1	Proposed Coring Location (Number) 150 mm / 200 mm
	Open Joint (F=fine, M=Medium, W=Wide)
	Construction Joint
	Pothole
	Gulley
	Manhole
	Edge Cracking
	Longitudinal Crack (W-wide, M-medium, F-fine)
	Transverse Crack (W-wide, M-medium, F-fine)
	Rut (Minor)
	Rut (Major)
	Induction Loops
4	Photograph Locations

AECOM
12 Regan Way
Chetwynd Business Park
Nottingham, UK
T +44-115-907-7000
aecom.com

Do Not Scale this Sketch

Project
Task 1-111 Collaborative Research Sub Task 2

Title
A5 Grendon to Mancetter Warm mix asphalt dominstration site

Surveyed By:	Drawn By:
Tom Bexton	Steve Pinder
Revision: 0	Chcked By: Jessica Tuck

Drawing No.: 554218_VCS_1

Appendix B – Core Log Information

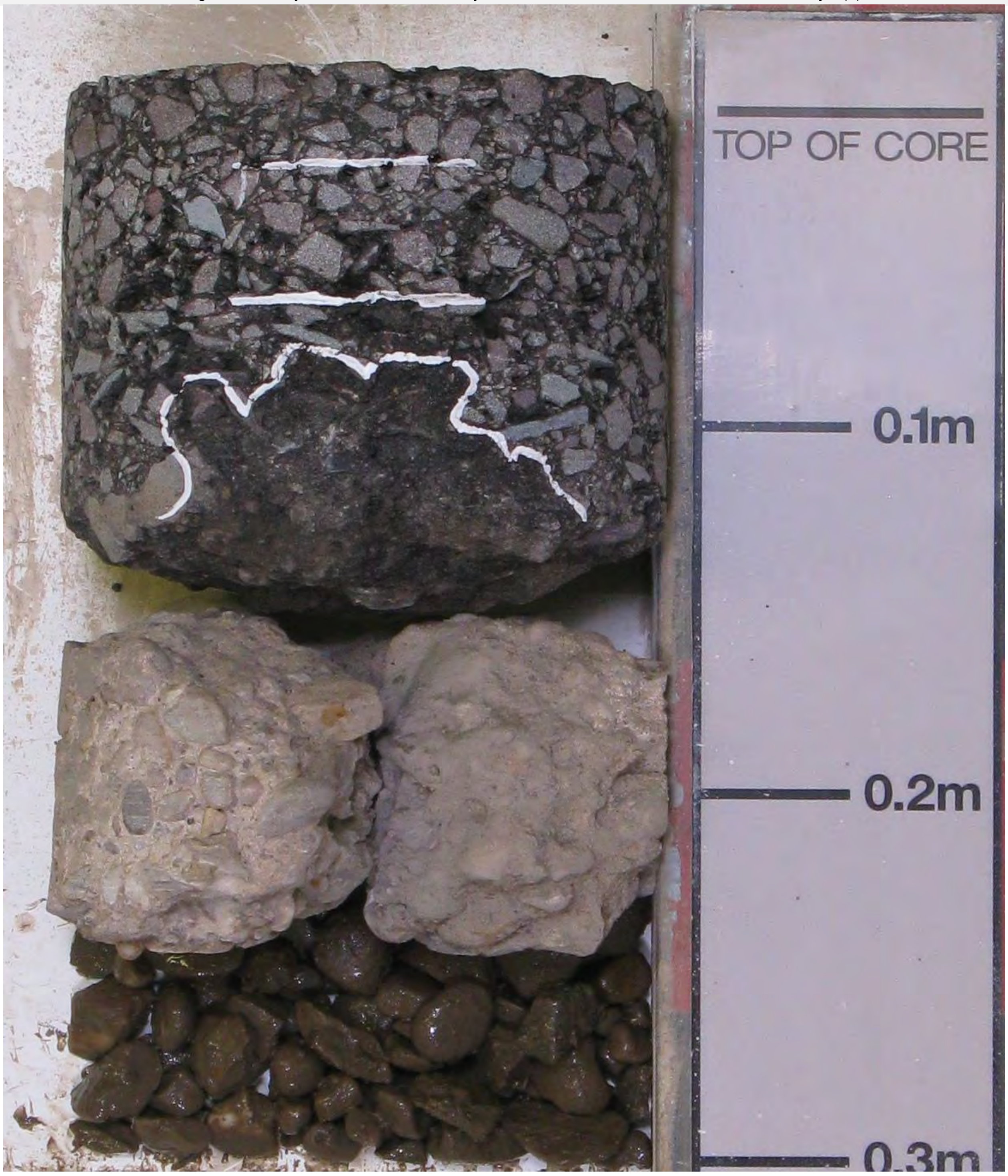
CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

Job Number :	**60523093**	Scheme :	**Task 1-111 A5 Warm mix Trials**
Sample Number :	**CR 01096**	Location :	**Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.66m**
Core Number :	**01**		**Survey Ch. 5m**
Cored / Logged By :	**TB / RBB**		
Date Cored / Logged :	**13-02-17 / 22-02-17**		**OSGR: SP 29510, 98451**
Nominal Diameter :	**150mm**		**Notes: Cored adjacent to area of Crazing and Depression**

Layer	Depth (mm)		Thickness (mm)	Material Description [1]	Suitable for NAT/CS Testing (Yes/No)	PAK-Marker [2]	Binder [3]	Aggregate	
	From	To						Size [4]	Type
1	0	28	28	Asphalt Surfacing	No	-ve	Bitumen	14	Crushed Rock
2	28	64	36	Asphalt Concrete (voided)	Yes	-ve	Bitumen	14	Crushed Rock
3	64	140	76	Asphalt Concrete (broken @ base and voided)	No	Inconclusive	Inconclusive	20	Crushed Rock
				Layers 3 & 4 Not Bonded					
4	140	300	160	Concrete - Type D Voids (broken up)	No	n/a	Cement	20	Crushed Rock/Gravel
				Loose Granular Material					

Notes : The scale is for guidance only. It does not necessarily reflect the actual thicknesses of individual layer(s).



Material Description [1]
The material description given (such as hot rolled asphalt or asphalt concrete) is generic only and is based upon a visual assessment of the material. Similarly, use of additional descriptive (such as voided) is based on visual assessment only and the relationship between air voids visually to the naked eye and degree of compaction is complex and materials specific.

PAK-Marker (PAH Spray) [2]
The Tar Spray Test is a rapid, qualitative indicator of the presence of polyaromatic compounds (PACs) typically found in tar. PACs also exist in other road construction materials (e.g. bitumen and cutbacks like kerosene), but at low concentrations. The probability of obtaining a false positive result in the tar spray test with such materials is low, and a positive result in the tar spray test is a strong (but not definitive) indicator of the presence of tar. For quantitative results, this test should be considered in conjunction with the results from other tests (i.e. Total Polynuclear Aromatic Hydrocarbons (PAH) by Gas Chromatography - Flame Ionisation Detection (GC-FID)).

Binder [3]
The binder type is assessed based on visual and aromatic inspection. The PAK-Marker result is also considered.

Aggregate Size [4]
The sizes indicated are given as the best estimate of the nominal size of the material.

CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

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Cored / Logged By :	**TB / RBB**		
Date Cored / Logged :	**13-02-17 / 22-02-17**		**OSGR: SP 29510, 98451**
Nominal Diameter :	**150mm**		**Notes: Cored adjacent to area of Crazing and Depression**

ROAD

CORE

HOLE

CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

Job Number :	**60523093**	Scheme :	**Task 1-111 A5 Warm mix Trials**
Sample Number :	**CR 01096**	Location :	**Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.65m**
Core Number :	**02**		**Survey Ch. 15m**
Cored / Logged By :	**TB / RBB**		
Date Cored / Logged :	**13-02-17 / 22-02-17**		**OSGR: SP 29502, 98456**
Nominal Diameter :	**150mm**		**Notes: N/A**

Layer	Depth (mm)		Thickness (mm)	Material Description [1]	Suitable for NAT/CS Testing (Yes/No)	PAK-Marker [2]	Binder [3]	Aggregate	
	From	To						Size [4]	Type
1	0	47	47	Asphalt Surfacing	Yes	-ve	Bitumen	14	Crushed Rock
2	47	140	93	Asphalt Concrete (broken @ base and top)	No	-ve	Bitumen	20	Crushed Rock
				Layers 2 & 3 Not Bonded					
3	140	255	115	Concrete - Type D Voids (broken up)	No	n/a	Cement	32	Crushed Rock
				Layers 3 & 4 Not Bonded					
4	255	350	95	Concrete - Type B Voids (broken @ base)	No	n/a	Cement	32	Crushed Rock/Gravel
				Loose Granular Material					

Notes : The scale is for guidance only. It does not necessarily reflect the actual thicknesses of individual layer(s).

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Binder [3]

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Aggregate Size [4]

The sizes indicated are given as the best estimate of the nominal size of the material.

CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

Job Number :	**60523093**	Scheme :	**Task 1-111 A5 Warm mix Trials**
Sample Number :	**CR 01096**	Location :	**Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.65m**
Core Number :	**02**		**Survey Ch. 15m**
Cored / Logged By :	**TB / RBB**		
Date Cored / Logged :	**13-02-17 / 22-02-17**		**OSGR: SP 29502, 98456**
Nominal Diameter :	**150mm**		**Notes: N/A**

ROAD

CORE

HOLE

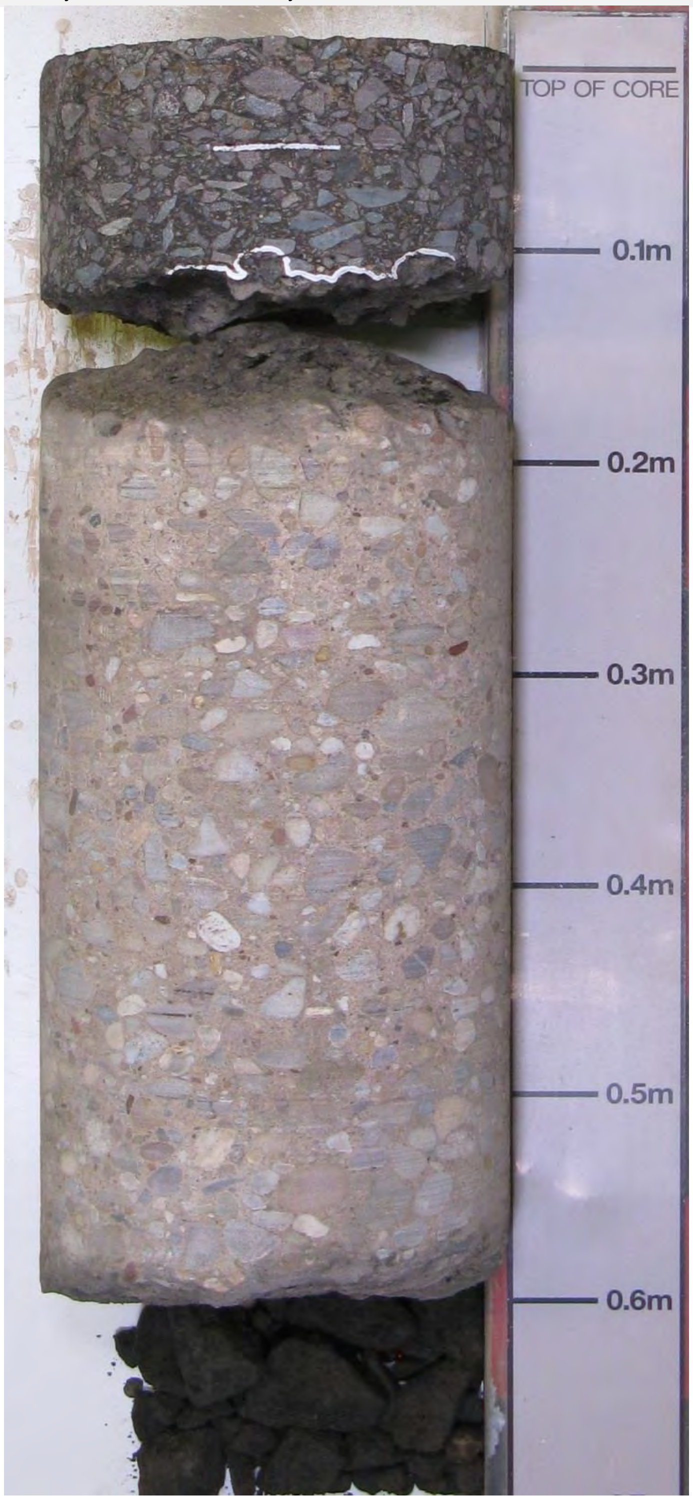
CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

Job Number :	**60523093**	Scheme :	**Task 1-111 A5 Warm mix Trials**
Sample Number :	**CR 01096**	Location :	**Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.67m**
Core Number :	**03**		**Survey Ch. 25m**
Cored / Logged By :	**TB / RBB**		
Date Cored / Logged :	**13-02-17 / 22-02-17**		**OSGR: SP 29459, 98461**
Nominal Diameter :	**200mm**		**Notes: N/A**

Layer	Depth (mm)		Thickness (mm)	Material Description [1]	Suitable for NAT/CS Testing (Yes/No)	PAK-Marker [2]	Binder [3]	Aggregate	
	From	To						Size [4]	Type
1	0	50	50	Asphalt Surfacing	Yes	-ve	Bitumen	14	Crushed Rock
2	50	130	80	Asphalt Concrete (broken @ base)	Yes	-ve	Bitumen	20	Crushed Rock
				Layers 2 & 3 Not Bonded					
3	130	580	450	Concrete - Type B Voids (broken @ base)	Yes	n/a	Cement	20	Crushed Rock/Gravel
				Loose Granular Material					

Notes : The scale is for guidance only. It does not necessarily reflect the actual thicknesses of individual layer(s).



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Binder [3]
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Aggregate Size [4]
The sizes indicated are given as the best estimate of the nominal size of the material.

AECOM

CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

Job Number :	**60523093**	Scheme :	**Task 1-111 A5 Warm mix Trials**
Sample Number :	**CR 01096**	Location :	**Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.67m**
Core Number :	**03**		**Survey Ch. 25m**
Cored / Logged By :	**TB / RBB**		
Date Cored / Logged :	**13-02-17 / 22-02-17**		**OSGR: SP 29459, 98461**
Nominal Diameter :	**200mm**		**Notes: N/A**

ROAD

CORE

HOLE

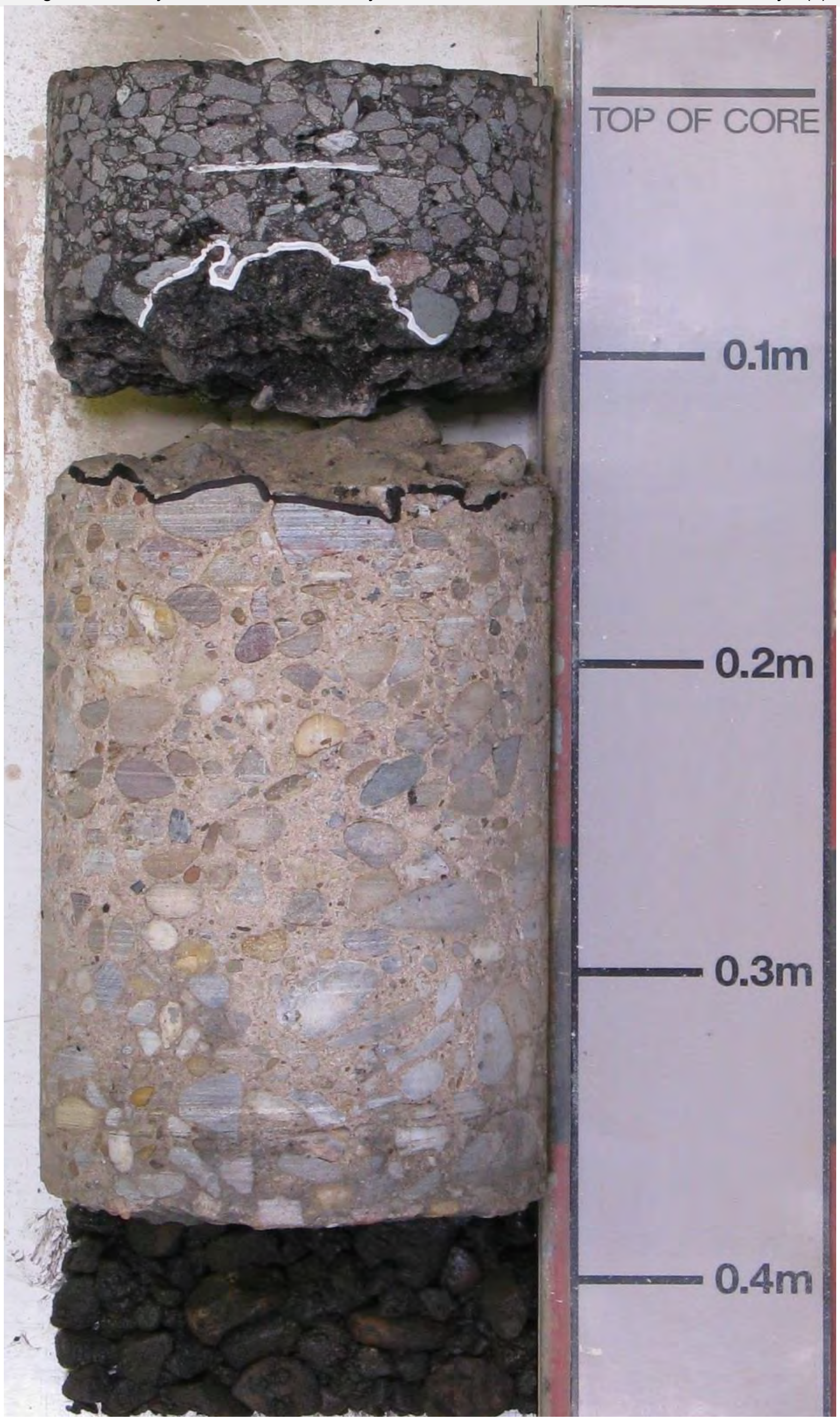
CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

Job Number :	**60523093**	Scheme :	**Task 1-111 A5 Warm mix Trials**
Sample Number :	**CR 01096**	Location :	**Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.65m**
Core Number :	**04**		**Survey Ch. 35m**
Cored / Logged By :	**TB / RBB**		
Date Cored / Logged :	**13-02-17 / 22-02-17**		**OSGR: SP 29487, 98464**
Nominal Diameter :	**150mm**		**Notes: N/A**

Layer	Depth (mm)		Thickness (mm)	Material Description [1]	Suitable for NAT/CS Testing (Yes/No)	PAK-Marker [2]	Binder [3]	Aggregate	
	From	To						Size [4]	Type
1	0	35	35	Asphalt Surfacing	Yes	-ve	Bitumen	14	Crushed Rock
2	35	110	75	Asphalt Concrete (broken @ base)	No	-ve	Bitumen	20	Crushed Rock
				Layers 2 & 3 Not Bonded					
3	110	368	258	Concrete - Type B Voids (broken @ top)	Yes	n/a	Cement	32	Crushed Rock/Gravel
				Loose Granular Material					

Notes : The scale is for guidance only. It does not necessarily reflect the actual thicknesses of individual layer(s).



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Binder [3]

The binder type is assessed based on visual and aromatic inspection. The PAK-Marker result is also considered.

Aggregate Size [4]

The sizes indicated are given as the best estimate of the nominal size of the material.

AECOM

CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

UKAS TESTING 4410

Job Number :	**60523093**	Scheme :	**Task 1-111 A5 Warm mix Trials**
Sample Number :	**CR 01096**	Location :	**Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.65m**
Core Number :	**04**		**Survey Ch. 35m**
Cored / Logged By :	**TB / RBB**		
Date Cored / Logged :	**13-02-17 / 22-02-17**		**OSGR: SP 29487, 98464**
Nominal Diameter :	**150mm**		**Notes: N/A**

ROAD

CORE

HOLE

CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

Job Number :	**60523093**	Scheme :	**Task 1-111 A5 Warm mix Trials**
Sample Number :	**CR 01096**	Location :	**Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.56m**
Core Number :	**05**		**Survey Ch. 45m**
Cored / Logged By :	**TB / RBB**		
Date Cored / Logged :	**13-02-17 / 22-02-17**		**OSGR: SP 29477, 98468**
Nominal Diameter :	**150mm**		**Notes: N/A**

Layer	Depth (mm)		Thickness (mm)	Material Description [1]	Suitable for NAT/CS Testing (Yes/No)	PAK-Marker [2]	Binder [3]	Aggregate	
	From	To						Size [4]	Type
1	0	35	35	Asphalt Surfacing	Yes	-ve	Bitumen	14	Crushed Rock
2	35	75	40	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
3	75	135	60	Asphalt Concrete (broken @ base)	No	-ve	Bitumen	20	Crushed Rock
				Layers 3 & 4 Not Bonded					
4	135	310	175	Concrete - Type B Voids (broken up)	No	n/a	Cement	20	Crushed Rock/Gravel
				Loose Granular Material					

Notes : The scale is for guidance only. It does not necessarily reflect the actual thicknesses of individual layer(s).

Material Description [1]

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PAK-Marker (PAH Spray) [2]

The Tar Spray Test is a rapid, qualitative indicator of the presence of polyaromatic compounds (PACs) typically found in tar. PACs also exist in other road construction materials (e.g. bitumen and cutbacks like kerosene), but at low concentrations. The probability of obtaining a false positive result in the tar spray test with such materials is low, and a positive result in the tar spray test is a strong (but not definitive) indicator of the presence of tar. For quantitative results, this test should be considered in conjunction with the results from other tests (i.e. Total Polynuclear Aromatic Hydrocarbons (PAH) by Gas Chromatography - Flame Ionisation Detection (GC-FID)).

Binder [3]

The binder type is assessed based on visual and aromatic inspection. The PAK-Marker result is also considered.

Aggregate Size [4]

The sizes indicated are given as the best estimate of the nominal size of the material.

CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

Job Number :	**60523093**	Scheme :	**Task 1-111 A5 Warm mix Trials**
Sample Number :	**CR 01096**	Location :	**Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.56m**
Core Number :	**05**		**Survey Ch. 45m**
Cored / Logged By :	**TB / RBB**		
Date Cored / Logged :	**13-02-17 / 22-02-17**		**OSGR: SP 29477, 98468**
Nominal Diameter :	**150mm**		**Notes: N/A**

ROAD

CORE

HOLE

CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

Job Number :	60523093	Scheme :	Task 1-111 A5 Warm mix Trials
Sample Number :	CR 01096	Location :	Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.69m
Core Number :	06		Survey Ch. 55m
Cored / Logged By :	TB / RBB		
Date Cored / Logged :	14-02-17 / 22-02-17		OSGR: SP 29465, 98473
Nominal Diameter :	200mm		Notes: N/A

Layer	Depth (mm)		Thickness (mm)	Material Description [1]	Suitable for NAT/CS Testing (Yes/No)	PAK-Marker [2]	Binder [3]	Aggregate	
	From	To						Size [4]	Type
1	0	50	50	Asphalt Surfacing	Yes	-ve	Bitumen	14	Crushed Rock
2	50	170	120	Asphalt Concrete (broken @ base)	Yes	-ve	Bitumen	20	Crushed Rock
				Layers 2 & 3 Not Bonded					
3	170	340	170	Concrete - Type B Voids (broken @ base)	No	n/a	Cement	32	Crushed Rock/Gravel
				Concrete Layer Not Recovered					

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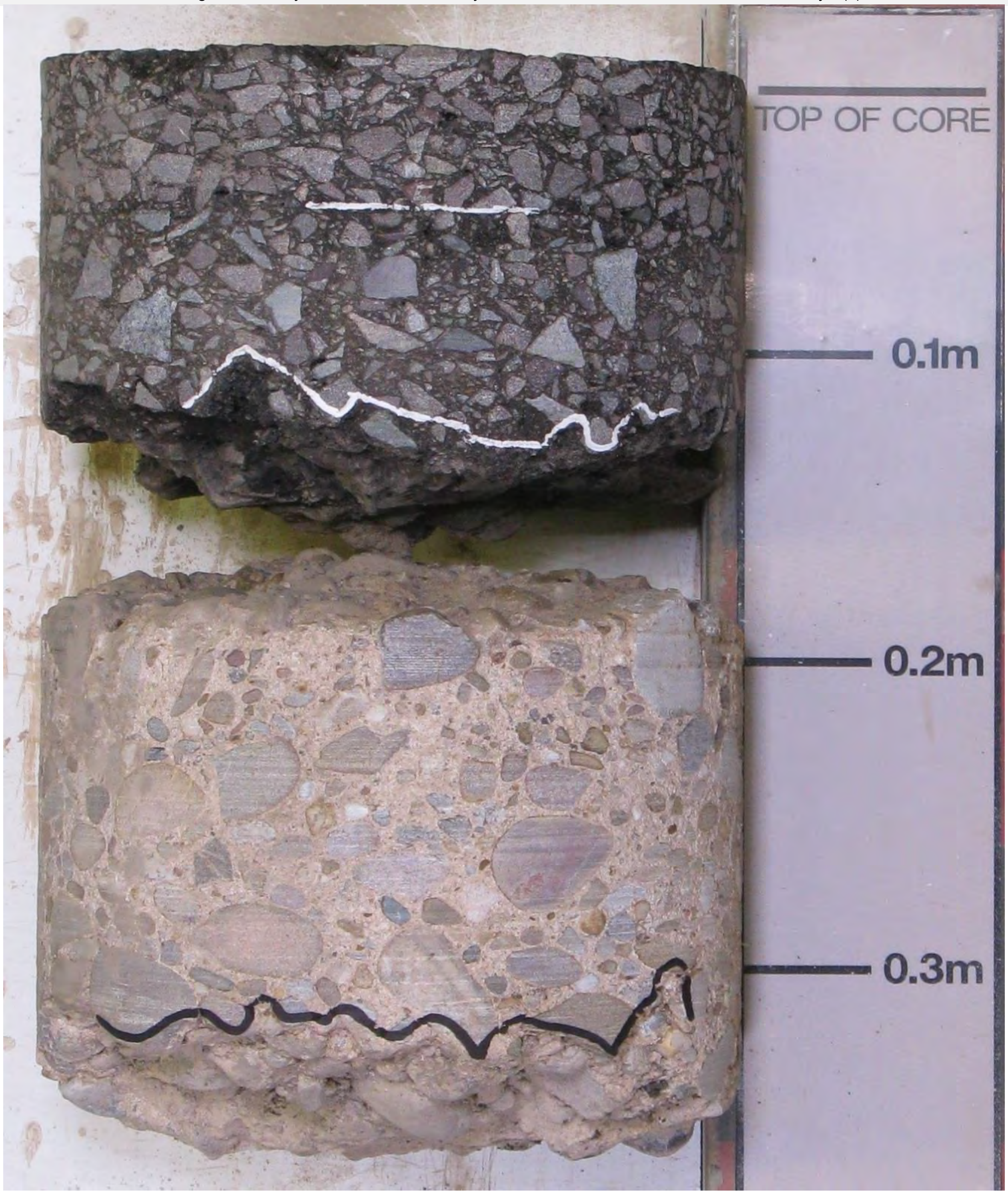

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AECOM	CORE LOGGING OF PAVEMENT MATERIAL
	In Accordance with AECOM in House Procedures

Job Number :	**60523093**	Scheme :	**Task 1-111 A5 Warm mix Trials**
Sample Number :	**CR 01096**	Location :	**Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.69m**
Core Number :	**06**		**Survey Ch. 55m**
Cored / Logged By :	**TB / RBB**		
Date Cored / Logged :	**14-02-17 / 22-02-17**		**OSGR: SP 29465, 98473**
Nominal Diameter :	**200mm**		**Notes: N/A**

ROAD

CORE

HOLE

CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

Job Number :	**60523093**	Scheme :	**Task 1-111 A5 Warm mix Trials**
Sample Number :	**CR 01096**	Location :	**Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.63m**
Core Number :	**07**		**Survey Ch. 55m**
Cored / Logged By :	**TB / RBB**		
Date Cored / Logged :	**14-02-17 / 22-02-17**		**OSGR: SP 29460, 98478**
Nominal Diameter :	**150mm**		**Notes: N/A**

Layer	Depth (mm)		Thickness (mm)	Material Description [1]	Suitable for NAT/CS Testing (Yes/No)	PAK-Marker [2]	Binder [3]	Aggregate	
	From	To						Size [4]	Type
1	0	45	45	Asphalt Surfacing	Yes	-ve	Bitumen	14	Crushed Rock
2	45	85	40	Asphalt Concrete (voided)	Yes	-ve	Bitumen	20	Crushed Rock
				Layers 2 & 3 Not Bonded					
3	85	120	35	Asphalt Concrete (broken @ base)	No	-ve	Bitumen	20	Crushed Rock
				Layers 3 & 4 Not Bonded					
4	120	180	60	Concrete (disintegrated)	No	n/a	Cement	32	Crushed Rock
				Layers 4 & 5 Not Bonded					
5	180	390	210	Concrete - Type B Voids	Yes	n/a	Cement	32	Crushed Rock/Gravel
				Loose Granular Material					

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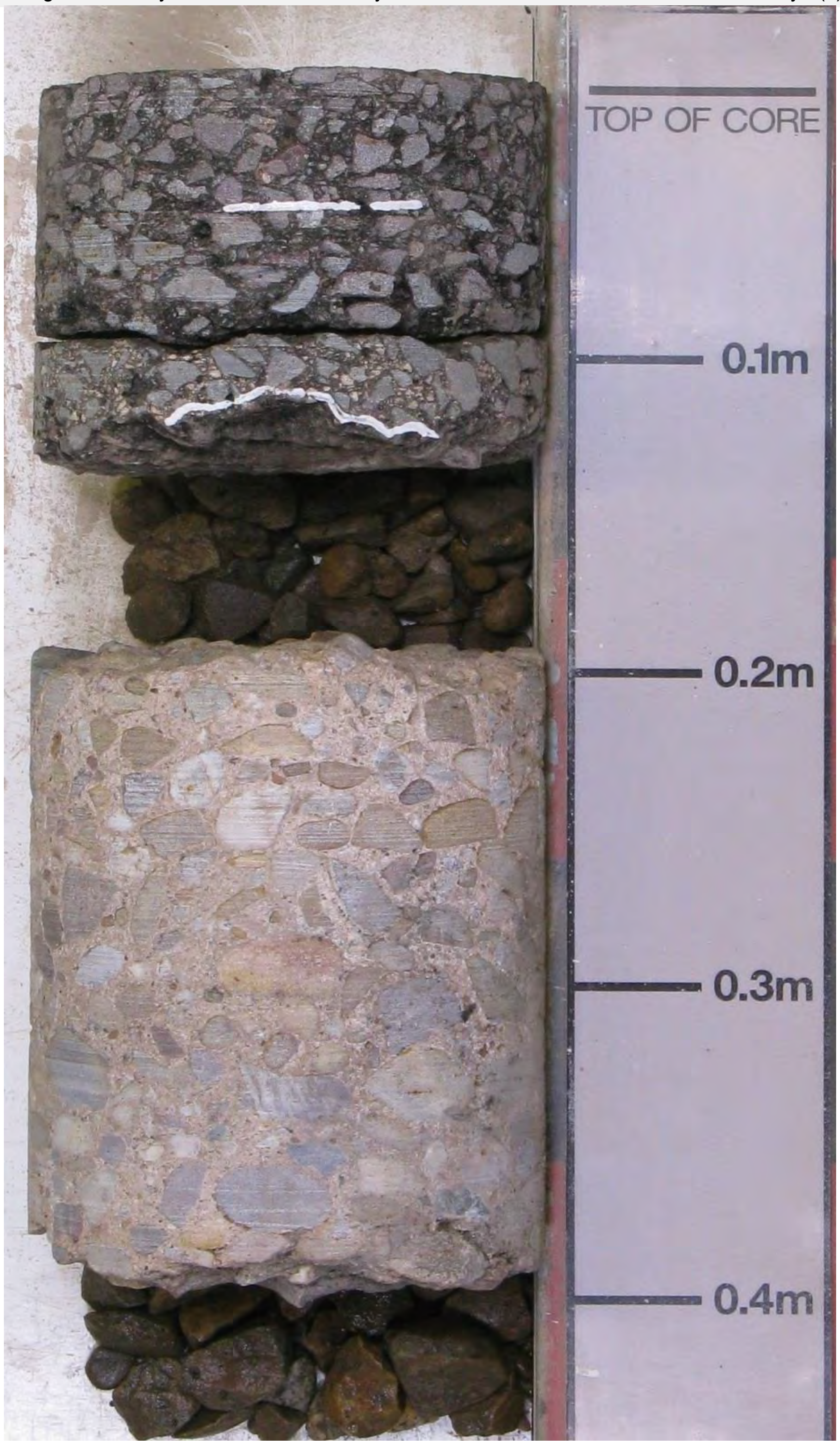

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CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

Job Number :	60523093	Scheme :	Task 1-111 A5 Warm mix Trials
Sample Number :	CR 01096	Location :	Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.63m
Core Number :	07		Survey Ch. 55m
Cored / Logged By :	TB / RBB		
Date Cored / Logged :	14-02-17 / 22-02-17		OSGR: SP 29460, 98478
Nominal Diameter :	150mm		Notes: N/A

ROAD

CORE

HOLE

CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

Job Number :	**60523093**	Scheme :	**Task 1-111 A5 Warm mix Trials**
Sample Number :	**CR 01096**	Location :	**Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.65m**
Core Number :	**08**		**Survey Ch. 75m**
Cored / Logged By :	**TB / RBB**		
Date Cored / Logged :	**14-02-17 / 22-02-17**		**OSGR: SP 29451, 98483**
Nominal Diameter :	**150mm**		**Notes: N/A**

Layer	Depth (mm)		Thickness (mm)	Material Description [1]	Suitable for NAT/CS Testing (Yes/No)	PAK-Marker [2]	Binder [3]	Aggregate	
	From	To						Size [4]	Type
1	0	40	40	Asphalt Surfacing	Yes	-ve	Bitumen	14	Crushed Rock
2	40	100	60	Asphalt Concrete (voided)	Yes	-ve	Bitumen	20	Crushed Rock
				Layers 2 & 3 Not Bonded					
3	100	154	54	Hot Rolled Asphalt (broken up)	No	-ve	Bitumen	14	Crushed Rock
				Layers 3 & 4 Not Bonded					
4	154	350	196	Concrete (disintegrated)	No	n/a	Cement	32	Crushed Rock/Gravel
				Concrete Layer Not Recovered					

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Material Description [1]

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CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

Job Number :	**60523093**	Scheme :	**Task 1-111 A5 Warm mix Trials**
Sample Number :	**CR 01096**	Location :	**Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.65m**
Core Number :	**08**		**Survey Ch. 75m**
Cored / Logged By :	**TB / RBB**		
Date Cored / Logged :	**14-02-17 / 22-02-17**		**OSGR: SP 29451, 98483**
Nominal Diameter :	**150mm**		**Notes: N/A**

ROAD

CORE

HOLE

CORE LOGGING OF PAVEMENT MATERIAL

AECOM

In Accordance with AECOM in House Procedures

UKAS TESTING 4410

Job Number :	60523093	Scheme :	Task 1-111 A5 Warm mix Trials
Sample Number :	CR 01096	Location :	Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.63m
Core Number :	09		Survey Ch. 120m
Cored / Logged By :	TB / RBB		
Date Cored / Logged :	14-02-17 / 22-02-17		OSGR: SP 29408, 98501
Nominal Diameter :	150mm		Notes: N/A

Layer	Depth (mm)		Thickness (mm)	Material Description [1]	Suitable for NAT/CS Testing (Yes/No)	PAK-Marker [2]	Binder [3]	Aggregate	
	From	To						Size [4]	Type
1	0	35	35	Asphalt Surfacing	Yes	-ve	Bitumen	14	Crushed Rock
2	35	90	55	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
3	**90**	**205**	**115**	**Asphalt Concrete (broken up)**	**No**	**+ve**	**Tar**	**40**	**Crushed Rock**
				Layers 3 & 4 Not Bonded					
4	205	475	270	Concrete - Type C Voids (damage to face)	No	n/a	Cement	32	Crushed Rock/Gravel
				Loose Granular Material					

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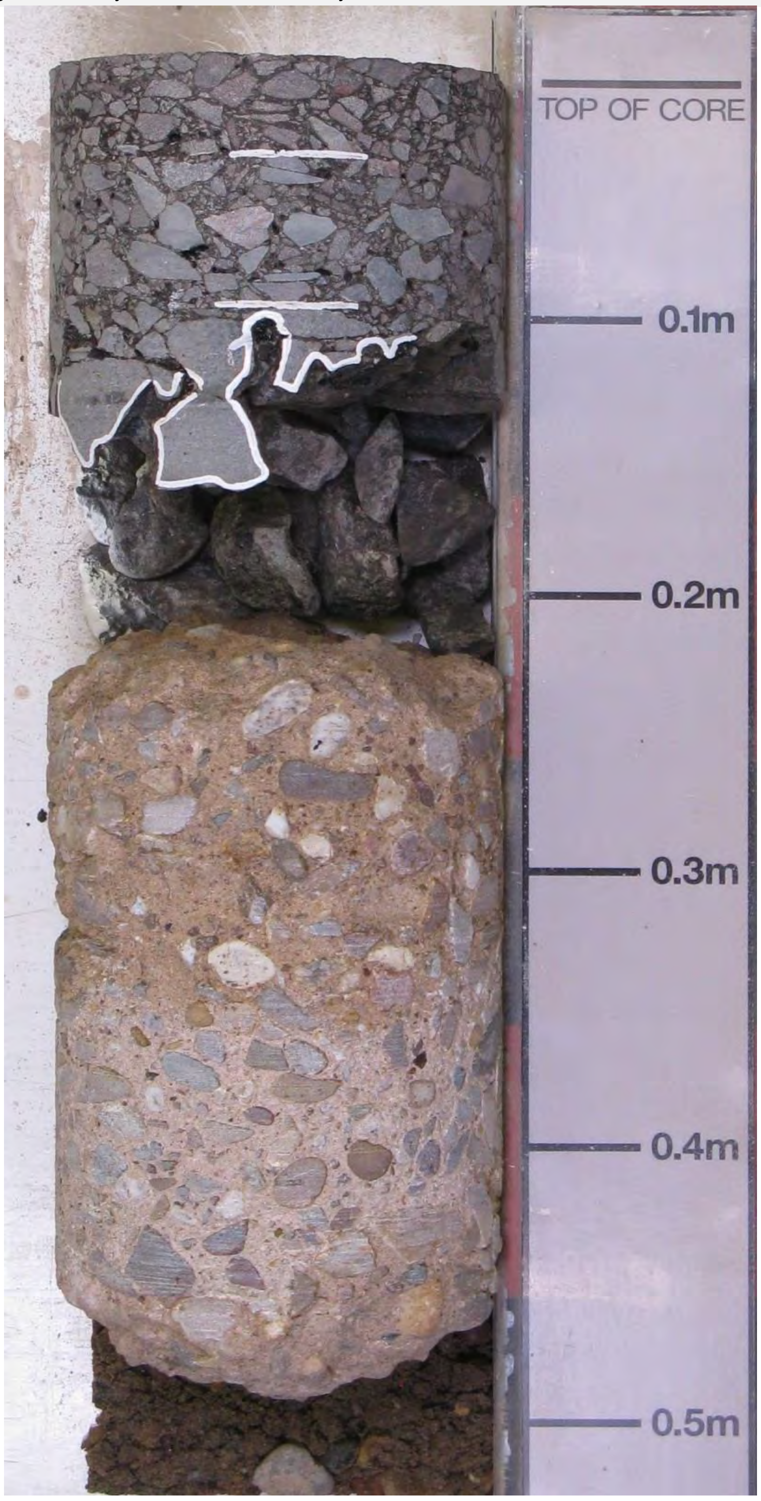

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CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

Job Number :	60523093	Scheme :	Task 1-111 A5 Warm mix Trials
Sample Number :	CR 01096	Location :	Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.63m
Core Number :	09		Survey Ch. 120m
Cored / Logged By :	TB / RBB		
Date Cored / Logged :	14-02-17 / 22-02-17		OSGR: SP 29408, 98501
Nominal Diameter :	150mm		Notes: N/A

ROAD

CORE

HOLE

CORE LOGGING OF PAVEMENT MATERIAL

AECOM

In Accordance with AECOM in House Procedures

UKAS TESTING 4410

Job Number :	**60523093**	Scheme :	**Task 1-111 A5 Warm mix Trials**
Sample Number :	**CR 01096**	Location :	**Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.65m**
Core Number :	**10**		**Survey Ch. 130m**
Cored / Logged By :	**TB / RBB**		
Date Cored / Logged :	**14-02-17 / 22-02-17**		**OSGR: SP 29402, 98503**
Nominal Diameter :	**150mm**		**Notes: N/A**

Layer	Depth (mm)		Thickness (mm)	Material Description [1]	Suitable for NAT/CS Testing (Yes/No)	PAK-Marker [2]	Binder [3]	Aggregate	
	From	To						Size [4]	Type
1	0	40	40	Asphalt Surfacing	Yes	-ve	Bitumen	14	Crushed Rock
2	40	105	65	Asphalt Concrete (broken @ base and voided)	Yes	-ve	Bitumen	20	Crushed Rock
				Layers 2 & 3 Not Bonded					
3	**105**	**175**	**70**	**Asphalt Concrete (disintegrated)**	**No**	**+ve**	**Tar**	**32**	**Crushed Rock**
				Layers 3 & 4 Not Bonded					
4	175	385	210	Concrete - Type B Voids	Yes	n/a	Cement	32	Crushed Rock/Gravel
				Loose Granular Material					

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AECOM

CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

UKAS TESTING 4410

Job Number :	**60523093**	Scheme :	**Task 1-111 A5 Warm mix Trials**
Sample Number :	**CR 01096**	Location :	**Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.65m**
Core Number :	**10**		**Survey Ch. 130m**
Cored / Logged By :	**TB / RBB**		
Date Cored / Logged :	**14-02-17 / 22-02-17**		**OSGR: SP 29402, 98503**
Nominal Diameter :	**150mm**		**Notes: N/A**

ROAD

CORE

HOLE

CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

Job Number :	**60523093**	Scheme :	**Task 1-111 A5 Warm mix Trials**
Sample Number :	**CR 01096**	Location :	**Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.78m**
Core Number :	**11**		**Survey Ch. 140m**
Cored / Logged By :	**TB / RBB**		
Date Cored / Logged :	**14-02-17 / 22-02-17**		**OSGR: SP 29392, 98508**
Nominal Diameter :	**200mm**		**Notes: N/A**

Layer	Depth (mm)		Thickness (mm)	Material Description [1]	Suitable for NAT/CS Testing (Yes/No)	PAK-Marker [2]	Binder [3]	Aggregate	
	From	To						Size [4]	Type
1	0	31	31	Asphalt Surfacing	Yes	-ve	Bitumen	14	Crushed Rock
2	31	91	60	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
3	**91**	**135**	**44**	**Asphalt Concrete (damage to face)**	**No**	**+ve**	**Tar**	**32**	**Crushed Rock**
4	135	395	260	Concrete - Type B Voids	Yes	n/a	Cement	32	Crushed Rock/Gravel
				Loose Granular Material					

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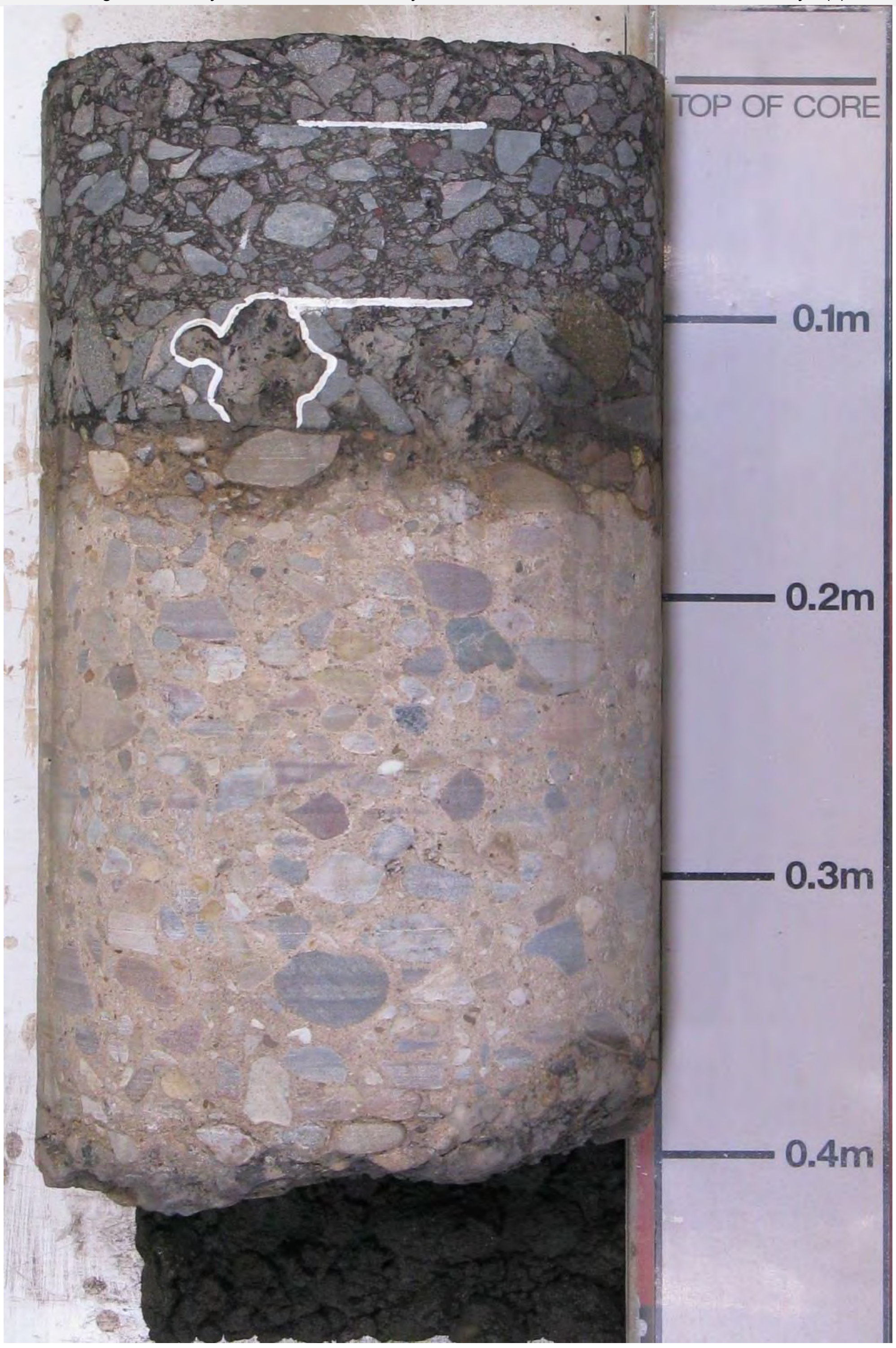

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AECOM

CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

Job Number :	60523093	Scheme :	Task 1-111 A5 Warm mix Trials
Sample Number :	CR 01096	Location :	Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.78m
Core Number :	11		Survey Ch. 140m
Cored / Logged By :	TB / RBB		
Date Cored / Logged :	14-02-17 / 22-02-17		OSGR: SP 29392, 98508
Nominal Diameter :	200mm		Notes: N/A

ROAD

CORE

HOLE

CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

Job Number :	**60523093**	Scheme :	**Task 1-111 A5 Warm mix Trials**
Sample Number :	**CR 01096**	Location :	**Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.68m**
Core Number :	**12**		**Survey Ch. 150m**
Cored / Logged By :	**TB / RBB**		
Date Cored / Logged :	**14-02-17 / 23-02-17**		**OSGR: SP 29382, 98513**
Nominal Diameter :	**150mm**		**Notes: N/A**

Layer	Depth (mm)		Thickness (mm)	Material Description [1]	Suitable for NAT/CS Testing (Yes/No)	PAK-Marker [2]	Binder [3]	Aggregate	
	From	To						Size [4]	Type
1	0	30	30	Asphalt Surfacing	Yes	-ve	Bitumen	14	Crushed Rock
2	30	82	52	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
3	82	150	68	Asphalt Concrete (damage to face - delaminated @ 12mm)	No	-ve	Bitumen	32	Crushed Rock
				Layers 3 & 4 Not Bonded					
4	150	410	260	Concrete - Type B Voids	Yes	n/a	Cement	32	Crushed Rock/Gravel
				Loose Granular Material					

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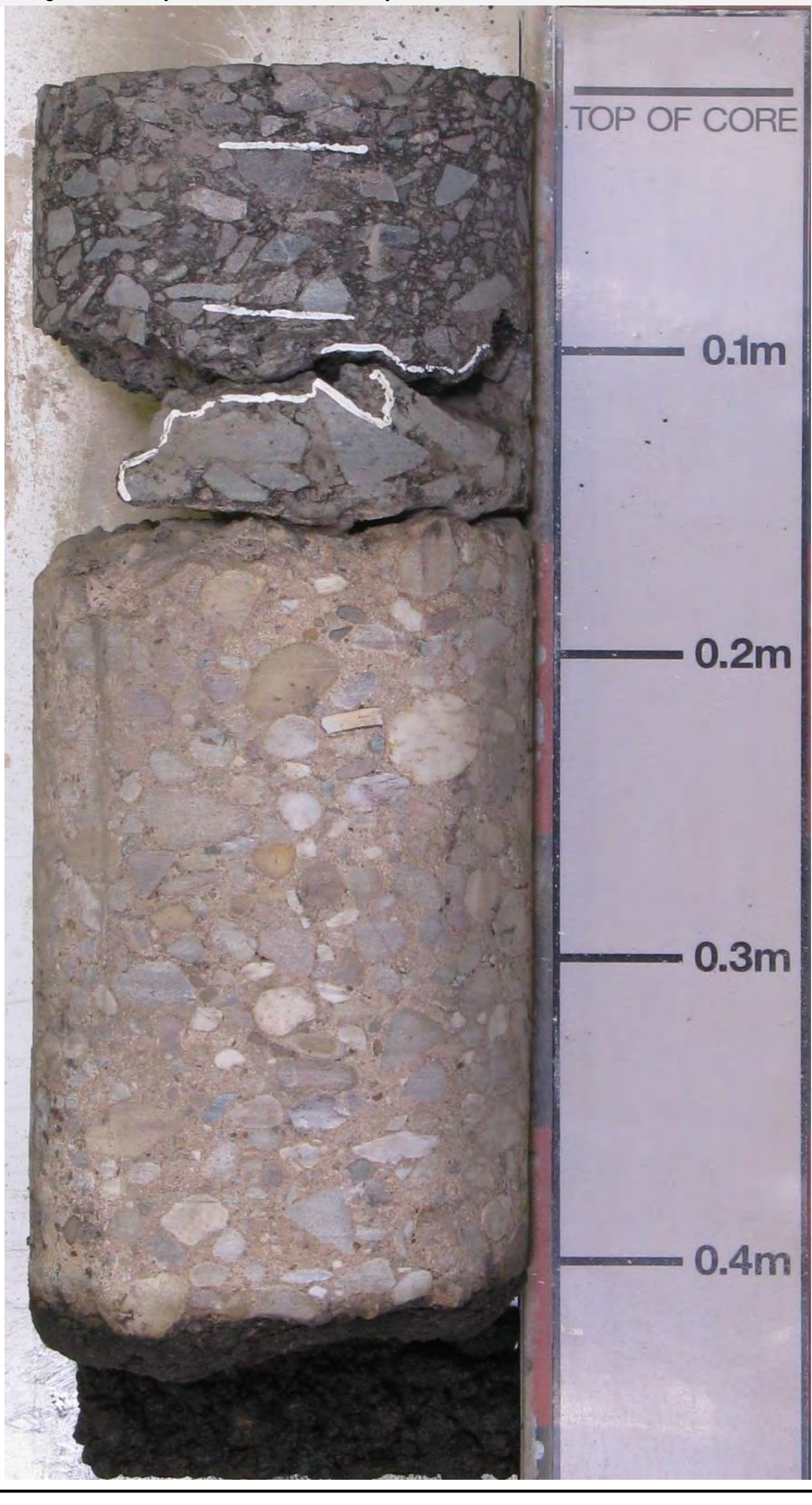

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AECOM

CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

UKAS TESTING 4410

Job Number :	**60523093**	Scheme :	**Task 1-111 A5 Warm mix Trials**
Sample Number :	**CR 01096**	Location :	**Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.68m**
Core Number :	**12**		**Survey Ch. 150m**
Cored / Logged By :	**TB / RBB**		
Date Cored / Logged :	**14-02-17 / 23-02-17**		**OSGR: SP 29382, 98513**
Nominal Diameter :	**150mm**		**Notes: N/A**

ROAD

CORE

HOLE

CORE LOGGING OF PAVEMENT MATERIAL

AECOM

In Accordance with AECOM in House Procedures

UKAS TESTING 4410

Job Number :	60523093	Scheme :	Task 1-111 A5 Warm mix Trials
Sample Number :	CR 01096	Location :	Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.6m
Core Number :	13		Survey Ch. 160m
Cored / Logged By :	TB / RBB		
Date Cored / Logged :	14-02-17 / 23-02-17		OSGR: SP 29374, 98517
Nominal Diameter :	150mm		Notes: N/A

Layer	Depth (mm)		Thickness (mm)	Material Description [1]	Suitable for NAT/CS Testing (Yes/No)	PAK-Marker [2]	Binder [3]	Aggregate	
	From	To						Size [4]	Type
1	0	30	30	Asphalt Surfacing	Yes	-ve	Bitumen	14	Crushed Rock
2	30	80	50	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
3	**80**	**150**	**70**	**Asphalt Concrete (broken up)**	**No**	**+ve**	**Tar**	**32**	**Crushed Rock**
				Layers 3 & 4 Not Bonded					
4	150	435	285	Concrete - Type C Voids (broken up from 260mm - 300mm)	Yes	n/a	Cement	32	Crushed Rock/Gravel
				Loose Granular Material					

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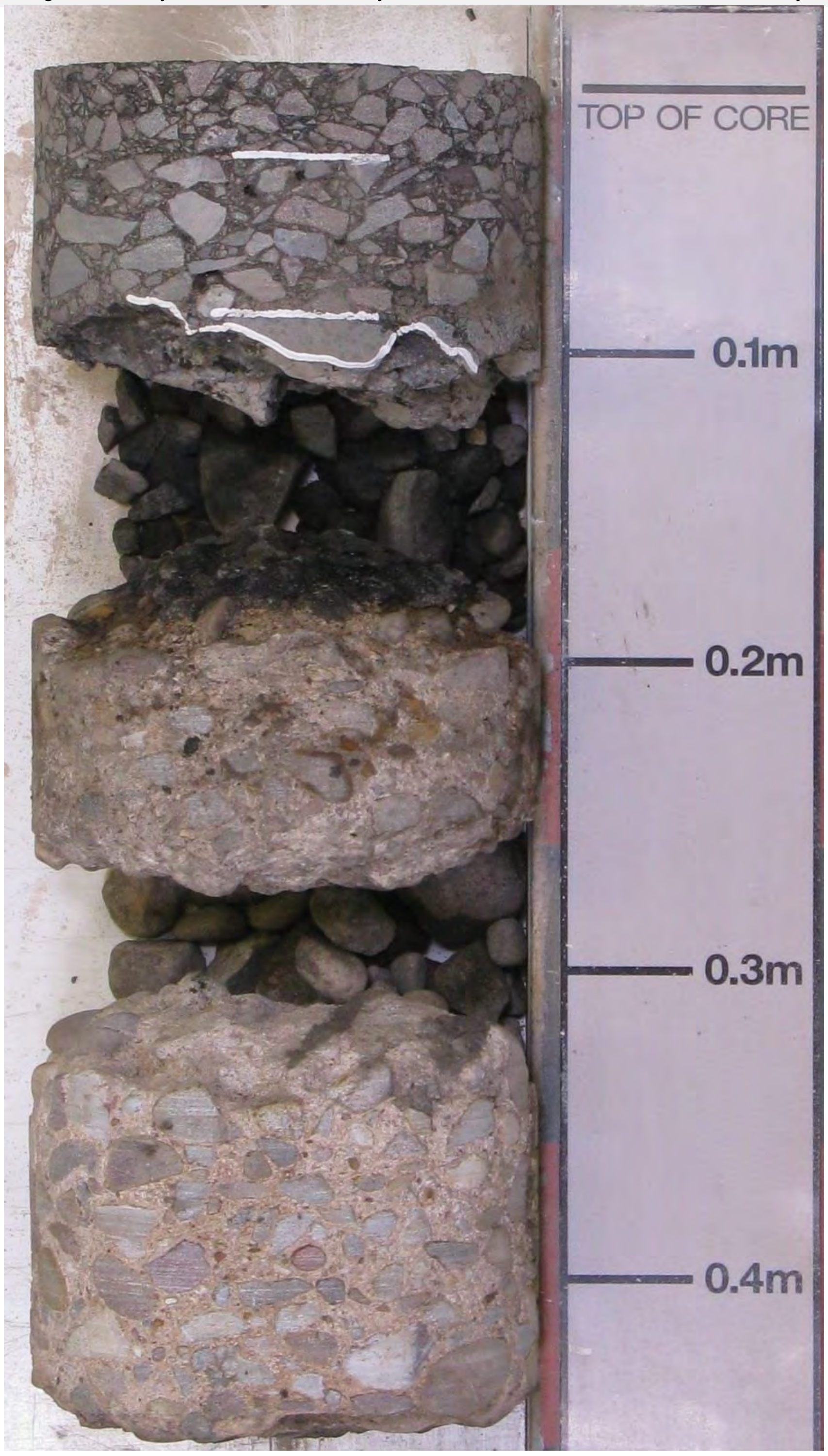


Material Description [1]

The material description given (such as hot rolled asphalt or asphalt concrete) is generic only and is based upon a visual assessment of the material. Similarly, use of additional descriptive (such as voided) is based on visual assessment only and the relationship between air voids visually to the naked eye and degree of compaction is complex and materials specific.

PAK-Marker (PAH Spray) [2]

The Tar Spray Test is a rapid, qualitative indicator of the presence of polyaromatic compounds (PACs) typically found in tar. PACs also exist in other road construction materials (e.g. bitumen and cutbacks like kerosene), but at low concentrations. The probability of obtaining a false positive result in the tar spray test with such materials is low, and a positive result in the tar spray test is a strong (but not definitive) indicator of the presence of tar. For quantitative results, this test should be considered in conjunction with the results from other tests (i.e. Total Polynuclear Aromatic Hydrocarbons (PAH) by Gas Chromatography - Flame Ionisation Detection (GC-FID)).

Binder [3]

The binder type is assessed based on visual and aromatic inspection. The PAK-Marker result is also considered.

Aggregate Size [4]

The sizes indicated are given as the best estimate of the nominal size of the material.

AECOM

CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

Job Number :	**60523093**	Scheme :	**Task 1-111 A5 Warm mix Trials**
Sample Number :	**CR 01096**	Location :	**Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.6m**
Core Number :	**13**		**Survey Ch. 160m**
Cored / Logged By :	**TB / RBB**		
Date Cored / Logged :	**14-02-17 / 23-02-17**		**OSGR: SP 29374, 98517**
Nominal Diameter :	**150mm**		**Notes: N/A**

ROAD

CORE

HOLE

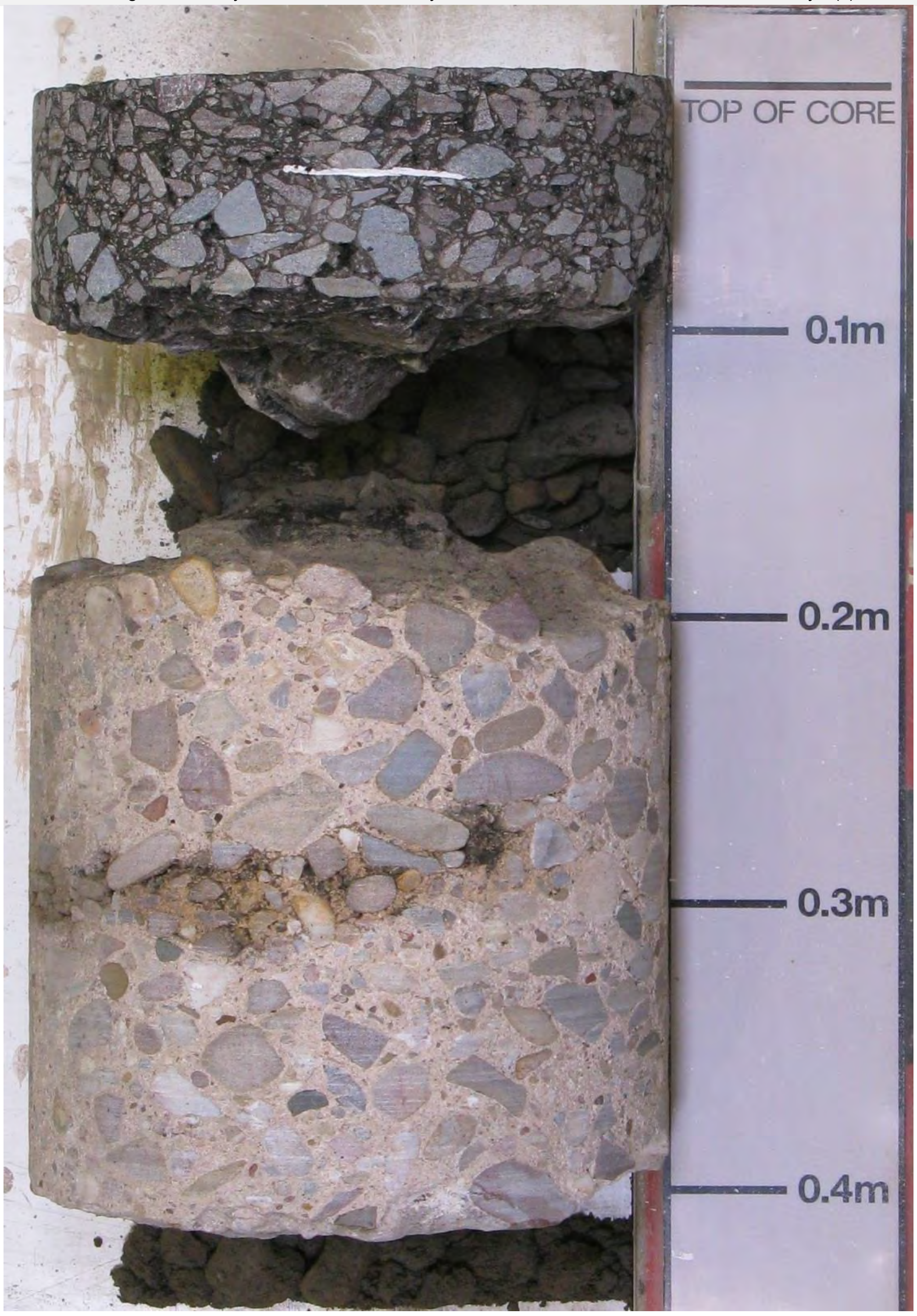
CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

Job Number :	**60523093**	Scheme :	**Task 1-111 A5 Warm mix Trials**
Sample Number :	**CR 01096**	Location :	**Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.4m**
Core Number :	**14**		**Survey Ch. 170m**
Cored / Logged By :	**TB / RBB**		
Date Cored / Logged :	**14-02-17 / 23-02-17**		**OSGR: SP 29365, 98520**
Nominal Diameter :	**200mm**		**Notes: N/A**

Layer	Depth (mm)		Thickness (mm)	Material Description [1]	Suitable for NAT/CS Testing (Yes/No)	PAK-Marker [2]	Binder [3]	Aggregate	
	From	To						Size [4]	Type
1	0	36	36	Asphalt Surfacing	Yes	-ve	Bitumen	14	Crushed Rock
2	36	80	44	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
				Layers 2 & 3 Not Bonded					
3	80	170	90	Asphalt Concrete (disintegrated)	No	-ve	Bitumen	32	Crushed Rock
				Layers 3 & 4 Not Bonded					
4	170	390	220	Concrete - Type B Voids (broken @ top)	Yes	n/a	Cement	32	Crushed Rock
				Loose Granular Material					

Notes : The scale is for guidance only. It does not necessarily reflect the actual thicknesses of individual layer(s).



Material Description [1]
The material description given (such as hot rolled asphalt or asphalt concrete) is generic only and is based upon a visual assessment of the material. Similarly, use of additional descriptive (such as voided) is based on visual assessment only and the relationship between air voids visually to the naked eye and degree of compaction is complex and materials specific.

PAK-Marker (PAH Spray) [2]
The Tar Spray Test is a rapid, qualitative indicator of the presence of polyaromatic compounds (PACs) typically found in tar. PACs also exist in other road construction materials (e.g. bitumen and cutbacks like kerosene), but at low concentrations. The probability of obtaining a false positive result in the tar spray test with such materials is low, and a positive result in the tar spray test is a strong (but not definitive) indicator of the presence of tar. For quantitative results, this test should be considered in conjunction with the results from other tests (i.e. Total Polynuclear Aromatic Hydrocarbons (PAH) by Gas Chromatography - Flame Ionisation Detection (GC-FID)).

Binder [3]
The binder type is assessed based on visual and aromatic inspection. The PAK-Marker result is also considered.

Aggregate Size [4]
The sizes indicated are given as the best estimate of the nominal size of the material.

AECOM

CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

UKAS TESTING 4410

Job Number :	60523093	Scheme :	Task 1-111 A5 Warm mix Trials
Sample Number :	CR 01096	Location :	Northbound, Lane 1, Lane Centre, Offset from nearside white line 1.4m
Core Number :	14		Survey Ch. 170m
Cored / Logged By :	TB / RBB		
Date Cored / Logged :	14-02-17 / 23-02-17		OSGR: SP 29365, 98520
Nominal Diameter :	200mm		Notes: N/A

ROAD

CORE

HOLE

CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

Job Number :	60523093	Scheme :	Task 1-111 A5 Warm mix Trials
Sample Number :	CR 01096	Location :	Northbound, Lane 1, Lane Centre, Offset from nearside white line 1m
Core Number :	15		Survey Ch. 180m
Cored / Logged By :	TB / RBB		
Date Cored / Logged :	14-02-17 / 23-02-17		OSGR: SP 29356, 98523
Nominal Diameter :	150mm		Notes: N/A

Layer	Depth (mm)		Thickness (mm)	Material Description [1]	Suitable for NAT/CS Testing (Yes/No)	PAK-Marker [2]	Binder [3]	Aggregate	
	From	To						Size [4]	Type
1	0	31	31	Asphalt Surfacing	Yes	-ve	Bitumen	14	Crushed Rock
2	31	90	59	Asphalt Concrete (broken @ base and voided)	Yes	-ve	Bitumen	20	Crushed Rock
				Layers 2 & 3 Not Bonded					
3	90	175	85	Asphalt Concrete (disintegrated)	No	-ve	Bitumen	32	Crushed Rock
				Layers 3 & 4 Not Bonded					
4	175	355	180	Concrete - Type B Voids	Yes	n/a	Cement	32	Crushed Rock/Gravel
				Loose Granular Material					

Notes : The scale is for guidance only. It does not necessarily reflect the actual thicknesses of individual layer(s).

Material Description [1]

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PAK-Marker (PAH Spray) [2]

The Tar Spray Test is a rapid, qualitative indicator of the presence of polyaromatic compounds (PACs) typically found in tar. PACs also exist in other road construction materials (e.g. bitumen and cutbacks like kerosene), but at low concentrations. The probability of obtaining a false positive result in the tar spray test with such materials is low, and a positive result in the tar spray test is a strong (but not definitive) indicator of the presence of tar. For quantitative results, this test should be considered in conjunction with the results from other tests (i.e. Total Polynuclear Aromatic Hydrocarbons (PAH) by Gas Chromatography - Flame Ionisation Detection (GC-FID)).

Binder [3]

The binder type is assessed based on visual and aromatic inspection. The PAK-Marker result is also considered.

Aggregate Size [4]

The sizes indicated are given as the best estimate of the nominal size of the material.

CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

Job Number :	60523093	Scheme :	Task 1-111 A5 Warm mix Trials
Sample Number :	CR 01096	Location :	Northbound, Lane 1, Lane Centre, Offset from nearside white line 1m
Core Number :	15		Survey Ch. 180m
Cored / Logged By :	TB / RBB		
Date Cored / Logged :	14-02-17 / 23-02-17		OSGR: SP 29356, 98523
Nominal Diameter :	150mm		Notes: N/A

ROAD

CORE

HOLE

AECOM

CORE LOGGING OF PAVEMENT MATERIAL

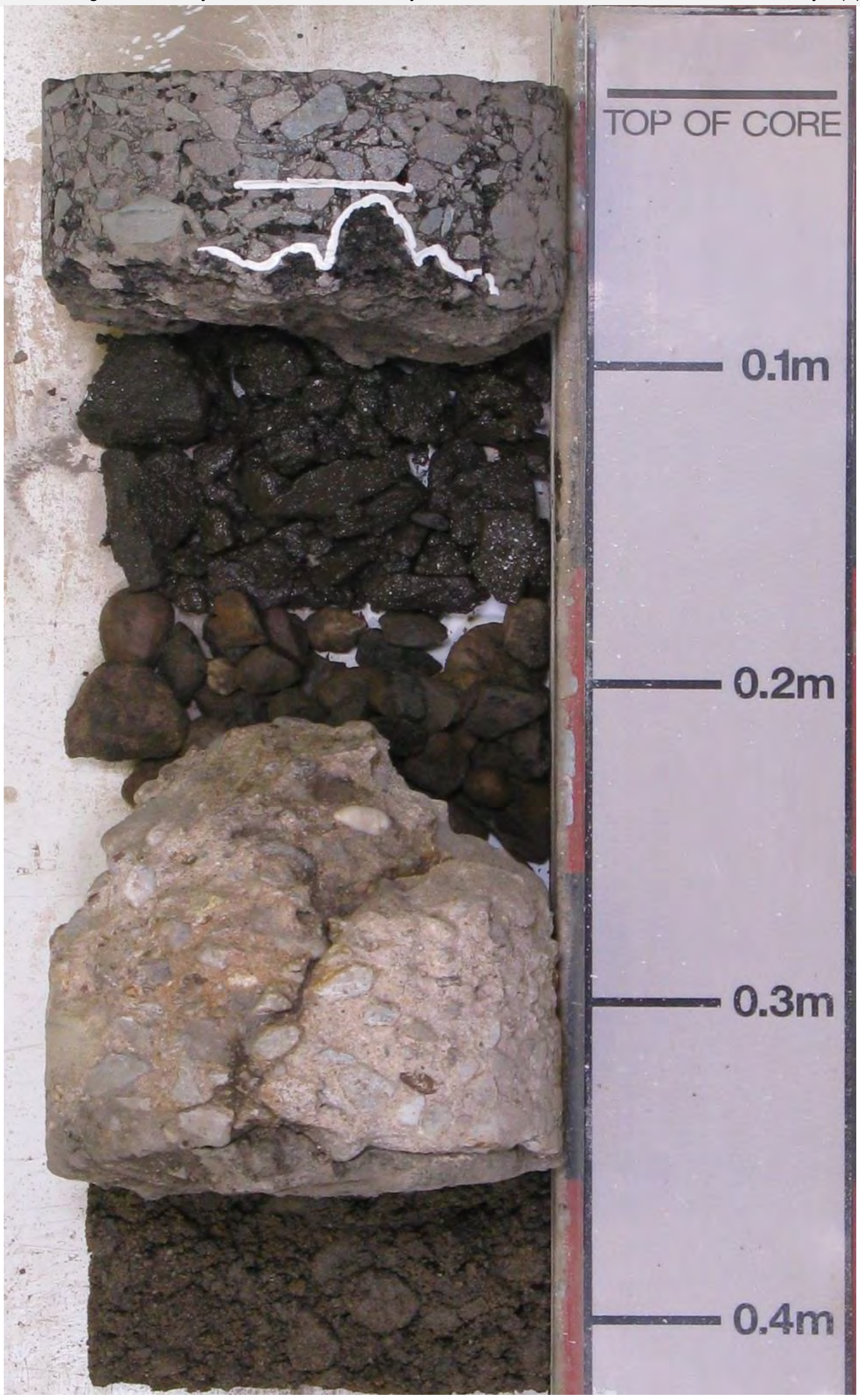
In Accordance with AECOM in House Procedures

UKAS TESTING 4410

Job Number :	60523093	Scheme :	Task 1-111 A5 Warm mix Trials
Sample Number :	CR 01096	Location :	Northbound, Lane 1, Lane Centre, Offset from nearside white line 0.91m
Core Number :	16		Survey Ch. 190m
Cored / Logged By :	TB / RBB		
Date Cored / Logged :	14-02-17 / 23-02-17		OSGR: SP 29345, 98527
Nominal Diameter :	150mm		Notes: N/A

Layer	Depth (mm)		Thickness (mm)	Material Description [1]	Suitable for NAT/CS Testing (Yes/No)	PAK-Marker [2]	Binder [3]	Aggregate	
	From	To						Size [4]	Type
1	0	35	35	Asphalt Surfacing (voided)	Yes	-ve	Bitumen	14	Crushed Rock
2	35	75	40	Asphalt Concrete (broken @ base)	No	-ve	Bitumen	20	Crushed Rock
				Layers 2 & 3 Not Bonded					
3	75	170	95	Asphalt Concrete (disintegrated)	No	-ve	Bitumen	32	Crushed Rock
				Layers 3 & 4 Not Bonded					
4	170	340	170	Concrete - Type E Voids (broken up)	No	n/a	Cement	32	Crushed Rock
				Loose Granular Material					

Notes : The scale is for guidance only. It does not necessarily reflect the actual thicknesses of individual layer(s).



Material Description [1]

The material description given (such as hot rolled asphalt or asphalt concrete) is generic only and is based upon a visual assessment of the material. Similarly, use of additional descriptive (such as voided) is based on visual assessment only and the relationship between air voids visually to the naked eye and degree of compaction is complex and materials specific.

PAK-Marker (PAH Spray) [2]

The Tar Spray Test is a rapid, qualitative indicator of the presence of polyaromatic compounds (PACs) typically found in tar. PACs also exist in other road construction materials (e.g. bitumen and cutbacks like kerosene), but at low concentrations. The probability of obtaining a false positive result in the tar spray test with such materials is low, and a positive result in the tar spray test is a strong (but not definitive) indicator of the presence of tar. For quantitative results, this test should be considered in conjunction with the results from other tests (i.e. Total Polynuclear Aromatic Hydrocarbons (PAH) by Gas Chromatography - Flame Ionisation Detection (GC-FID)).

Binder [3]

The binder type is assessed based on visual and aromatic inspection. The PAK-Marker result is also considered.

Aggregate Size [4]

The sizes indicated are given as the best estimate of the nominal size of the material.

CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures

Job Number :	60523093	Scheme :	Task 1-111 A5 Warm mix Trials
Sample Number :	CR 01096	Location :	Northbound, Lane 1, Lane Centre, Offset from nearside white line 0.91m
Core Number :	16		Survey Ch. 190m
Cored / Logged By :	TB / RBB		
Date Cored / Logged :	14-02-17 / 23-02-17		OSGR: SP 29345, 98527
Nominal Diameter :	150mm		Notes: N/A

ROAD

CORE

HOLE

Appendix C – Mixture Volumetrics

MAXIMUM DENSITY & AIR VOIDS

BS EN 12697-5 : 2009 - Procedure A & BS EN 12697-8 : 2003

UKAS TESTING 4410

Project Title :	**Task 1-111 A5 Warm Mix Trials**	Tested By :	**NAL**
Job Number :	**60523093**	Reported By :	**NAL**
Bulk Reference :	**CR 01096**	Checked By :	**BA**
Location of Testing :	**AECOM Laboratory, NG9 6RZ**	Date of Issue :	**23 March 2017**

Sample Reference	Date of Test	Bulk Density Method	Bulk Density (kg/m³)	Maximum Density Test Temperature (˚C)		**Maximum Density (kg/m³)***	**Air Voids (% v/v)**
01L1	17-Mar-17	B	2410	20.0		2554	**5.6**
01L2	17-Mar-17	B	2269	20.0		2598	**12.7**
02L1	17-Mar-17	B	2353	20.0		2554	**7.9**
04L1	17-Mar-17	B	2438	20.0		2554	**4.5**
04L2	17-Mar-17	B	2360	20.0		2598	**9.1**
05L1	17-Mar-17	B	2433	20.0		2554	**4.7**
05L2	17-Mar-17	B	2344	20.0		2598	**9.8**
07L1	17-Mar-17	B	2429	20.0		2554	**4.9**
07L2	17-Mar-17	B	2271	20.0		2598	**12.6**
08L1	17-Mar-17	B	2355	20.0		2554	**7.8**
08L2	17-Mar-17	B	2325	20.0		2598	**10.5**
09L1	17-Mar-17	B	2459	20.0		2555	**3.8**
09L2	17-Mar-17	B	2477	20.0		2616	**5.3**
10L1	17-Mar-17	B	2445	20.0		2555	**4.3**
10L2	17-Mar-17	B	2360	20.0		2616	**9.8**
12L1	17-Mar-17	B	2418	20.0		2555	**5.4**
12L2	17-Mar-17	B	2413	20.0		2616	**7.8**
13L1	17-Mar-17	B	2418	20.0		2555	**5.4**
13L2	17-Mar-17	B	2446	20.0		2616	**6.5**
15L1	17-Mar-17	B	2445	20.0		2555	**4.3**
15L2	17-Mar-17	B	2407	20.0		2616	**8.0**
16L1	17-Mar-17	B	2406	20.0		2555	**5.8**
03L2	17-Mar-17	B	2348	20.0		2598	**9.6**
06L2	17-Mar-17	B	2393	20.0		2598	**7.9**
11L2	17-Mar-17	B	2417	20.0		2616	**7.6**
14L2	17-Mar-17	B	2465	20.0		2616	**5.8**

Comments and Deviations:

m_1= mass of pyknometer (g), m_2= m_1 and sample (g), m_3= m_2 and filled with water (g), Vp= volume of pyknometer (m³)

ρw= density of water (mg/m³), ρmv= sample maximum density (mg/m³) * $\times 10^{-3}$ Mg/m³

$$\rho w = 1.00025205 + \frac{7.59t - 5.32t^2}{10^6} \qquad \rho mv = \frac{(m_2 - m_1)}{10^6 \times Vp - (m_3 - m_2)/\rho w}$$

Origin of Specimen : Extracted from Site

Checked by: - [signature] Date: - **23 March 2017**

MAXIMUM DENSITY & AIR VOIDS

BS EN 12697-5 : 2009 - Procedure A & BS EN 12697-8 : 2003

Project Title :	**Task 1-111 A5 Warm Mix Trials**	Tested By :	**NAL**
Job Number :	**60523093**	Reported By :	**NAL**
Bulk Reference :	**CR 01096**	Checked By :	**BA**
Location of Testing :	**AECOM Laboratory, NG9 6RZ**	Date of Issue :	**23 March 2017**

Sample Reference	Date of Test	Bulk Density Method	Bulk Density (kg/m³)	Maximum Density Test Temperature (˚C)		**Maximum Density (kg/m³)***	**Air Voids (% v/v)**
01L1	17-Mar-17	C	2339	20.0		2554	**8.4**
01L2	17-Mar-17	C	2220	20.0		2598	**14.5**
02L1	17-Mar-17	C	2307	20.0		2554	**9.7**
04L1	17-Mar-17	C	2392	20.0		2554	**6.3**
04L2	17-Mar-17	C	2311	20.0		2598	**11.0**
05L1	17-Mar-17	C	2397	20.0		2554	**6.1**
05L2	17-Mar-17	C	2330	20.0		2598	**10.3**
07L1	17-Mar-17	C	2406	20.0		2554	**5.8**
07L2	17-Mar-17	C	2170	20.0		2598	**16.5**
08L1	17-Mar-17	C	2356	20.0		2554	**7.8**
08L2	17-Mar-17	C	2308	20.0		2598	**11.2**
09L1	17-Mar-17	C	2431	20.0		2555	**4.9**
09L2	17-Mar-17	C	2469	20.0		2616	**5.6**
10L1	17-Mar-17	C	2408	20.0		2555	**5.7**
10L2	17-Mar-17	C	2332	20.0		2616	**10.9**
12L1	17-Mar-17	C	2376	20.0		2555	**7.0**
12L2	17-Mar-17	C	2398	20.0		2616	**8.3**
13L1	17-Mar-17	C	2373	20.0		2555	**7.1**
13L2	17-Mar-17	C	2422	20.0		2616	**7.4**
15L1	17-Mar-17	C	2390	20.0		2555	**6.5**
15L2	17-Mar-17	C	2371	20.0		2616	**9.4**
16L1	17-Mar-17	C	2366	20.0		2555	**7.4**
03L2	17-Mar-17	C	2329	20.0		2598	**10.4**
06L2	17-Mar-17	C	2382	20.0		2598	**8.3**
11L2	17-Mar-17	C	2406	20.0		2616	**8.0**
14L2	17-Mar-17	C	2444	20.0		2616	**6.6**

Comments and Deviations:

m_1= mass of pyknometer (g), m_2= m_1 and sample (g), m_3= m_2 and filled with water (g), Vp= volume of pyknometer (m³)

ρw= density of water (mg/m³), ρmv= sample maximum density (mg/m³) * x10⁻³ Mg/m³

$$\rho w = 1.00025205 + \frac{7.59t - 5.32t^2}{10^6} \qquad \rho mv = \frac{(m_2 - m_1)}{10^6 x Vp - (m_3 - m_2)/\rho w}$$

Origin of Specimen : Extracted from Site

Checked by: - [signature] Date: - **23 March 2017**

Appendix D – Indirect Tensile Stiffness Modulus Test Results

SUMMARY OF INDIRECT TENSILE STIFFNESS MODULUS (ITSM) DATA

BS EN 12697-26 : 2004 (Annex C)

Project Title :	**Task 1-111 A5 Warm Mix Trials**	Location of Testing :	**AECOM Laboratory, NG9 6RZ**	Reported By :	**SF**
Job Number :	**60523093**	Date of Issue :	**01 January 1900**	Checked By :	**NAL**
Bulk Reference :	**CR 01096**	Tested By :	**SF**		

Sample Reference	Thickness (mm)	Diameter (mm)	Bulk Density (kg/m³)	Horizontal Deformation at 20℃ (microns)	Rise Time at 20℃ (m.sec)	ITSM at 20℃ (MPa)
01L1	25.2 *	151.8	2339	7.5	126	**1910**
01L2	32.2	151.9	2220	6.9	123	**1710**
02L1	44.4	151.3	2307	7.0	124	**1980**
04L1	29.8 *	151.3	2392	7.0	123	**3400**
05L1	29.9 *	152.0	2397	6.9	122	**2490**
05L2	36.5	152.3	2330	6.9	125	**4350**
07L1	42.2	149.2	2406	7.0	123	**3230**
08L1	36.6	151.5	2356	6.9	124	**2830**
08L2	31.0	152.1	2308	6.3	124	**3580**
09L1	31.6	152.2	2431	7.0	126	**4200**
09L2	50.0	152.3	2469	7.0	124	**7830**
10L1	30.9	152.1	2408	7.0	123	**3550**
10L2	33.2	152.2	2332	6.9	123	**8210**
12L1	32.6	151.4	2376	6.9	124	**3730**
12L2	42.1	151.4	2398	7.0	125	**8300**
Test Annulus	70	150	n/a	n/a	n/a	Test Annulus Reference : 0127 Test Annulus Percentage Difference : 0.0%

Comments and Deviations:

Origin of specimen : Extracted from Site

Density Method Used : Procedure C - Sealed

* Sample outside of the recommended thickness range.

Checked by: - N A [signature]

Date: - **10 March 2017**

SUMMARY OF INDIRECT TENSILE STIFFNESS MODULUS (ITSM) DATA

AECOM

BS EN 12697-26 : 2004 (Annex C)

UKAS TESTING 4410

Project Title :	**Task 1-111 A5 Warm Mix Trials**	Location of Testing :	**AECOM Laboratory, NG9 6RZ**	Reported By :	**SF**
Job Number :	**60523093**	Date of Issue :	**01 January 1900**	Checked By :	**NAL**
Bulk Reference :	**CR 01096**	Tested By :	**SF**		

Sample Reference	Thickness (mm)	Diameter (mm)	Bulk Density (kg/m³)	Horizontal Deformation at 20℃ (microns)	Rise Time at 20℃ (m.sec)	**ITSM at 20℃ (MPa)**
13L1	37.8	151.7	2373	7.0	125	**3430**
13L2	36.7	151.8	2422	7.1	122	**7500**
15L2	32.4	151.8	2371	7.0	125	**9510**
16L1	34.6	151.8	2366	6.9	123	**2840**
Test Annulus	70	150	n/a	n/a	n/a	Test Annulus Reference : 0127 Test Annulus Percentage Difference : 0.0%

Comments and Deviations:

Origin of specimen : Extracted from Site

Density Method Used : Procedure C - Sealed

* Sample outside of the recommended thickness range.

Checked by: - N A [signature]

Date: - **10 March 2017**

Appendix E – Wheel Tracking Tests

AECOM

WHEEL TRACKING

BS EN 12697-22:2003+A1:2007 - Procedure B in Air

UKAS TESTING 4410

Project Title :	**Task 1-111 A5 Warm Mix Trials**	Tested By :	**NAL**
Job Number :	**60523093**	Reported By :	**NAL**
Bulk Reference :	**CR 01096**	Checked By :	**BA**
Location of Testing :	**AECOM Laboratory, NG9 6RZ**	Date of Issue :	**23 March 2017**

Sample Number	Thickness (mm)	Bulk density (kg/m³)	Test Temperature (℃)	**Wheel-Tracking Slope in Air (mm/10³ cycles)**	**Proportional Rut Depth at 10000 Cycles (%)**	**Rut Depth at 10000 Cycles (mm)**
03L2	38	2329	60	**3.0E-02**	**5.9**	**2.3**
06L2	38	2382	60	**3.5E-02**	**5.7**	**2.2**
Mean Wheel-Tracking Slope in Air (mm/10³ cycles)				**1.6E-02**		
Mean Proportion Rut Depth at 10000 Cycles (%)					**5.8**	
Mean Rut Depth at 10000 Cycles (mm)						**1.1**
11L2	56	2406	60	**6.2E-02**	**4.5**	**2.5**
14L2	26	2444	60	**1.8E-02**	**3.8**	**1.0**
Mean Wheel-Tracking Slope in Air (mm/10³ cycles)				**4.0E-02**		
Mean Proportion Rut Depth at 10000 Cycles (%)					**4.1**	
Mean Rut Depth at 10000 Cycles (mm)						**1.7**
Mean Wheel-Tracking Slope in Air (mm/10³ cycles)						
Mean Proportion Rut Depth at 10000 Cycles (%)						
Mean Rut Depth at 10000 Cycles (mm)						
Mean Wheel-Tracking Slope in Air (mm/10³ cycles)						
Mean Proportion Rut Depth at 10000 Cycles (%)						
Mean Rut Depth at 10000 Cycles (mm)						

Checked by: -		Date: -	**22 March 2017**

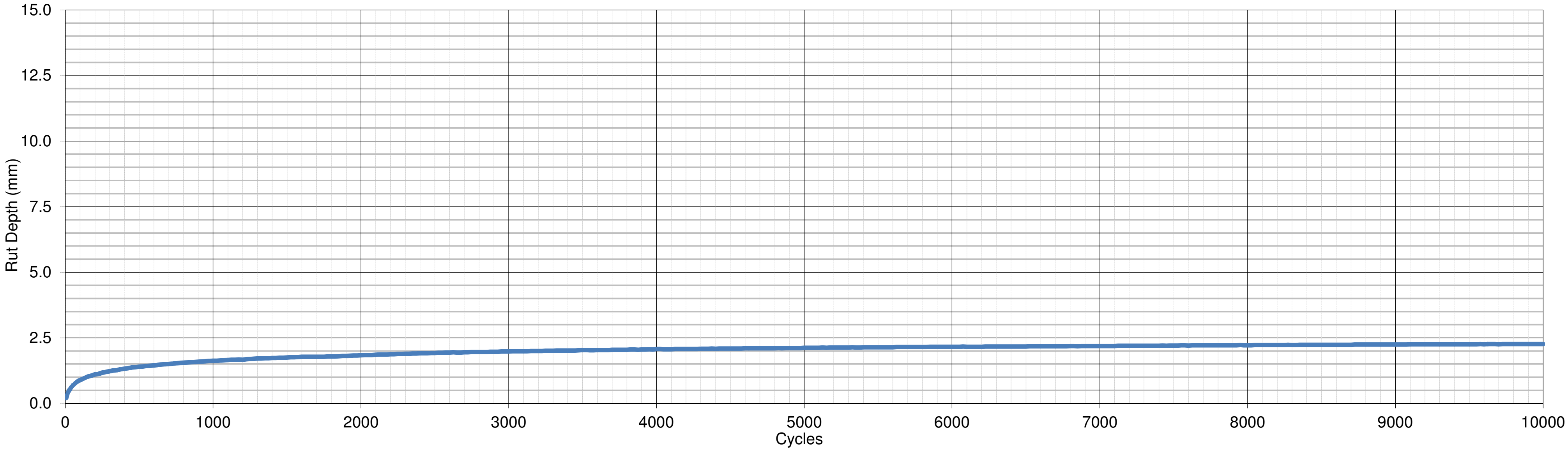
WHEEL-TRACKING

BS EN 12697-22:2003+A1:2007 - Procedure B in Air

Project Title :	**Task 1-111 A5 Warm Mix Trials**	Location of Testing :	**AECOM Laboratory, NG9 6RZ**	Reported By :	**NAL**
Job Number :	**60523093**	Date of Issue :	**23 March 2017**	Checked By :	**BA**
Bulk Reference :	**CR 01096**	Tested By :	**NAL**		

Sample reference: **03L2**

Rut Depth Plot



Comments and Deviations:

Origin of Sample : Extracted from Site

Date Cored : 13 & 14 February 2017

Date of Compaction : n/a

Sample Certificate Available : n/a

Rut Depth at 10000 cycles 2.26 mm

Checked by: -

Date: - **22 March 2017**

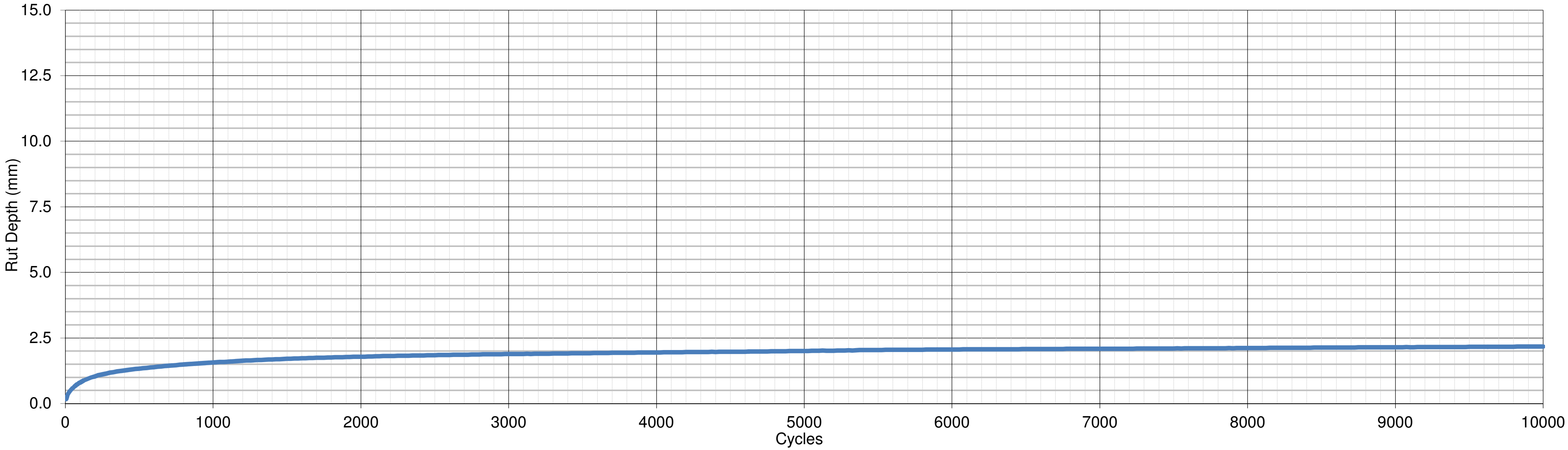
WHEEL-TRACKING

BS EN 12697-22:2003+A1:2007 - Procedure B in Air

Project Title :	**Task 1-111 A5 Warm Mix Trials**	Location of Testing :	**AECOM Laboratory, NG9 6RZ**	Reported By :	**NAL**
Job Number :	**60523093**	Date of Issue :	**23 March 2017**	Checked By :	**BA**
Bulk Reference :	**CR 01096**	Tested By :	**NAL**		

Sample reference: **06L2**

Rut Depth Plot



Comments and Deviations:

Origin of Sample : Extracted from Site

Date Cored : 13 & 14 February 2017

Date of Compaction : n/a

Sample Certificate Available : n/a

Rut Depth at 10000 cycles 2.18 mm

Checked by: -

Date: - **22 March 2017**

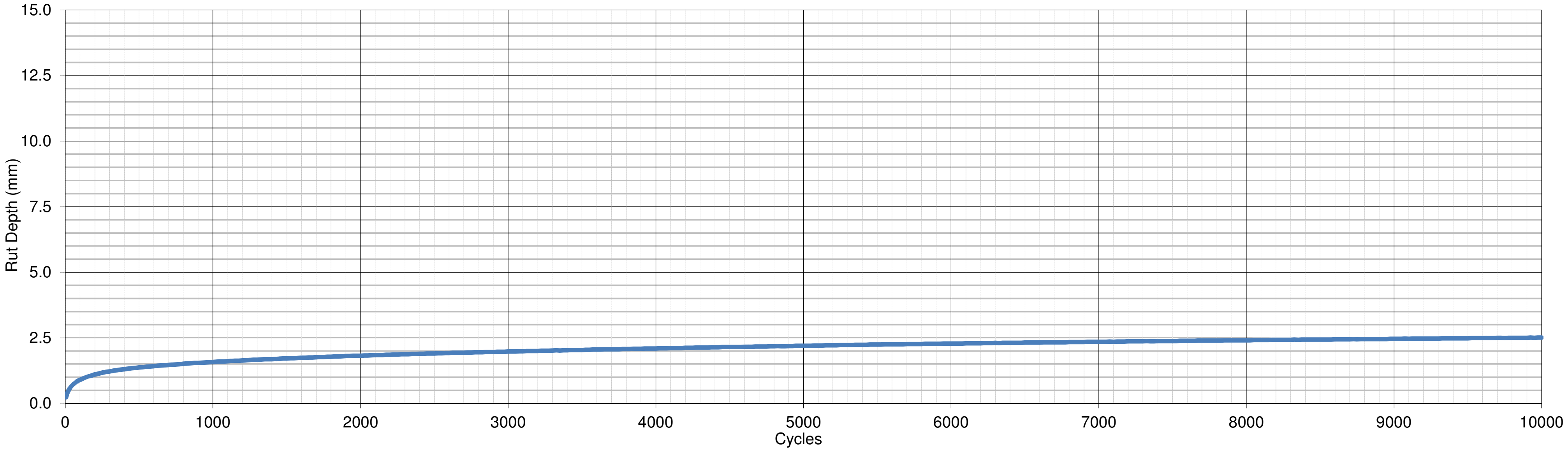
WHEEL-TRACKING

BS EN 12697-22:2003+A1:2007 - Procedure B in Air

Project Title :	**Task 1-111 A5 Warm Mix Trials**	Location of Testing :	**AECOM Laboratory, NG9 6RZ**	Reported By :	**NAL**
Job Number :	**60523093**	Date of Issue :	**23 March 2017**	Checked By :	**BA**
Bulk Reference :	**CR 01096**	Tested By :	**NAL**		

Sample reference: **11L2**

Rut Depth Plot



Comments and Deviations:

Origin of Sample : Extracted from Site

Sample Certificate Available : n/a

Rut Depth at 10000 cycles 2.51 mm

Date Cored : 13 & 14 February 2017

Date of Compaction : n/a

Checked by: -

Date: - **22 March 2017**

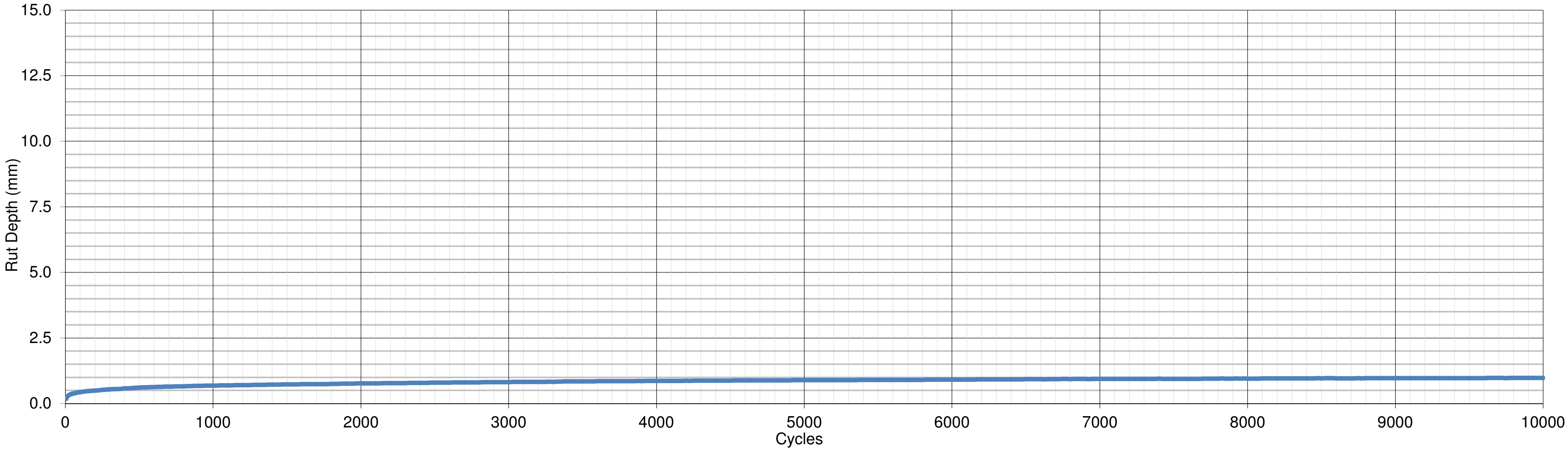
WHEEL-TRACKING

BS EN 12697-22:2003+A1:2007 - Procedure B in Air

Project Title :	**Task 1-111 A5 Warm Mix Trials**	Location of Testing :	**AECOM Laboratory, NG9 6RZ**	Reported By :	**NAL**
Job Number :	**60523093**	Date of Issue :	**23 March 2017**	Checked By :	**BA**
Bulk Reference :	**CR 01096**	Tested By :	**NAL**		

Sample reference: **14I2**

Rut Depth Plot



Comments and Deviations:

Origin of Sample : Extracted from Site

Date Cored : 13 & 14 February 2017

Date of Compaction : n/a

Sample Certificate Available : n/a

Rut Depth at 10000 cycles 0.98 mm

Checked by: -

Date: - **22 March 2017**

Appendix F – Binder Analysis

DETERMINATION OF NEEDLE PENETRATION AND SOFTENING POINT (RING AND BALL METHOD) OF BITUMINOUS BINDERS

BS EN 1426:2007 (BS 2000-49:2007) & BS EN 1427:2007 (BS 2000-58:2007)

UKAS TESTING 4410

Project Title :	**Task 1-111 A5 Warm Mix Trials**	Location of Testing :	**AECOM Laboratory, NG9 6RZ**	Reported By :	**BA**
Job Number :	**60523093**	Date of Issue :	**23 March 2017**	Checked By :	**NAL**
Bulk Reference :	**CR 01096**	Tested By :	**BA**		

Sample reference	Penetration BS EN 1426:2007 (BS 2000-49:2007)					Softening Point BS EN 1427:2007 (BS 2000-58:2007)		
	Test Date	Temperature (°C)	Mass of Weight (g)	Release Time (s)	Penetration (1/10mm)	Test Date	Bath Liquid	Softening Point (°C)
C1,2,4 L1	20-Mar-17	25	100.0	5.0	**87**	20-Mar-17	Distilled Water	**49.0**
C9,10,12 L1	20-Mar-17	25	100.0	5.0	**82**	20-Mar-17	Distilled Water	**50.4**
C1,4,5 L2	20-Mar-17	25	100.0	5.0	**42**	21-Jul-17	Distilled Water	**63.8**
C9,10,12 L2	20-Mar-17	25	100.0	5.0	**50**	21-Jul-17	Distilled Water	**55.2**

Comments and Deviations:

Origin of specimen : Extracted from Site

Calculations: The mean of three valid determinations used to achieve the penetration value (expressed in tenths of a millimetre rounded to the nearest integer).

The mean of two recorded values for softening point used to achieve softening point value (values below or equal to 80ºC rounded to the nearest 0.2ºC, values above 80ºC rounded to the nearest 0.5ºC)

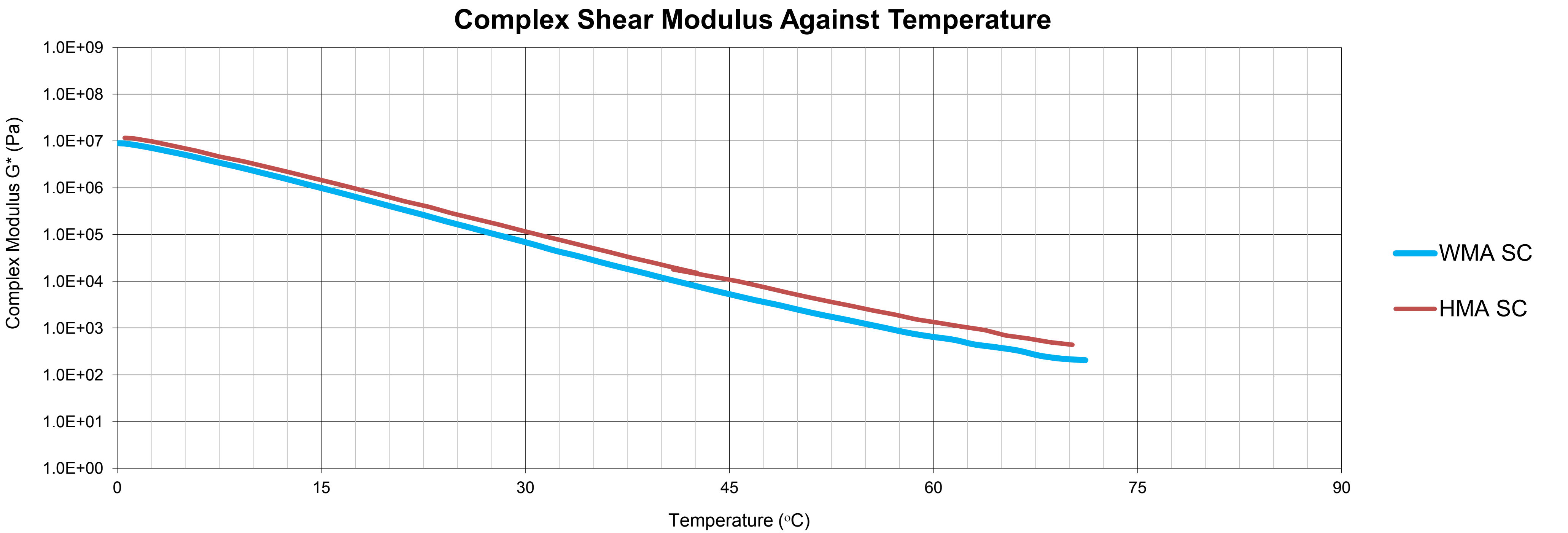
Checked by: - N A [signature]

Date: - **22 March 2017**

DETERMINATION OF COMPLEX SHEAR MODULUS AND PHASE ANGLE - DYNAMIC SHEAR RHEOMETER (DSR)

0078 SOP, BS EN 14770 : 2012

Project Title :	**Task 1-111 A5 Warm Mix Trials**	Client Sample ID :	**C1,2,4 L1**	Tested By :	**BA**
Job Number :	**60523093**	Location of Testing :	**Nottingham**	Reported By :	**BA**
Bulk Reference :	**CR 01096**	Date of Issue :	**23 March 2017**	Checked By :	**EKD**



Comments and Deviations:

Origin of samples :Extracted from Site

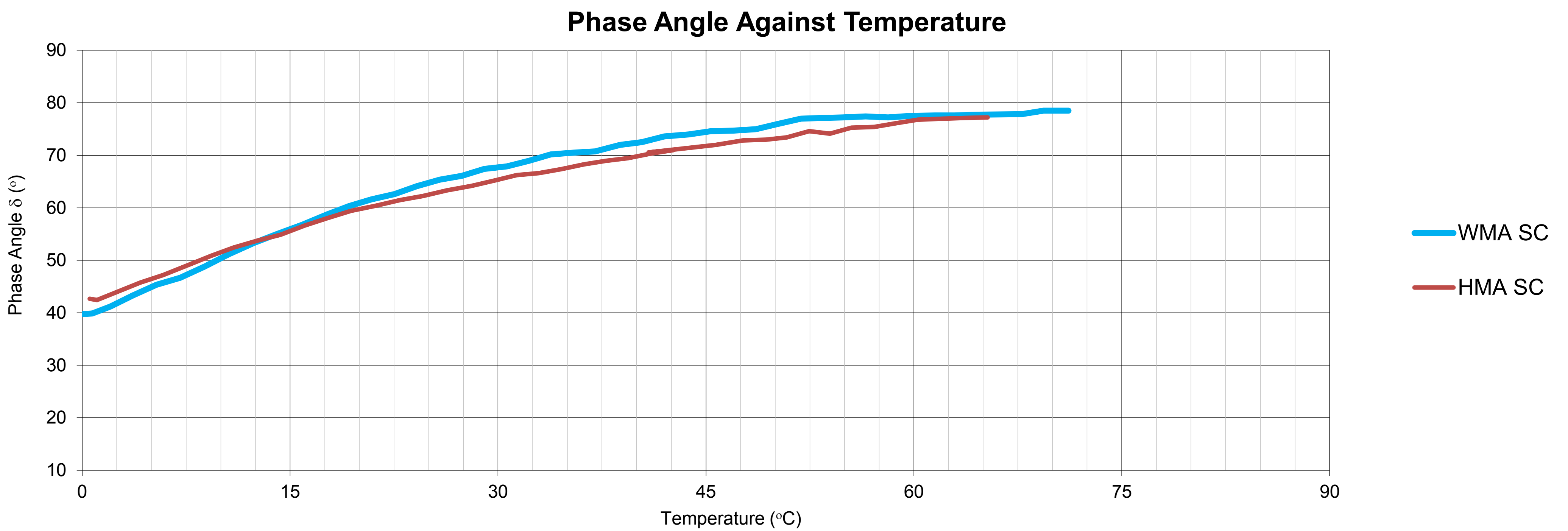
Testing carried out using 8 mm Spindle, 1mm gap, 1% Strain, Equilibration Time of 600s.

Checked by: -	**Eric Draper**	Date: -	**23 March 2017**

DETERMINATION OF COMPLEX SHEAR MODULUS AND PHASE ANGLE - DYNAMIC SHEAR RHEOMETER (DSR)

0078 SOP, BS EN 14770 : 2012

Project Title :	**Task 1-111 A5 Warm Mix Trials**	Client Sample ID :	**WMA and HMA**	Tested By :	**BA**
Job Number :	**60523093**	Location of Testing :	**Nottingham**	Reported By :	**BA**
Bulk Reference :	**CR 01096**	Date of Issue :	**23 March 2017**	Checked By :	**EKD**



Comments and Deviations:

Origin of samples :Extracted from Site

Testing carried out using 8 mm Spindle, 1mm gap, 1% Strain, Equilibration Time of 600s.

Checked by: -	**Eric Draper**	Date: -	**23 March 2017**

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