Ex Situ Cold Recycled Bound Material

Updates to DMRB CD 226
Stage 1.1.2 - Condition assessment

National Highways

Project reference: T0054 - Pavement Call-Off Support 2021-2024
Project number: 60658793

22 November 2022

Delivering a better world

Quality information

Prepared by	Checked by	Verified by	Approved by
Joe Poulsom Principal Pavement Engineer	Martyn Jones Associate	Jessica Tuck Technical Director	Ramesh Perera Technical Director

Revision History

Revision	Revision date	Details	Authorized	Name	Position

Distribution List

# Hard Copies	PDF Required	Association / Company Name

Project reference: T0054 - Pavement Call-Off Support 2021-2024
Project number: 60658793

Prepared for:

National Highways

Prepared by:

Joe Poulsom
Principal Pavement Engineer
E: Joe.Poulsom@aecom.com

AECOM Infrastructure & Environment UK Limited
12 Regan Way
Chetwynd Business Park
Nottingham NG9 6RZ
United Kingdom

T: +44 (115) 907 7000
aecom.com

Table of Contents

Figures

Tables

1. Introduction

National Highways has commissioned the Arup AECOM consortium to recommend updates to their requirement and advice documents (RADs) in relation to ex situ manufactured cold recycled bound material (CRBM). Current design requirements for ex situ CRBM are contained within the Design Manual for Roads and Bridges (DMRB) CD 226 'Design for new pavement construction', which refers to TRL 611 for CRBM design curves. Product and installation requirements for CRBM are currently contained within Clause 948 of the Specification for Highway Works (SHW).

Currently, DMRB CD 226 imposes restrictions on CRBM to limit its use to sites with a design traffic of 30 million standard axles (msa) or less. This was on the basis of a lack of evidence of in situ performance of the CRBM beyond 25 msa as outlined in TRL 611, which states *'… the road trials on which the design guidance contained in this report was formed carried a maximum traffic of 25 msa; therefore designs for heavily traffic roads [>30 msa] are based upon extrapolations of existing knowledge and they should therefore be treated with caution'*. Consequentially, the use of CRBM on sites with a design traffic greater than 30 msa requires a 'departure from standard' application. As such, in order to reduce departure from standard applications and support decarbonisation, the scope of this task is to:

- Establish a new maximum permitted design traffic (msa) for ex situ CRBM QVE Class B3 and Class B4 based on the in situ performance of ex situ CRBM on the Strategic Road Network (SRN).
- Develop design curves for ex situ CRBM QVE Class B4 to accompany the design charts in TRL 611 for QVE Class B3.
- Introduce a minimum asphalt overlay thickness for ex situ CRBM QVE Class B3 and Class B4. CD 226 currently requires a minimum thickness of bituminous surface course of 20 mm; and TRL 611 a minimum total asphalt surfacing thickness (including binder course) of 50 mm for designs up to 10 msa, and 70 mm for designs up to 30 msa.

Work Stage 1.1.1 'Establishing Acceptance Criteria' was delivered in July 2022 and proposed outline design options for ex situ CRBM QVE for verification or challenge by the current Work Stage 1.1.2 'Condition Assessment'. This included:

- a maximum design life of 80 msa [i.e. not applicable to >80 msa 'long-life']
- a reduced end-product ITSM (4,700 MPa) to design layer stiffness (3100 MPa) ratio for CRBM QVE Class B4

  [For comparison, the layer stiffness for design is taken to be around 130% of the laboratory ITSM for AC 40/60 and 100% of the laboratory ITSM for CRBM QVE Class B3 (TRL, 2004). The proposed maximum of around 70% of the laboratory ITSM for CRBM Class B4 is to account for the contribution of the additional cement that makes this material more susceptible to cracking.]
- design thicknesses for QVE B4 (based on nomographs in HD 26/06 for HRA 50, i.e. layer stiffness 3100 MPa) for pavement foundation Class 2 and Class 3, with a design asphalt overlay thickness (placed in 2 layers) ranging from 110 to 140 mm.

The proposed outline design options were based on the over-arching assumption that pavements designed using the TRL 611 design curve for CRBM QVE B3 complying with Clause 948 (i.e. achieving 3100 MPa ITSM and with a corresponding design layer stiffness of 3100 MPa) are durable up to 30 msa.

This technical note presents the findings from Work Stage 1.1.2 to verify, or otherwise challenge, the above outline design life expectations. On safety grounds, the 'essential' information considered for this in situ performance review of the CRBM was based on a desk-based study of available data sources (typically network level survey data and published literature) or new condition data that could be collected at traffic speed.

Given that there may be limitations with available data sources or new data collected at traffic speed, or they may be inconclusive versus slow / static surveys, it was agreed to include hold points within the task at regular intervals to present findings and agree the next steps with National Highways. The work stages, activities and hold points in each work stage within this task are summarised in Figure 1.1.

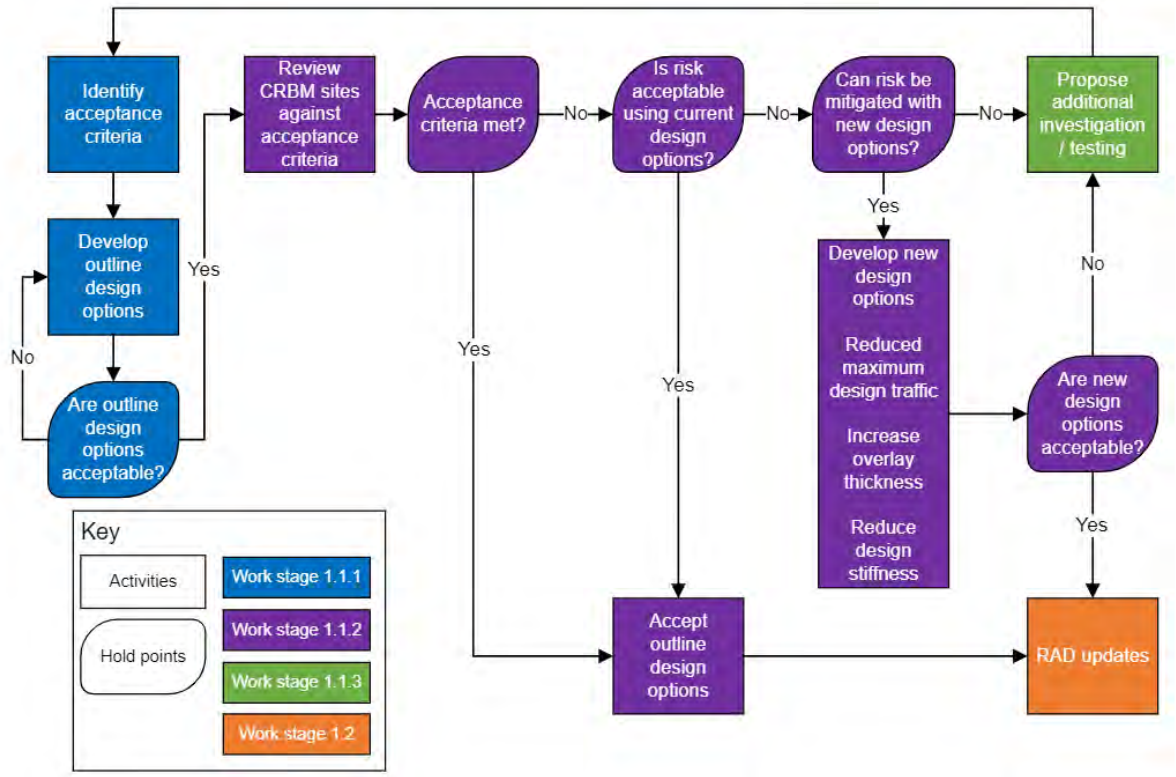


Figure 1.1 - Work stages

2. Approach

The implementation within the DMRB, of the outline ex situ CRBM design thicknesses versus life designs, as proposed in Table 4 of the Work Stage 1.1.1 report, is subject to the confirmation of satisfactory in situ performance, otherwise an adjusted design, based on the candidate ex situ CRBM sites reviewed during this Work Stage 1.1.2. As such, a performance / condition assessment of these candidate ex situ CRBM sites on the SRN has been carried out, and presented in this report, to validate the performance of sites that were designed and constructed following the methodology outlined in TRL 611 or its precursor TRL 386.

2.1 Applicability of lengths of ex situ CRBM on the SRN for assessment

As outlined in Work Stage 1.1.1, CRBM is assumed to perform (and deteriorate) in the same manner as other flexible (asphalt) pavement layers. The failure criteria is taken to be fatigue cracking induced by cumulative traffic loading, and the primary design criteria is to limit the horizontal strain at the bottom of the CRBM layer by increasing the pavement layer thickness(es) and/or enhancing the material stiffness and/or fatigue performance properties. In addition to traffic loading, environmental loading can cause distress in the upper pavement layers including thermal effects and ageing (oxidation). For lower pavement layers, the sub-surface drainage provision can have a significant impact on the durability of pavement materials.

Ex situ CRBM was first installed on the SRN in 2002, so lengths of ex situ CRBM in situ on the SRN are a maximum of 20 years old. For the purposes of this analysis, sites that are more than 10 years old are considered to have been subject to long-term trafficking sufficient to be candidate sites.

The cumulative traffic (in msa) since the installation of the CRBM will vary from site to site; however, in order to account for the importance of cumulative traffic loading on fatigue performance, only Lane 1 (the most heavily trafficked lane) has been considered. Lanes with a cumulative traffic of more than 15 msa are considered to have been subject to long-term trafficking sufficient to be candidate sites.

As the proposed designs include a maximum asphalt overlay thickness of 140 mm, only those sites with a maximum 150 mm asphalt overlay are considered to be candidate sites.

The proposed outline designs to be included in the DMRB are limited to ex situ CRBM QVE B3 and B4 materials. It is understood that all ex situ CRBM QVE on the SRN was designed to be Class B3 or Class B4. Any QVE B3 or B4 identified as present on the SRN is to be verified by published literature or via the supply chain. Herein, ex situ CRBM QVE is abbreviated to 'CRBM'. The criteria for the candidate CRBM sites to be included in the current Work Stage 1.1.2 condition assessment are summarised in Table 2.1.

Table 2.1 - Criteria for candidate CRBM sites

Parameter	Criteria
Age of CRBM material	> 10 years old
Cumulative Lane 1 traffic	≥ 15 msa
Asphalt overlay thickness (mm)	< 150 mm
CRBM type	QVE B3 or B4 only

2.2 CRBM Condition assessment methodology

In order to support an intact condition assessment of in-service CRBM, a description of 'satisfactory performance' and the associated 'acceptance criteria' for CRBM are summarised in Table 2.2. Those parameters considered 'essential information' are discussed further in the following sub-sections.

Table 2.2 - CRBM condition acceptance criteria

Parameter	Satisfactory performance	Acceptance criteria
Essential information		
Network Structural Condition (NSC) (Section 2.2.1)	• The network level condition aligns with that of a 'technically simple scheme' by DMRB CS 230, i.e. free from structural deterioration and can be maintained with surface course replacement / surface treatments. • Comparable with any adjacent lengths of non-CRBM flexible pavement.	• Min. 85% of 100 m sub-lengths exhibiting condition category 1 or 2 • Alignment with characteristic sections of the SRN
Enhanced Longitudinal Profile Variance (eLPV) (Section 2.2.1)		• Min. 85% of 100 m sub-lengths exhibiting condition category 1 or 2 • Alignment with characteristic sections of the SRN
Rut depth (Section 2.2.1)		• 100% length in condition category 1 or 2 (<11 mm)
Surface course maintenance history (Section 2.2.2)	• The length has not been subject to excessive surface maintenance versus typical requirements since the installation of the CRBM.	• Surface course replaced at intervals less than around 12 years in Lane 1
Visual condition (Section 2.2.3)	• The length does not include structural defects related to the CRBM.	• No visible structural defects or evidence of repairs of structural defects.
Desirable additional information		
Cores	• Core Logs show CRBM is intact.	• No visible cracking or deterioration, except that a single transverse crack with good aggregate interlock remains acceptable
Falling Weight Deflectometer	• Layer stiffness indicative of intact condition	• Back-analysed layer stiffness >2 GPa

2.2.1 Network level condition

Network structural condition (NSC) is derived from Traffic Speed Deflectometer (TSD) measurements considering the pavement construction and traffic data in the analysis. As outlined in DMRB CS 230, NSC category 3 indicates the length of pavement is likely to require structural maintenance, and category 4 indicates the length of pavement is very likely to require structural maintenance. 100 m sub-lengths of CRBM in these categories taken in isolation could be interpreted as unsatisfactory performance of the CRBM. However, pavement design considers an 85% probability of achieving the design life; indeed, CS 230 permits deeper treatments to be undertaken on 10% of the pavement area within a Technically Simple Scheme. Therefore, if less than around 15% of the 100 m sub-lengths of CRBM falls within NSC category 3 or 4, with the remainder sub-lengths to the scheme length falling within NSC category 1 or 2, the CRBM is still offering satisfactory performance.

TRAffic-speed Condition Surveys (TRACS), specifically the parameters 'enhanced longitudinal profile variance' (eLPV) and 'rut depth' are indicative measures of pavement structural condition. CS 230 outlines that where these parameters are condition category 3 or 4, either moderate or severe deterioration of the pavement is likely. Rut depth is considered within the assessment approach for technically simple schemes, whereas eLPV is not considered; however, a length of pavement within eLPV condition category 1 or 2 is indicative that the pavement roughness has not deteriorated to an extent to require further investigation for maintenance.

2.2.2 Surface course maintenance history

Beyond network level condition parameters, pavements which require increased surface maintenance can offer reduced value for money and increased disruption to road users. Surface maintenance can be linked to surface and/or underlying structural characteristics, i.e. pavements in poor structural condition are likely to require increased surface maintenance so that the pavement surface remains safe and serviceable.

Therefore, increased surface maintenance (i.e. resurfacing) of CRBM lengths is likely to indicate structural deterioration. Given that the CRBM was installed 20 years ago or less, it is highly likely that the surface course over the CRBM will be a thin surface course system (TSCS). The typical lifespan of TSCS on the SRN is well understood. Therefore, comparison with typical expectations for surface course replacement rates, approximately once every 12 years for TSCS in Lane 1, will provide an understanding of whether lengths may be affected by an underlying structural concern that might be related to the CRBM or the foundation.

HAPMS contains information on the surface course replacement history. However, the data set can be unreliable on the basis that resurfacing events are not always captured in the data set and it is difficult to distinguish between resurfacing events and data corrections or changes, which are relatively common, without secondary verification e.g. via Google Street View imagery.

2.2.3 Visual condition

Visual defects that indicate the presence of structural problems include cracking (longitudinal or block), surface depressions and pumping. Given that the CRBM lengths being assessed are more than 10 years old, surface-only defects (e.g. fretting, open construction joints) can be expected in lengths where the surfacing has not been replaced.

Lengths of CRBM on the SRN are known to have suffered from transverse reflective cracking as a result of excessive stiffness causing embrittlement of the CRBM linked to increased cement content. However, in some circumstances, transverse cracking has been shown to have propagated from underlying hydraulically bound mixture (HBM) layers (Atkins Jacobs JV, 2020). Therefore, it is expected that transverse cracking will be present on the candidate lengths of pavement assessed as part of this task. Work is being undertaken as part of this task (under Work Stage 2.1) to develop options to limit the stiffness of CRBM in situ.

The aim of a visual condition assessment under this Work Stage 1.1.2 is to obtain an understanding of the relative surface condition of the site only by identifying any structural defects or evidence of structural defect repairs (i.e. asphalt patches (which may not be inputted into HAPMS)) that are present.

3. Candidate CRBM lengths

Five sites were identified as candidates, i.e. those meeting the applicability criteria detailed in Section 2.1, to verify, otherwise to challenge, the outline design life expectations. The location of these sites and the construction information is provided in Table 3.1. National Highways pavement management system, HAPMS, inaccurately represents the construction of two of the sites in Table 3.1 as the CRBM layer present is not documented.

Table 3.1 - Summary of location and construction of CRBM sites reviewed

Road	Site	NH Area	Year laid	HAPMS sections	Total length (lane km)	Cumulative traffic (msa)	Asphalt Overlay	CRBM	Substrate	Contractor	CRBM in HAPMS?
A21	Sevenoaks	4	2002	2200A21/755, 756, 759, 760, 763, 764, 767, 768, 771 ,772	24	34	50 mm TSCS 20 mm SMA	195 mm QVE B3	HBM	Tarmac	Yes
A38	Buckfastleigh, Devon	1	2005/ 2006	1100A38/213, 217, 218, 381, 382, 383, 389	43	35	40 mm TSCS 60 mm SMA	220 - 280 mm QVE B3	Granular subbase	Tarmac	Yes
A52	Stragglethorpe Rd to Nottingham Rd	7	2007	3000A52/315, 316	1.6	32	30 mm TSCS 60 mm AC 40/60	280 mm QVE B4	Varies	Tarmac	No
A46	Stratford upon Avon Northern Bypass	9	2006	3700A46/566, 560	4	19	30 mm TSCS 70 mm AC 40/60	140 mm QVE	Cracked and seated HBM	Cemex	Yes
A45	Ryton-on-Dunsmore	9	2009	3700A45/135, 140, 150, 155, 160	10	26	40 mm TSCS 60 mm AC 40/60	300 mm QVE	Varies	Cemex	No

Table 3.2 summarises the condition of the CRBM sites, considering Lane 1 only, including the:

- number of times that lengths of the site have been resurfaced
- NSC category of 100 m sub-lengths within the site
- weighted average of these parameters for all CRBM lengths.

Those parameters considered essential, including rut depth, are discussed further in the following sub-sections.

Table 3.2 - Summary of condition of CRBM sites reviewed

Road	Site	Age (years)	NSC Category of site (2021)				Number of times lengths of site (%) resurfaced			Avg. surfacing life (years)
			1	2	3	4	Zero	Once	Twice	
A21	Sevenoaks	20	89%	11%	0%	0%	0%	86%	14%	14
A38	Buckfastleigh, Devon	17	15%	72%	7%	5%	0%	50%	50%	8
A52	Stragglethorpe Rd to Nottingham Rd	15	55%	45%	0%	0%	100%	0%	0%	15
A46	Stratford upon Avon Northern Bypass	16	95%	5%	0%	0%	100%	0%	0%	16
A45	Ryton-on-Dunsmore	13	49%	38%	9%	4%	90%	10%	0%	11
Average for all CRBM		**-**	**61%**	**34%**	**3%**	**2%**	**29%**	**48%**	**23%**	**11**

The location, surfacing history and network level condition data (TRACS and NSC) that is available for these candidate sites has been presented in strip plans in AECOM's web-based pavement data platform, Linear Data Visualisation (LDV), with web-links provided in Table 3.3 (registration required). As discussed earlier in this section, the construction history on HAPMS of some lengths is inaccurate based on information provided by the supply chain.

Table 3.3 - Hyperlinks to strip plans of sites

Site	Link	
A21 Sevenoaks	Direction A (Southbound)	Direction B (Northbound)
A38 Buckfastleigh	Direction A (Northbound)	Direction B (Southbound)
A52 Stragglethorpe Rd to Nottingham Rd	Direction A (Eastbound)	Direction B (Westbound)
A46 Stratford-upon-Avon	Direction A	
A45 Ryton-on-Dunsmore	Direction A (Westbound)	Direction B (Eastbound)

3.1 Overall condition of CRBM sites reviewed

3.1.1 Network structural condition

Figure 3.1 shows the NSC category of 100 m sub-lengths of the candidate CRBM sites outlined in Table 3.1 in each survey year. Where the section has not been surveyed in a year, the most recent survey has been considered. As a comparison, Figure 3.2 shows the NSC category of 100 m sub-lengths of pavement for the Area 10 network. Area 10 was chosen as a benchmark as it primarily comprises motorways with an asphalt surfacing, hence should be representative of a predominantly flexible pavement network in typical in-service condition.

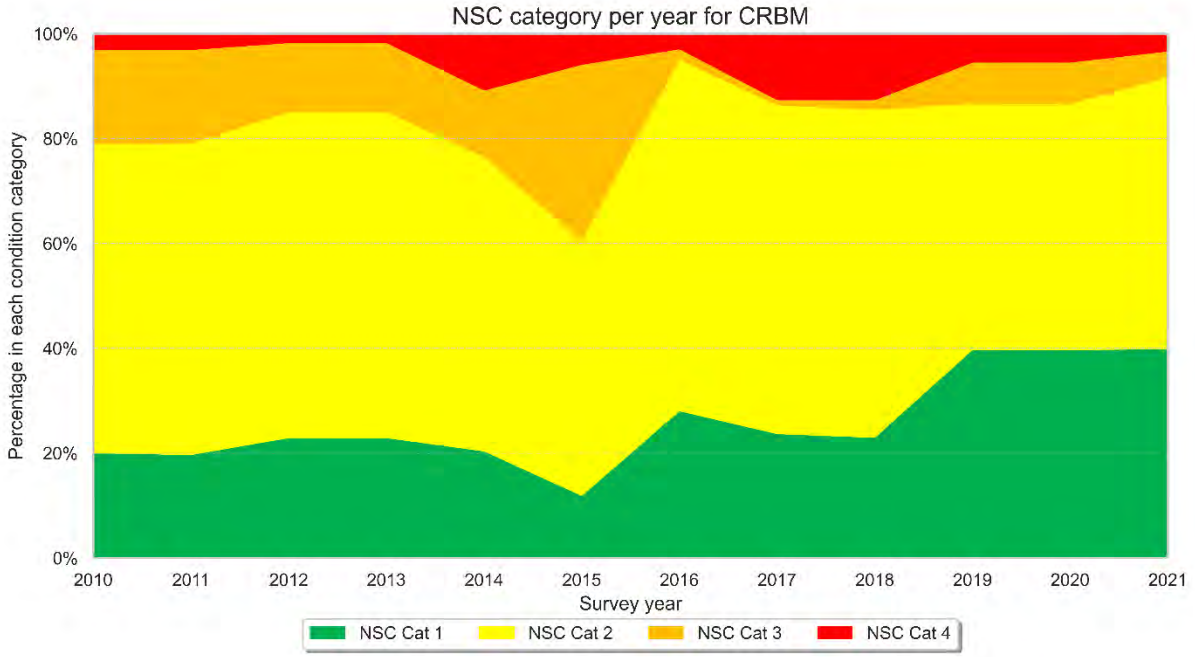


Figure 3.1 - NSC Category per year for 100 m sub-lengths of CRBM

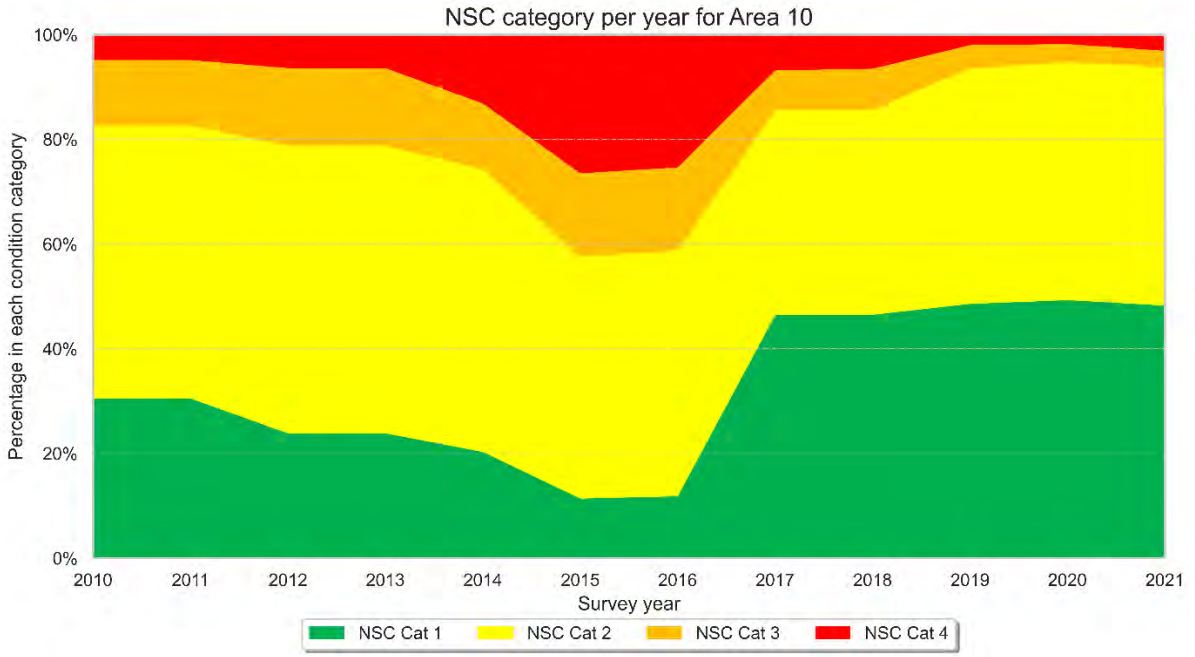


Figure 3.2 - NSC Category per year for 100 m sub-lengths of pavement in Area 10 (benchmark)

The number of sub-lengths for the CRBM considered in Figure 3.1 and Figure 3.2 are presented in Table 3.4. The number of sub-lengths increases with successive years as an increasing number of sections of road are surveyed by the TSD.

Table 3.4 - Count of sub-lengths considered in network structural condition analysis

Year	Number of sub-lengths for CRBM candidate sites	Number of sub-lengths for Area 10
2010	1222	7253
2011	1232	7253
2012	1242	9370
2013	1242	9370
2014	1368	9434
2015	1420	12153
2016	1422	12224
2017	1422	20466
2018	1422	20466
2019	1422	20486
2020	1422	20932
2021	1422	20932

Comparing Figure 3.1 and Figure 3.2, it is apparent that in 2015 there was a significant increase in the NSC categories 3 and 4 reported (i.e. suggesting deterioration) across the SRN. However, the condition quickly recovered in subsequent survey years, which indicates that this is most likely a function of the survey analysis (i.e. a common TSD survey factor or perhaps a common environmental factor) rather than a deterioration in the pavement structural condition that was subsequently treated.

Based on Figure 3.1 and Figure 3.2, it can be concluded that:

- The NSC category indicates that the candidate CRBM sites are generally consistent with a typical in-service condition and not generally in need of structural maintenance.
- Typically less than 10% of CRBM is in NSC category 3 or 4 in any year, which is aligned with other pavement types on the SRN.

The structural condition of the CRBM sites appears to be broadly stable with the cumulative years and traffic in-service, and there is no apparent deterioration of the structural condition.

3.1.2 Longitudinal profile variance (eLPV)

The 3 m, 10 m and 30 m eLPV for 2021 for each length of CRBM is shown in Table 3.5. Data for the A52 Stragglethorpe Road to Nottingham Road section was not available in HAPMS and so hence, could not be considered here. Lengths of CRBM are largely in condition categories 1 and 2, indicating a low level of deterioration.

Table 3.5 - 2021 3 m, 10 m and 30 m eLPV for CRBM sites

	eLPV 3 m Cat (% site) (2021)				eLPV 10 m Cat (% site) (2021)				eLPV 30 m Cat (% site) (2021)			
Category	1	2	3	4	1	2	3	4	1	2	3	4
A21 Sevenoaks	91%	8%	1%	0%	48%	50%	2%	0%	82%	18%	0%	0%
A38 Buckfastleigh	95%	5%	0%	0%	61%	39%	0%	0%	84%	16%	0%	0%
A45 Ryton-on-Dunsmore	56%	37%	6%	2%	23%	67%	8%	0%	46%	38%	4%	0%
A46 Stratford-upon-Avon	93%	7%	0%	0%	64%	36%	0%	0%	83%	9%	9%	0%

Some lengths of the CRBM are in condition category 3 and 4; however, it can be seen in Figure 3.3 that the percentage of lengths in each category are comparable with that of the Area 10 network used as a benchmark. On this basis, it is considered that the profile evenness of the lengths of CRBM is indicative of pavement lengths delivering satisfactory performance and not exhibiting an excessive level of deterioration.

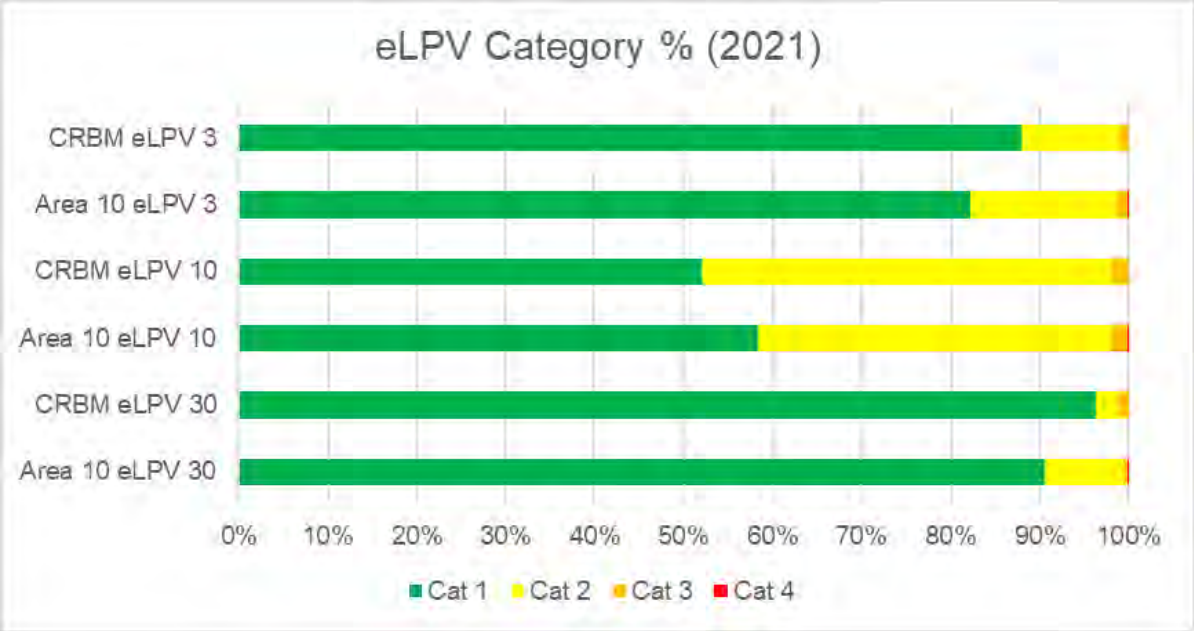


Figure 3.3 - eLPV Category for CRBM (excluding A52 candidate site) and Area 10 network benchmark

3.1.3 Rut Depth

TRACS rut depth data has been reviewed, as proposed in Table 2.2, but the review indicates (as expected) that the values are more linked to surface condition than structural condition; and, since the sites are surfaced with TSCS and this does not typically rut, this parameter has been excluded from the assessment.

3.1.4 Surface Course Maintenance History

All sites are surfaced with thin surface course system (TSCS). The average lifespan expected for TSCS is typically accepted to be 12 years in Lane 1. Three of the five sites meet or exceed the average life and are therefore performing as expected. The two sites that are not are considered below:

- The A38 at Buckfastleigh has an average TSCS life of 8 years. Whilst this is less than the typical average, resurfacing of some sections appears unrelated to structural deterioration. This is discussed further in Section 3.2.2.
- The A45 Ryton-on-Dunsmore has a marginally lower-than-average TSCS life. Multiple resurfacing patches have been undertaken on the eastbound carriageway as discussed further in Section 3.2.5.

3.2 Condition of individual sites

The following sections provide supplementary site-specific details to the overall condition summaries previously presented.

3.2.1 A21 Sevenoaks

The A21 at Sevenoaks in Kent is a dual carriageway with a combination of two lanes and three lanes (following a widening project in 2002) in each direction. CRBM was installed along a 5 km section in 2002 by Tarmac as an inlay over an existing HBM except in the widening locations which created a new Lane 1. The CRBM was overlaid with 70 mm asphalt.

The traffic on this site since the installation of the CRBM is estimated to be 34 msa based on DfT data.

The condition of the CRBM on this site is documented by Atkins Jacobs JV report Task 1-583 Subtask 3.3 (dated July 2020) (Atkins Jacobs JV, 2020). The site was subject to a factual pavement investigation by AECOM (formerly URS) in 2014. Cores were recovered (representative cores are shown in Figure 3.4) and falling weight deflectometer testing was undertaken; however, cores were not tested for stiffness. The FWD back-analysed stiffness of the CRBM layer averaged 5253 MPa with a minimum of 3400 MPa and a maximum of 7900 MPa.

This suggests the layer is exhibiting 'some deterioration' in accordance with CD 227, as expected of a generally intact in-service asphalt material. Indeed, the cores are intact and the minimum back-analysed stiffness on the site is greater than the design stiffness for a QVE B3 (3100 MPa).

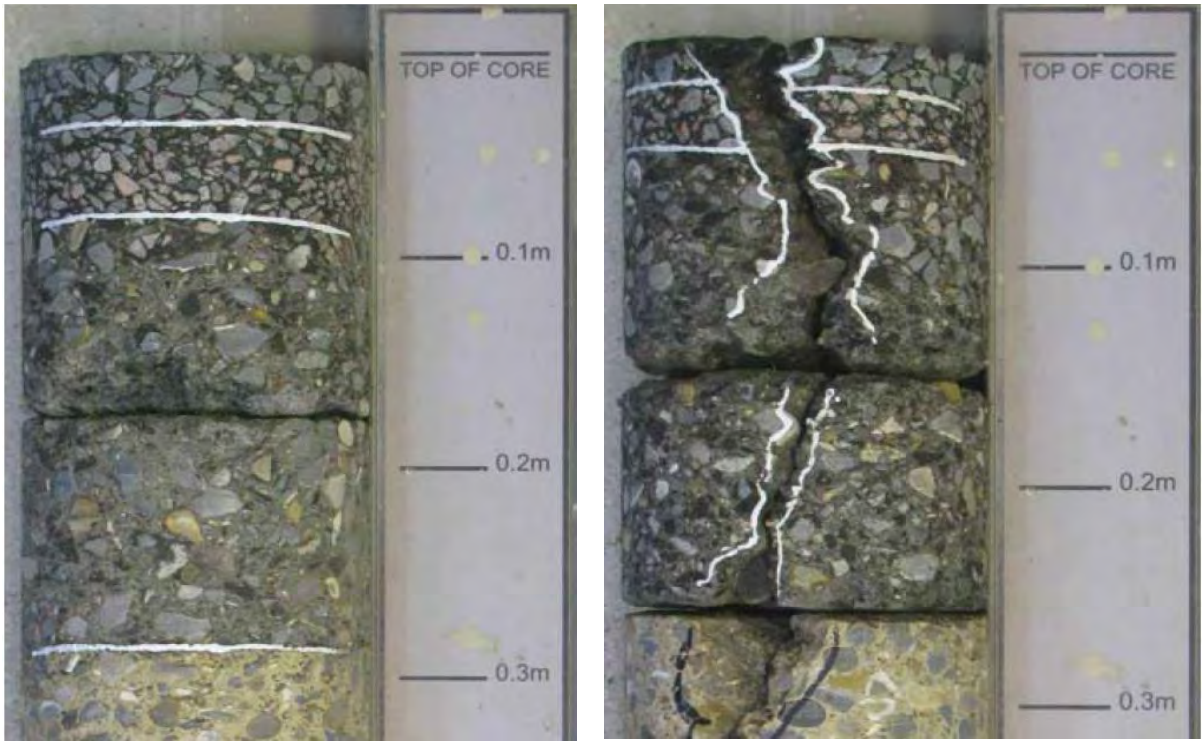


Figure 3.4 - A21 Sevenoaks cores, construction core (left) and defect core (right) (AECOM, 2014)

The eLPV and NSC categories for the site are indicative of a length of pavement not requiring structural maintenance. The number of resurfacing treatments are reported in Table 3.2. The age of the surfacing at replacement is greater than the typical average of 12 years in Lane 1 for the SRN. The Atkins Jacobs JV report outlined that overall the site was performing well, but regular transverse reflective cracking was present that is assumed to be propagating from the underlying HBM (constructed 1967).

3.2.2 A38 Buckfastleigh

The A38 at Buckfastleigh in Devon, South West is a dual carriageway with two lanes in each direction. CRBM QVE B3 was installed under a renewal scheme along a 12 km section in 2006 over an unbound foundation by Tarmac. The CRBM was overlaid with 100 mm asphalt.

The traffic on this site since the installation of the CRBM is estimated to be 35 msa based on DfT data.

The condition of the CRBM on this site is documented by Atkins Jacobs JV report Task 1-583 Subtask 3.3 (dated July 2020) (Atkins Jacobs JV, 2020). The eLPV and NSC categories for the site are indicative of a length of pavement not requiring structural maintenance and the site has not been subject to major structural maintenance since the installation of the CRBM.

The entire length has been resurfaced with TSCS once, which is expected given the age of the section (16 years old), but some locations have been resurfaced twice. However, based on visual condition alone of the TSCS prior to replacement, the driving reason for the resurfacing does not appear to be the condition of the TSCS linked to structural deterioration i.e. cracking, crazing or potholing. There are number of structures within the site and the TSCS on the structures was in poor visual condition prior to resurfacing, so this may have been the driver for the treatment of specific lengths in between structures where the CRBM is located.

The site appears to be in good visual condition (Google Street View, October 2022) with no evidence of cracking, crazing or other deterioration associated with structural deterioration. On this basis, the CRBM appears to be performing satisfactorily.

3.2.3 A52 Stragglethorpe Road to Nottingham Road

The A52 between Stragglethorpe Road to Nottingham Road, Radcliffe, Nottinghamshire (Area 7) is a dual carriageway with two lanes in each direction. CRBM was installed by Tarmac in 2007 under a renewal scheme along a 400 m section over a granular/weakly bound foundation. The CRBM was overlaid with 95 mm asphalt. This length of CRBM is not reported in HAPMS and information on this site was provided by Tarmac.

The traffic on this site since the installation of the CRBM is estimated to be 32 msa based on DfT data.

The NSC categories for the site are indicative of a length of pavement not requiring structural maintenance. eLPV data was not available in HAPMS. The site has not been resurfaced since the installation of the CRBM, so the surfacing is 15 years old. As expected for a site of this age, recent imagery (Google Street View, April 2022) indicates that the surfacing is now showing signs of deterioration including transverse cracking as shown in Figure 3.5, assumed to be propagating from the underlying CRBM.

Figure 3.5 - A52 Stragglethorpe Rd to Nottingham Rd transverse cracking and ravelling

3.2.4 A46 Stratford-upon-Avon Bypass

The A46 Stratford-upon-Avon Bypass is a two-way single carriageway. CRBM was installed on a section of pavement approximately 2 km in length in 2006 by Cemex over cracked and seated HBM. The crack and seat and subsequent CRBM works are discussed further in TRL PPR 228. The CRBM was overlaid with 90 mm asphalt. The traffic on this site since the installation of the CRBM is estimated to be 19 msa based on DfT data.

Longitudinal cracking in the asphalt surfacing is prevalent in the lane centres along the site, aligned with the longitudinal construction joints in the HBM which are present in the centre of each lane as shown in Figure 3.6. Longitudinal cracking is not expected to emanate from construction joints through a 230 mm thick flexible layer (combined CRBM and asphalt thickness). However, PPR 228 states that the construction joints at the time of construction of the CRBM were wide (>10 mm) as a result of embankment settlement. Some of these construction joints had been subject to trench repairs with asphalt prior to the crack and seat and CRBM works. Visually, the cracking, located outside the wheel tracks, appears to be consistent with the historical settlement rather than the structural integrity of the pavement layers.

Regular transverse cracking in the asphalt surfacing is present on the site. It is not known whether transverse cracks are propagating from:

- the underlying cracked and seated HBM layer, and/or
- the CRBM layer, and/or
- the asphalt surfacing, i.e. top-down cracking.

Cores for this site were taken by AECOM in 2019 and are provided in Appendix A. The cores were taken through sound uncracked surfacing only, and indicate that the CRBM was in good condition and intact as shown in the representative photos in Figure 3.7. On the basis of the above, the CRBM is considered to be performing well.

Figure 3.6 - A46 Stratford-upon-Avon Bypass longitudinal cracking from underlying HBM joints

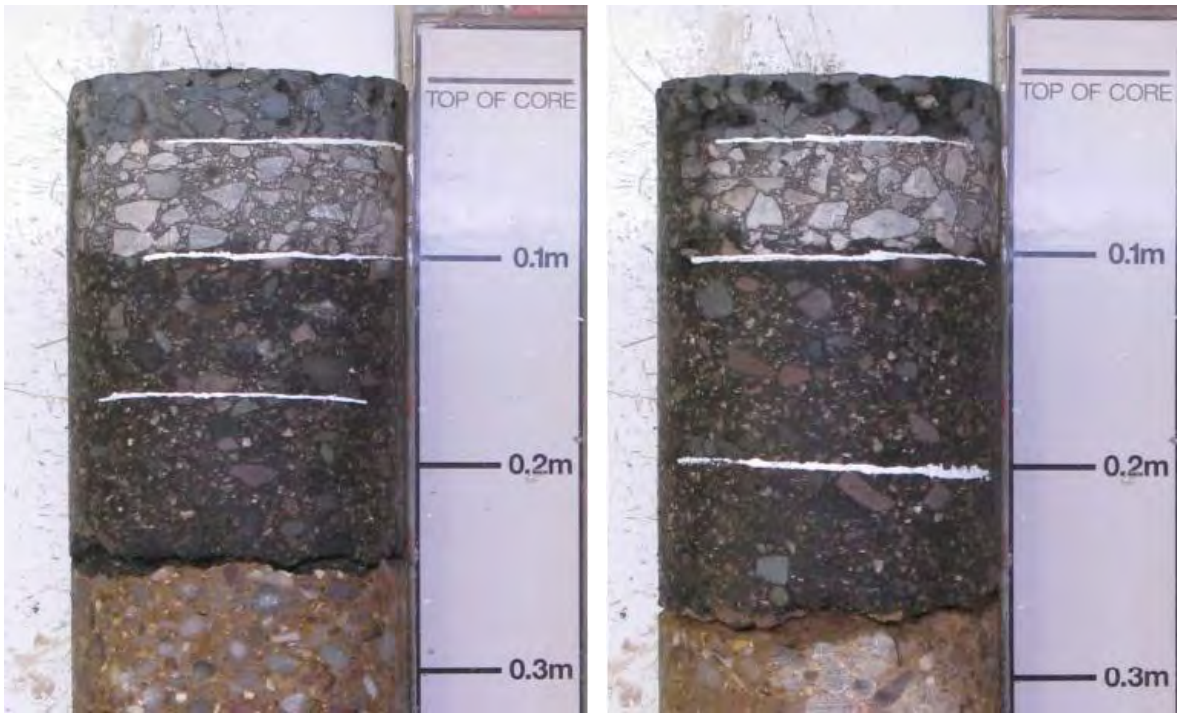


Figure 3.7 - A46 Stratford upon Avon bypass cores from 2019

3.2.5 A45 Ryton-on-Dunsmore

The A45 at Ryton-on-Dunsmore in Warwickshire (Area 9) is a dual carriageway with two lanes in each direction. CRBM QVE was installed under a renewal scheme along a 2.5 km section in 2009 by Cemex. According to HAPMS, the substrate that CRBM was placed on varies between granular material, HBM and tar bound macadam. The CRBM was overlaid with 100 mm asphalt.

This length of CRBM is not reported in HAPMS and information on this site was provided by Cemex. It is reported in HAPMS as Tar Bound Macadam.

The traffic on this site since the installation of the CRBM is estimated to be 26 msa based on DfT data.

The eLPV and NSC categories for the site in 2021 are indicative of a length of pavement not requiring structural maintenance. The site has not been resurfaced in its entirety since the installation of the CRBM; however, the eastbound carriageway has been subject to extensive patching which appear consistent with structural deterioration which suggests that the CRBM has degraded. Approximately 18% of the eastbound carriageway has been resurfaced with short asphalt patches.

This deterioration, that has led to the need for patching, takes the form of potholing in the nearside wheel track of Lane 1, without any other significant deterioration present in the surfacing including transverse cracking as shown in Figure 3.8 and Figure 3.9. The deterioration appears to be concentrated in the nearside wheel track around sections which are likely to be subject to higher stress due to carriageway geometry (positive gradients and curvature) and fill locations (embankments). However, other sections have deteriorated and been subject to patching that are not in apparent high stress locations, see Figure 3.10.

Those sections of the eastbound carriageway requiring regular intervention are indicative of a CRBM pavement that is in an 'unsatisfactory' structural condition.

In contrast, the westbound carriageway is largely free from deterioration and has only had an asphalt patch applied in one location. Other sections on the eastbound are largely free from defects and there is not widespread transverse cracking across the site. This may suggest that the assumed deterioration of the CRBM on the eastbound carriageway is as a result of the local foundation and/or loading conditions.

Intrusive investigation is recommended to gain a better understanding of the condition of the pavement and the cause of the deterioration and the comparative differences between the westbound and eastbound carriageway.

Figure 3.8 - A45 Ryton-on-Dunsmore apparent structural deterioration (Google Street View, 2018)

Figure 3.9 - A45 Ryton-on-Dunsmore apparent structural deterioration (Google Street View, 2018)

Figure 3.10 - A45 Ryton-on-Dunsmore significant transverse cracking (Google Street View, 2022)

3.3 CRBM Sites on the SRN not included within this review

The sites identified in Table 3.6 are CRBM pavements that have not been identified as candidate sites for consideration during this Work Stage 1.1.2 as, whilst they meet the criteria for age, they either do not meet the criteria for cumulative traffic, or overlay thickness, or the location of the sections on the SRN could not be validated. The condition of some of these sites is reported in Atkins Jacobs JV Task 1-583 Sub-task 3.3 Report.

Table 3.6 - Sites on the SRN not assessed

Road	Location	Area	Year laid	HAPMS sections	Contractor	Length (lane km)	Cumulative traffic	Overlay thickness
A38	Trerulefoot	SW	2007	0800A38/666, 667	Unknown	~3	~10 msa	100 mm
A40	Gloucester	SW	2008	1600A40/635, 638, 642, 640, 645	Tarmac	~9	~10 msa	135 – 165 mm
A46	Seagrave L2 only	7	2010	2400A46/175, 176*	Lafarge	Unknown	~ 1 msa	Unknown
A3	Shottermill	SE	2010	3600A3/824, 825, 831, 840	Unknown	Unknown	Unknown	100 mm
M6	Junction 11	9	2006	Unknown*	Tarmac	Unknown	Unknown	Unknown
M1	Junction 9	East	2007	Unknown*	Tarmac	Unknown	Unknown	Unknown

*Construction data not in HAPMS

4. Summary

Five candidate sites have been identified where ex situ CRBM QVE Class B3 or Class B4 has been installed that are comparable to the proposed design approach detailed in Work Stage 1.1.1 and have been subject to long-term environmental and traffic loading. The flexible pavement constructions of these sites, incorporating a CRBM base layer, total 83 lane kilometres, are between 13 and 20 years old, and have been subject vehicular traffic ranging between 19 and 35 msa.

Based on the available as-built information, existing investigation data and published reports, HAPMS is incomplete or inaccurate for some of the sites and should be updated based on the details provided in this report.

The network level survey data reviewed in this Work Stage 1.1.2 report generally indicate, for the five candidate sites, satisfactory long-term structural performance of the flexible pavement incorporating a CRBM base layer with no trend towards early structural deterioration. In addition, the average surface course life for these lengths is aligned with the accepted average 12-year lifespan for a TSCS in Lane 1, indicating that these pavements are not subject to increased routine maintenance that would otherwise result in increased user disruption and reduced value for money.

There is one of the five sites that raises a potential CRBM durability concern that affects lengths of the eastbound pavement only on the A45 site at Ryton-on-Dunsmore. The affected lengths are exhibiting surface defects that may be indicators of structural deterioration, demonstrated by the lack of defects other than in the nearside wheel track, after having carried an estimated cumulative traffic of 26 msa over the last 13 years. This has resulted in the need for routine maintenance followed by patching. Whilst the causation of this deterioration may originate within the CRBM base layer, the deterioration is mostly concentrated in locations of highest stress due to the road geometry and the causation may be linked to increased loading effects and/or foundation conditions. The causation cannot be discerned from the limited data available; however, given that the adjacent westbound carriageway which has a similar construction is continuing performing satisfactorily, this site is not considered to support the current design traffic limit of 30 msa for CRBM until such time as when intrusive pavement investigations are undertaken to understand the deterioration causation further.

The visual condition of the other four sites are largely, or completely, free of visual defects associated with structural deterioration other than transverse cracking, which was expected based on other studies. Whilst longitudinal cracking is visible on the A46 site at Stratford-Upon-Avon, this is outside of the wheel track locations and is evidently associated with the well-documented poor substrate condition and a pre-existing crack in the underlying cracked and seated HBM.

Table 4.1 confirms the cumulative past traffic carried by each of the candidate sites and the current indicative CRBM condition detailed in this Work Stage 1.1.2 report, to show that their overall performance remains on-track to support the outline design life expectation proposed in Work Stage 1.1.1.

Table 4.1 - Summary of CRBM condition versus outline design life expectation

Road	Site	Cumulative traffic (msa)	Current indicative CRBM condition	Outline design life expectation (msa) [1]
A21	Sevenoaks	34	'Satisfactory' structural condition.	30 msa on bound FC3
A38	Buckfastleigh, Devon	35		80 msa on unbound FC2
A52	Stragglethorpe Rd to Nottingham Rd	32		80 msa on unbound FC2
A46	Stratford upon Avon Northern Bypass	19		<30 msa on bound FC3
A45	Ryton-on-Dunsmore	26	Eastbound carriageway 'unsatisfactory' structural condition. Westbound' satisfactory' structural condition	80 msa on unbound FC2

[1] Based on Table 4 of the Work Stage 1.1.1 report

CRBM pavements with 70 – 100 mm of asphalt surfacing do appear to be more susceptible to transverse cracking than standard flexible pavements, as evidenced in this report by transverse reflective crack propagation from HBM layers. A 'standard' flexible pavement design with 170 mm – 180 mm asphalt surfacing material

thickness is typically regarded as sufficient to delay such reflective crack propagation over a pre-cracked HBM base layer for a design life of 30 to 80 msa.

Transverse cracking is likely to result in increased maintenance over the lifespan of a CRBM pavement versus a standard flexible pavement construction and should be considered when evaluating design options. The risk of transverse cracking originating in the CRBM material may be related to the in situ stiffness and brittle nature of the material associated with increased cement content and may be mitigated through a specification update to limit in situ stiffness. The outline designs in Work Stage 1.1.1, require a minimum 110 – 140 mm of bituminous bound surfacing, which is an increase from the candidate sites reviewed.

The satisfactory in situ performance of the CRBM candidate sites reviewed during this Work Stage 1.1.2 supports the implementation of the designs proposed in Table 4 of Work Stage 1.1.1 within the DMRB.

5. Recommendations

The implementation of the outline design thicknesses for ex situ CRBM QVE Class B3 and Class B4 within the DMRB, as proposed in Work Stage 1.1.1, is subject to the confirmation of satisfactory in situ structural performance of candidate lengths of ex situ CRBM on the SRN from the desktop performance review presented in this report. Based on the findings from this review of 5 sites with a total lane length 83 lane km, having carried a cumulative traffic of 19 - 35 msa over the last 13 - 20 years, the following is recommended:

1. The outline design extrapolations in Work Stage 1.1.1, reproduced below in Table 5.1, are implemented within the DMRB without any additional risk mitigation being justified at this time.
2. The A45 site at Ryton-on-Dunsmore is subject to an invasive pavement evaluation comprising coring, foundation performance testing, Falling Weight Deflectometer (FWD) testing and Ground Penetrating Radar (GPR) to ascertain the causation for the apparent structural deterioration of the CRBM layers. The pavement evaluation should cover both carriageways to identify key factors in the current unsatisfactory and satisfactory performance between the eastbound and westbound carriageways, respectively.
3. HAPMS is updated to accurately reflect the correct ex situ CRBM QVE material type placed on all 5 sites assessed as part of this review.
4. Further investigation is undertaken into those CRBM sites in Table 3.6 which are known to industry but are not currently documented in HAPMS and were not reviewed in this report, so that their location, construction and condition can be updated in HAPMS for possible review in the future.

Table 5.1 - Extrapolated design thicknesses for QVE B3 and B4 for FC2 and FC3

CRBM Class	Foundation class	Design traffic (msa)	Asphalt thickness (mm)	CRBM thickness (mm)	Total bituminous bound thickness (mm)
QVE B4 (end-product ITSM 4700 MPa) equates to **Design Stiffness 3100 MPa**	FC2 (100 MPa)	30	110	235	345
		40	115	245	360
		50	120	250	370
		60	130	250	380
		70	135	255	390
		80	140	260	400
	FC3 (200 MPa)	30	110	215	325
		40	115	215	330
		50	120	215	335
		60	130	215	345
		70	135	215	350
		80	140	220	360

Appendix A – A46 Stratford-upon-Avon Cores

CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures 0061 - SOP

Job Number :	**60598963**	Scheme :	**University of Nottingham - A46 Stratford Northern Bypass**
Sample Number :	**T 1678 - 1**	Location :	**Southbound, Lane 1 (CL1), NSWT, Offset from nearside white line 0.2m**
Core Number :	**01**		**HAPMS Ch. 3700A46/566+875m**
Cored / Logged By :	**KS / SD**		
Date Cored / Logged :	**25-04-19 / 29-04-19**		**OSGR: SP 18020, 56203**
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	89	54	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
3	89	153	64	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
4	153	230	77	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
				Layers 4 & 5 Debonded After Extraction					
5	230	505	275	Concrete - Type B Voids	Yes	n/a	Cement	20	Crushed Rock
				Loose Granular Material Not Recovered					

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 0061 - SOP

UKAS TESTING 4410

Job Number :	**60598963**	Scheme :	**University of Nottingham - A46 Stratford Northern Bypass**
Sample Number :	**T 1678 - 1**	Location :	**Southbound, Lane 1 (CL1), NSWT, Offset from nearside white line 0.2m**
Core Number :	**01**		**HAPMS Ch. 3700A46/566+875m**
Cored / Logged By :	**KS / SD**		
Date Cored / Logged :	**25-04-19 / 29-04-19**		**OSGR: SP 18020, 56203**
Nominal Diameter :	**150mm**		**Notes: N/A**

ROAD

CORE

HOLE

CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures 0061 - SOP

UKAS TESTING 4410

Job Number :	**60598963**	Scheme :	**University of Nottingham - A46 Stratford Northern Bypass**
Sample Number :	**T 1678 - 1**	Location :	**Southbound, Lane 1 (CL1), NSWT, Offset from nearside white line 0.2m**
Core Number :	**02**		**HAPMS Ch. 3700A46/566+925m**
Cored / Logged By :	**KS / SD**		
Date Cored / Logged :	**25-04-19 / 29-04-19**		**OSGR: SP 17986, 56172**
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 (voided)	Yes	-ve	Bitumen	14	Crushed Rock
2	30	85	55	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
3	85	180	95	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
4	180	250	70	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
				Layers 4 & 5 Not Bonded					
5	250	490	240	Concrete - Type B Voids	Yes	n/a	Cement	20	Crushed Rock
				Loose Granular Material Not Recovered					

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 0061 - SOP

Job Number :	**60598963**	Scheme :	**University of Nottingham - A46 Stratford Northern Bypass**
Sample Number :	**T 1678 - 1**	Location :	**Southbound, Lane 1 (CL1), NSWT, Offset from nearside white line 0.2m**
Core Number :	**02**		**HAPMS Ch. 3700A46/566+925m**
Cored / Logged By :	**KS / SD**		
Date Cored / Logged :	**25-04-19 / 29-04-19**		**OSGR: SP 17986, 56172**
Nominal Diameter :	**150mm**		**Notes: N/A**

ROAD

CORE

HOLE

CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures 0061 - SOP

UKAS TESTING 4410

Job Number :	**60598963**	Scheme :	**University of Nottingham - A46 Stratford Northern Bypass**
Sample Number :	**T 1678 - 1**	Location :	**Southbound, Lane 1 (CL1), NSWT, Offset from nearside white line 0.3m**
Core Number :	**03**		**HAPMS Ch. 3700A46/566+975m**
Cored / Logged By :	**KS / SD**		
Date Cored / Logged :	**25-04-19 / 29-04-19**		**OSGR: SP 17948, 56136**
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	28	28	Asphalt Surfacing	No	-ve	Bitumen	14	Crushed Rock
2	28	93	65	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
3	93	153	60	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
4	153	230	77	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
				Layers 4 & 5 Debonded After Extraction					
5	230	460	230	Concrete - Type C Voids	Yes	n/a	Cement	20	Crushed Rock
				Loose Granular Material Not Recovered					

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 0061 - SOP

Job Number :	**60598963**	Scheme :	**University of Nottingham - A46 Stratford Northern Bypass**
Sample Number :	**T 1678 - 1**	Location :	**Southbound, Lane 1 (CL1), NSWT, Offset from nearside white line 0.3m**
Core Number :	**03**		**HAPMS Ch. 3700A46/566+975m**
Cored / Logged By :	**KS / SD**		
Date Cored / Logged :	**25-04-19 / 29-04-19**		**OSGR: SP 17948, 56136**
Nominal Diameter :	**150mm**		**Notes: N/A**

ROAD

CORE

HOLE

CORE LOGGING OF PAVEMENT MATERIAL

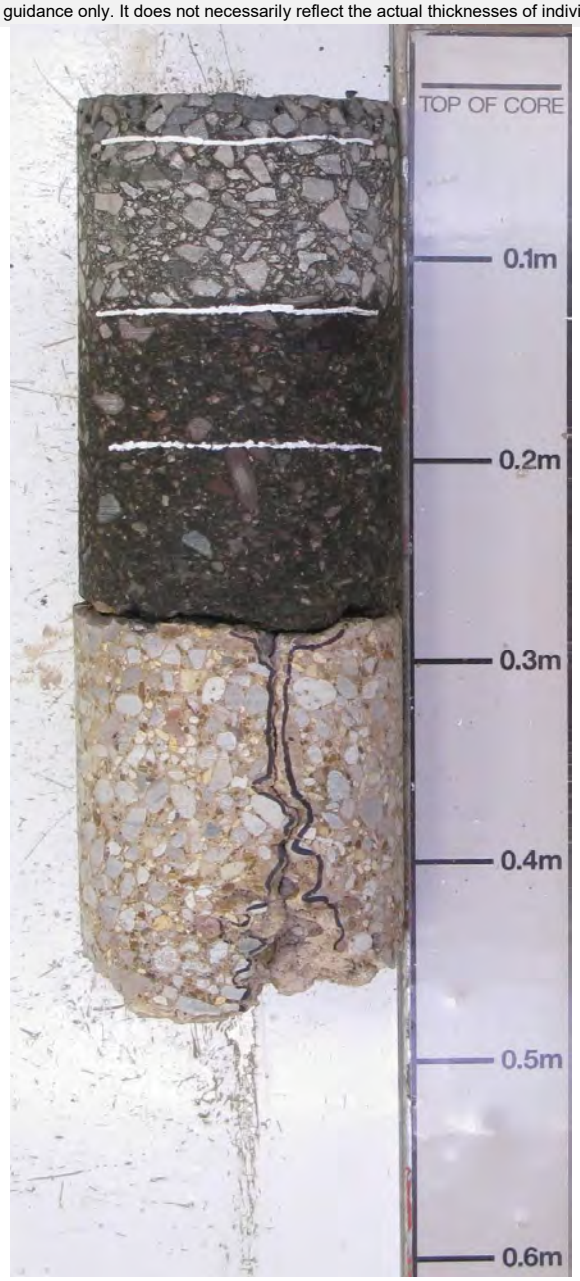
In Accordance with AECOM in House Procedures 0061 - SOP

UKAS TESTING 4410

Job Number :	**60598963**	Scheme :	**University of Nottingham - A46 Stratford Northern Bypass**
Sample Number :	**T - 1678**	Location :	**Southbound, Lane 1 (CL1), NSWT, Offset from nearside white line 0.9m**
Core Number :	**04**		**HAPMS Ch. 3700A46/566+1500m**
Cored / Logged By :	**KS / SD**		
Date Cored / Logged :	**15-04-19 / 29-04-19**		**OSGR: SP 17542, 55791**
Nominal Diameter :	**150mm**		**Notes: Core located 2m after transverse crack**

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	24	24	Asphalt Surfacing	No	-ve	Bitumen	14	Crushed Rock
2	24	105	81	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
3	105	170	65	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
4	170	250	80	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
				Layers 4 & 5 Not Bonded					
5	250	455	205	Concrete - Type C Voids (in half)	No	n/a	Cement	20	Crushed Rock
				Loose Granular Material Not Recovered					

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 0061 - SOP

UKAS TESTING 4410

Job Number :	**60598963**	Scheme :	**University of Nottingham - A46 Stratford Northern Bypass**
Sample Number :	**T - 1678**	Location :	**Southbound, Lane 1 (CL1), NSWT, Offset from nearside white line 0.9m**
Core Number :	**04**		**HAPMS Ch. 3700A46/566+1500m**
Cored / Logged By :	**KS / SD**		
Date Cored / Logged :	**15-04-19 / 29-04-19**		**OSGR: SP 17542, 55791**
Nominal Diameter :	**150mm**		**Notes: Core located 2m after transverse crack**

ROAD

CORE

HOLE

CORE LOGGING OF PAVEMENT MATERIAL

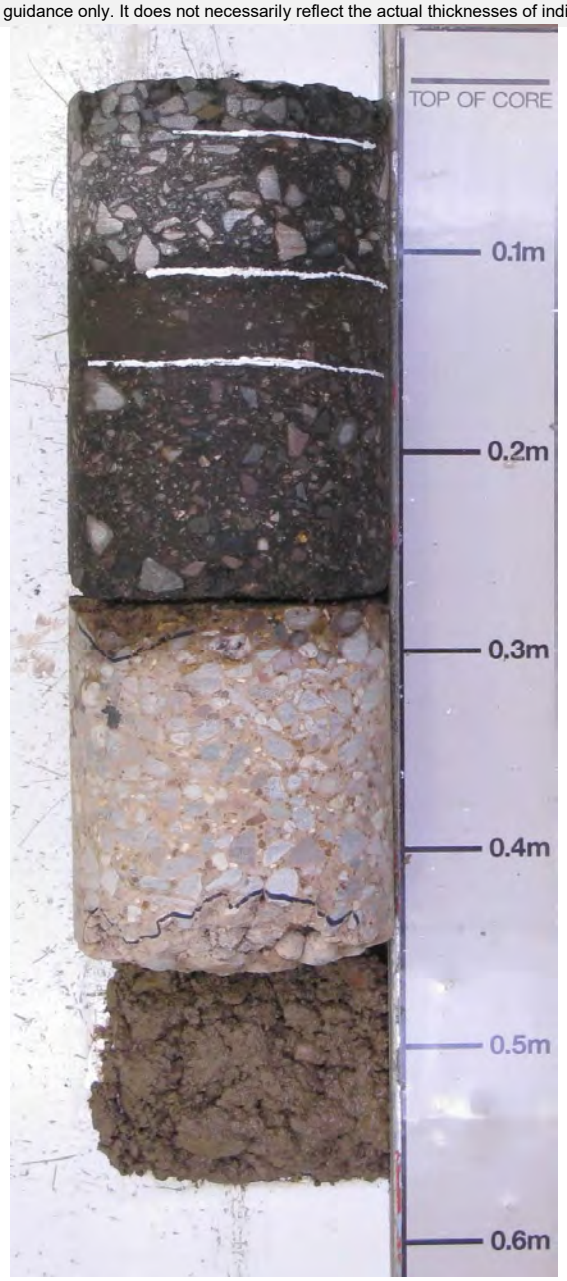
In Accordance with AECOM in House Procedures 0061 - SOP

UKAS TESTING 4410

Job Number :	**60598963**	Scheme :	**University of Nottingham - A46 Stratford Northern Bypass**
Sample Number :	**T - 1678**	Location :	**Southbound, Lane 1 (CL1), NSWT, Offset from nearside white line 0.8m**
Core Number :	**05**		**HAPMS Ch. 3700A46/566+1580m**
Cored / Logged By :	**KS / SD**		
Date Cored / Logged :	**15-04-19 / 29-04-19**		**OSGR: SP 17481, 55740**
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	26	26	Asphalt Surfacing	No	-ve	Bitumen	14	Crushed Rock
2	26	95	69	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
3	95	138	43	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
4	138	255	117	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
				Layers 4 & 5 Not Bonded					
5	255	445	190	Concrete - Type B Voids (broken @ base and top)	No	n/a	Cement	20	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 0061 - SOP

UKAS TESTING 4410

Job Number :	**60598963**	Scheme :	**University of Nottingham - A46 Stratford Northern Bypass**
Sample Number :	**T - 1678**	Location :	**Southbound, Lane 1 (CL1), NSWT, Offset from nearside white line 0.8m**
Core Number :	**05**		**HAPMS Ch. 3700A46/566+1580m**
Cored / Logged By :	**KS / SD**		
Date Cored / Logged :	**15-04-19 / 29-04-19**		**OSGR: SP 17481, 55740**
Nominal Diameter :	**150mm**		**Notes: N/A**

ROAD

CORE

HOLE

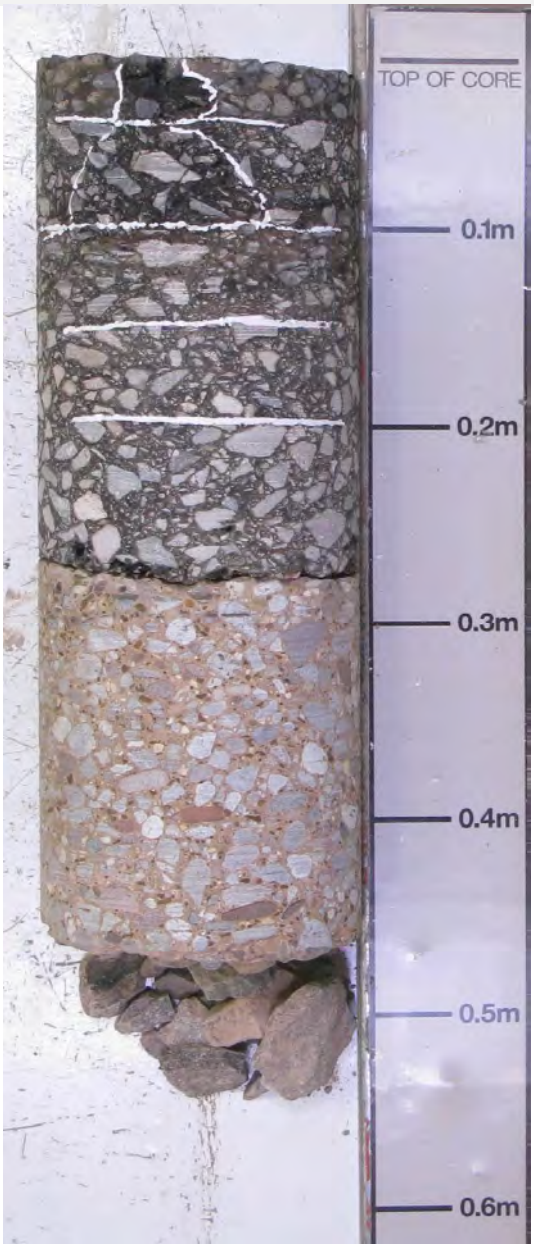
CORE LOGGING OF PAVEMENT MATERIAL

In Accordance with AECOM in House Procedures 0061 - SOP

Job Number :	**60598963**	Scheme :	**University of Nottingham - A46 Stratford Northern Bypass**
Sample Number :	**T - 1678**	Location :	**Southbound, Lane 1 (CL1), NSWT, Offset from nearside white line 0.8m**
Core Number :	**06**		**HAPMS Ch. 3700A46/566+1660m**
Cored / Logged By :	**KS / SD**		
Date Cored / Logged :	**15-04-19 / 29-04-19**		**OSGR: SP 17420, 55689**
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 (damage to face)	No	-ve	Bitumen	14	Crushed Rock
2	31	82	51	Asphalt Concrete (damage to face)	No	-ve	Bitumen	20	Crushed Rock
3	82	129	47	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
4	129	178	49	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
5	178	255	77	Asphalt Concrete	Yes	-ve	Bitumen	20	Crushed Rock
				Layers 5 & 6 Not Bonded					
6	255	470	215	Concrete - Type B Voids	Yes	n/a	Cement	20	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 0061 - SOP

UKAS TESTING 4410

Job Number :	**60598963**	Scheme :	**University of Nottingham - A46 Stratford Northern Bypass**
Sample Number :	**T - 1678**	Location :	**Southbound, Lane 1 (CL1), NSWT, Offset from nearside white line 0.8m**
Core Number :	**06**		**HAPMS Ch. 3700A46/566+1660m**
Cored / Logged By :	**KS / SD**		
Date Cored / Logged :	**15-04-19 / 29-04-19**		**OSGR: SP 17420, 55689**
Nominal Diameter :	**150mm**		**Notes: N/A**

ROAD

CORE

HOLE