Strategy Management and Maintenance for Thin Surface Course Systems

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Digital Object Identifier (DOI): dx.doi.org/10.14311/EE.2016.421

ABSTRACT

Thin surface course systems (TSCS) have been in widespread use on the Highways England Strategic Road Network since their introduction in the 1990s. A premature failure of TSCS will result in early intervention and hence a significant cost. Surface disintegration (fretting) is acknowledged to be the main defect within TSCS. It occurs when individual aggregate particles under the action of traffic and environmental factors are lost.

The aim of this research was to study and seek to set up a series of recommendations to improve the management and maintenance strategy of thin surface course systems for their entire serviceable life.

This research was planning to explore and investigate the long term performance of thin surfacing systems in particular in relation to surface disintegration (fretting) on site. As part of this research TSCS core samples were obtained from several sites. The cores were subjected to a comprehensive matrix of laboratory tests for determining the rheological behaviour characteristics of binders. This included Penetration grade, Softening Point determination and Sweep test using a Dynamic Shear Rheometer over a range of different temperatures (5oC to 80oC) and frequencies (0.1Hz to 10Hz) tests.

A set of laboratory tests for evaluating the mechanical performance characteristics of the mixtures were also carried out to fully investigate the effect of compaction on the long term performance of the mixtures. The resulting mixtures' properties were then investigated by looking at their compaction results including Bulk Density, Max density and air void Content.

The laboratory data was then interpreted and analysed against available in-situ performance data in order to find any possible correlation between the in-situ performance surface of TSCS (in particular fretting) and binder/mixture properties of Thin Surface Course Systems.

Keywords: Durability, Maintenance, Performance testing

1. INTRODUCTION

Thin surface course systems (TSCS) in England are defined as: “A proprietary thin surface course system in which a hot bituminous bound mixture is machine-laid with a controlled screed paver onto a bond or tack coat. Mixtures consist of aggregate, filler and bituminous binder which may be modified by the addition of polymers, rubber, resins, fibres or fillers such as hydrated lime or cement’’ (1).
However, recent harsh winters have led to some road surfaces deteriorating prematurely and very rapidly. There are perceived shortcomings and suggestions that they do not last as long as expected. Recent harsh weather conditions especially after the severe winters of 2009 and 2008 have given rise to what have been called “premature failures”.
While Highways England manages annual vehicle-based traffic speed surveys for road condition measurements that include a basic measure of road surface defectiveness, this measure is not sufficiently developed to enable the failure of the surfacing to be predicted.
A premature failure of TSCS will result in early intervention and hence a significant amount of money will be spent on new resurfacing. Robust evidence is required to demonstrate the Highways England is maximising the return on the investment made in surfacing the Strategic Road Network. It is essential to ensure that road surfaces are durable and are performing adequately and that expected economic/environmental benefits are realised.

2. SITE SELECTION, LABORATORY OPERATIONS AND FUNDAMENTAL INVESTIGATIONS

2.1 Site selection-core samples gathering from selected sites

Some 30 sites were going to be selected from the north east, east/southeast and south west of England. These regions had been chosen because the northeast (Area 14) presents the most surface fretting sites within the Network, the east/south east (Areas 6&8) are located within the driest areas of England and the south west (Areas 1 & 4) is one of the wettest areas. The number of cores gathered so far in total is 122. The Area Service Providers agreed to provide core samples on the basis that all subsequent reporting would be done anonymously. It should be mentioned that the diameter for all the samples were either 90-100mm or 140-155mm.

2.2 In-situ parameters - Highways Agency Pavement Management systems (HAPMS)

For each site the following parameters were gathered from Highways England’s Pavement Management System (HAPMS):
Age (years):
The "Date Laid" data from HAPMS is used to calculate the age (in years) at the start of the analysis period on 01/04/13.
Age range:
At the time of selecting cores to test in the laboratory it was not possible to comment on the degree of fretting or the serviceability of the site because of the lack of consistency and insufficient Value Management documents provided by the Area Service Providers. In the absence of this information the following age-based classification was adopted:
< 5yrs = Less than expected
5 to 10 yrs = Expected
>10 yrs = More than expected
The lower limit of 5 years was selected because this is the "surfacing integrity - performance guarantee period" required by the relevant specification (2).
The upper limit of 10 years was selected because Nicholls et al. (2009) reported an average service life of 9.9 years for TSCS.
Material name:
HAPMS Construction Records were used to source this information. The "Material Name" options were "Thin Surfacing (Generic)", "Thin Surfacing (Polymer)" and "Thin Surfacing (Fibre)".
Texture Depth:
Machine recorded texture data was gathered from HAPMS for all sites. For each individual core location the 10m texture data was recorded.
Season Laid:
There is not a clear definition for laying of asphalt in terms of seasonal laying time. Therefore "winter" was defined as November to March (inclusive) and "Not Winter" was defined as April to October. 45% of the TSCS materials were laid in the “Winter” period when the laying criteria contained in the Specification for Highway Works are less likely to be satisfied (1,2).

2.3 Value Management and Visual Condition Surveys

Visual Condition Survey data was used to identify the presence of fretting defects recorded at individual core locations. The classifications were
1 - " Other defects and possible fretting (No data available for fretting)",
2 - "No fretting ",

3 - "Minor fretting",
4 - "Severe fretting''

Figure 1 indicates a very important finding that most TSCS started indicating some areas of fretting and/or other defects after five years of being in service. This contradicts previous studies carried out in England Nicholls et al. (2009) where it was concluded that if a TSCS had performed well within the first five years then it would continue to perform well for up to 10 years in service.

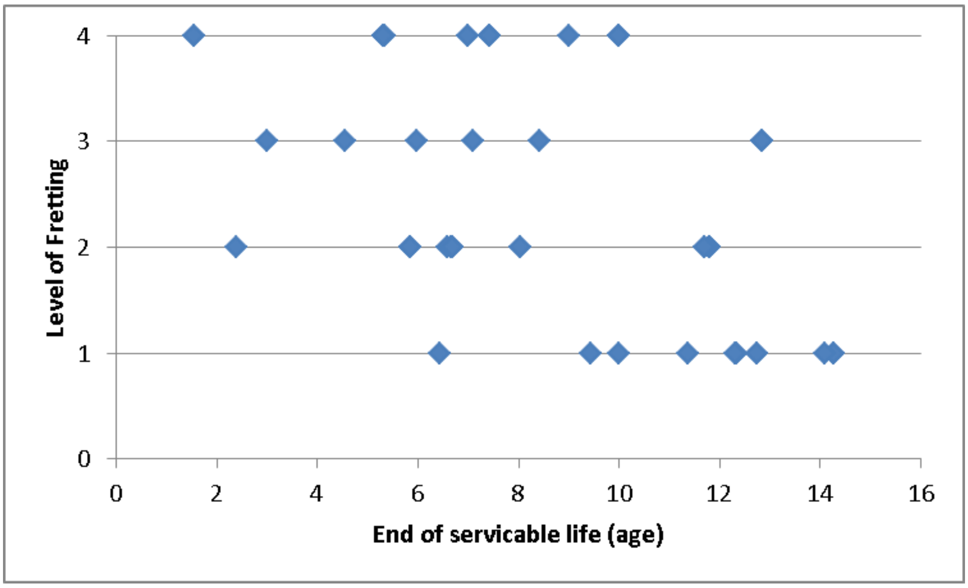

Figure 1 – TSCs serviceable life versus Fretting

Figure 2 indicates that some TSCS with a texture depth higher than 1.5 experienced some level of fretting or other surface defect (potholes and cracking). However, no correlation between texture depth and level of fretting was found.

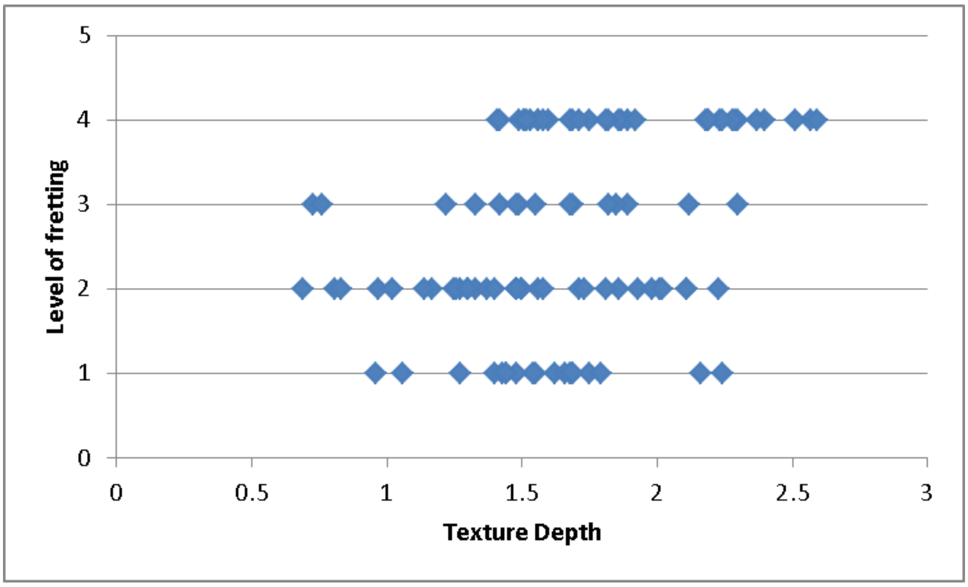

Figure 2 – Level of Fretting versus texture depth

2.4 Mixture testings - Volumetric test data

The volumetric properties of all specimens were evaluated in this step. This evaluation includes measuring their Bulk Density using the standard (sealed specimen) procedure described in BS EN 12697-6, Maximum density using the standard procedure described in BS EN 12697-5 and Air Void Content (AVC) was determined using a standard volumetric formula which considers the Maximum and Bulk Densities.

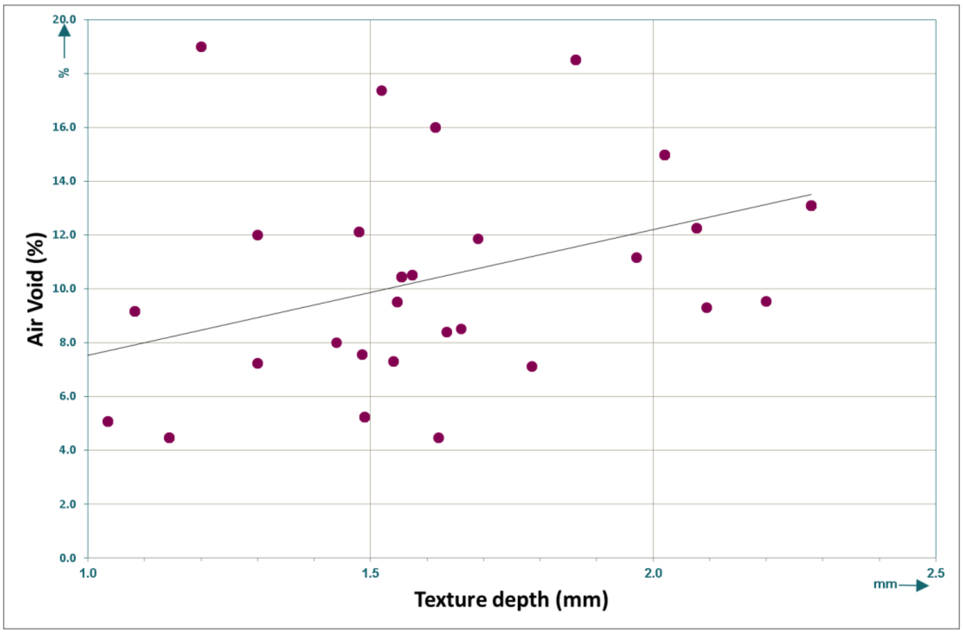

Figure 3 -Texture depth versus air voids

Figure 3 shows that in general most of sites had a very high void content and most of the sites with a texture depth higher than 1.5mm had void content of 7% or higher. Samples with higher texture depth were found to have higher air voids content although there is no significant trend. This is thought to be due to the loss of surface aggregates.

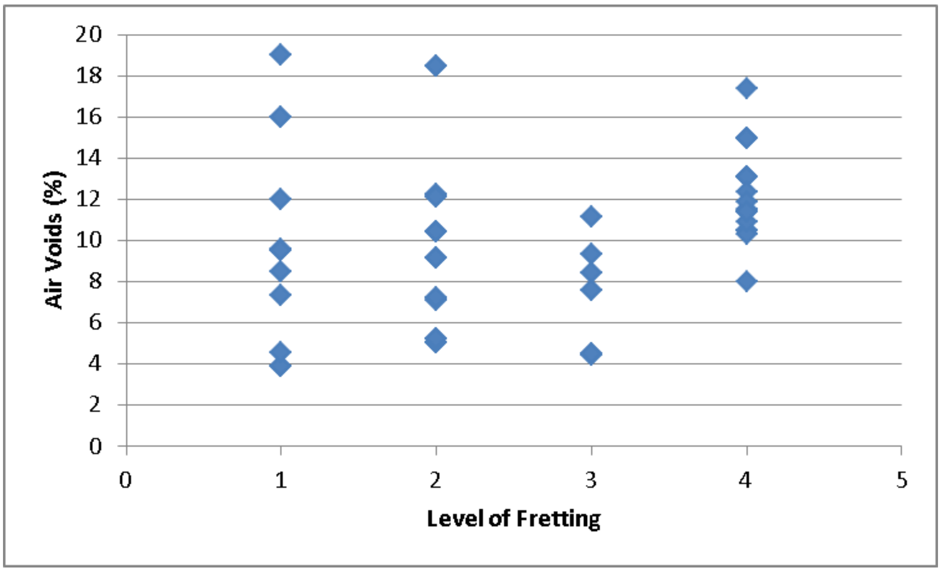

Figure 4 - Air Void versus Level Fretting

It is clear from Figure 4 that most of the sites with an air void of 8% or higher experienced some level of fretting (Level 3&4 Fretting). This is very much in line with all the previous research reports stating that any surface course with an air void of more 7% is considered as porous and this will have a significant impact of the durability performance of the mixture on site (12, 24 and 23).

2.5 Mixture performance testing on the core samples

This step was performed to evaluate the mechanical performance characteristics of the mixtures. Regarding the performance tests, an Indirect Tensile Stiffness Modulus (IT-CY) test was carried out to measure their indirect tensile modulus of elasticity. The stiffness modulus (Indirect Tension to Cylindrical specimens) was determined at a temperature of 20oC using the procedure described in BS EN 12697-26. Figure 5 shows an expected trend of increasing stiffness associated with ageing with prolonged exposure to traffic and environmental effects. However there was no correlation between ITCY and TSCS fretting level.

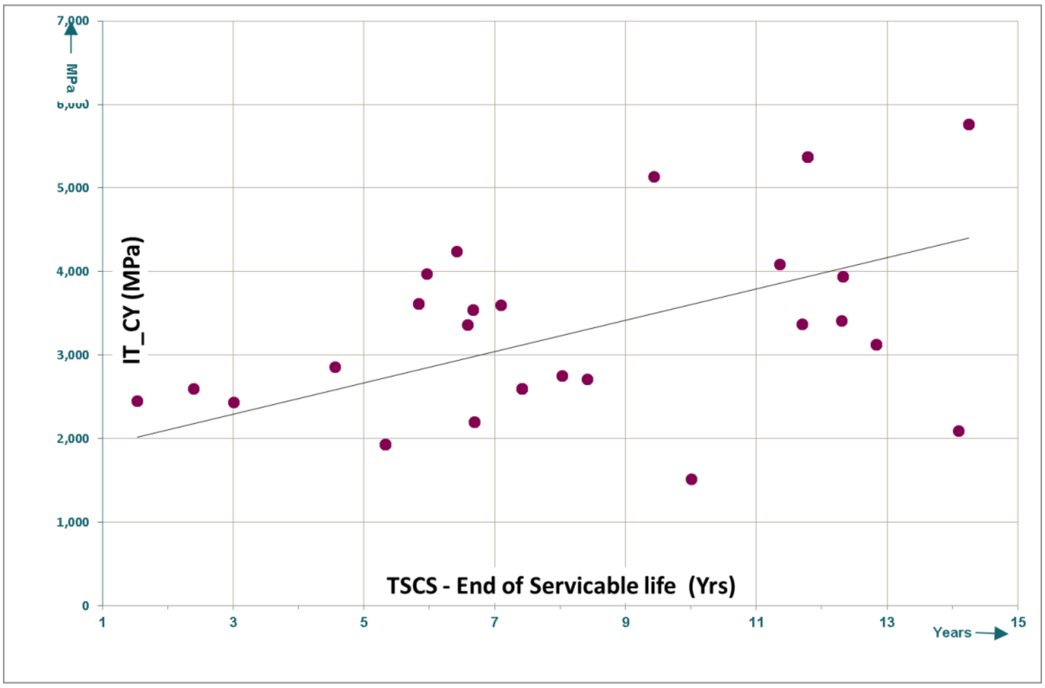

Figure 5 – ITCY versus TSCs serviceable life

2.6 Binder testing - Binder Content (%)

The binder content by percentage mass of the total asphalt mixture was determined through complete extraction of the binder according to BS 598: Part 102 (26). This was carried out for only one core for each site as the asphalt supplied for each site is believed to be from one mixture delivered to the site.
Figure 6 below, shows that the binder content ranges between 5% and 6% for the TSCS sites checked . This is low compared to some other European countries where the binder content for a typical SMA might be at 6.8%. This is reflective of the fact that there are currently no Minimum Binder content requirements within the National Specification (2, 22, and 23). However there were no correlations found as some of the TSCS with lower binder content outperformed others.

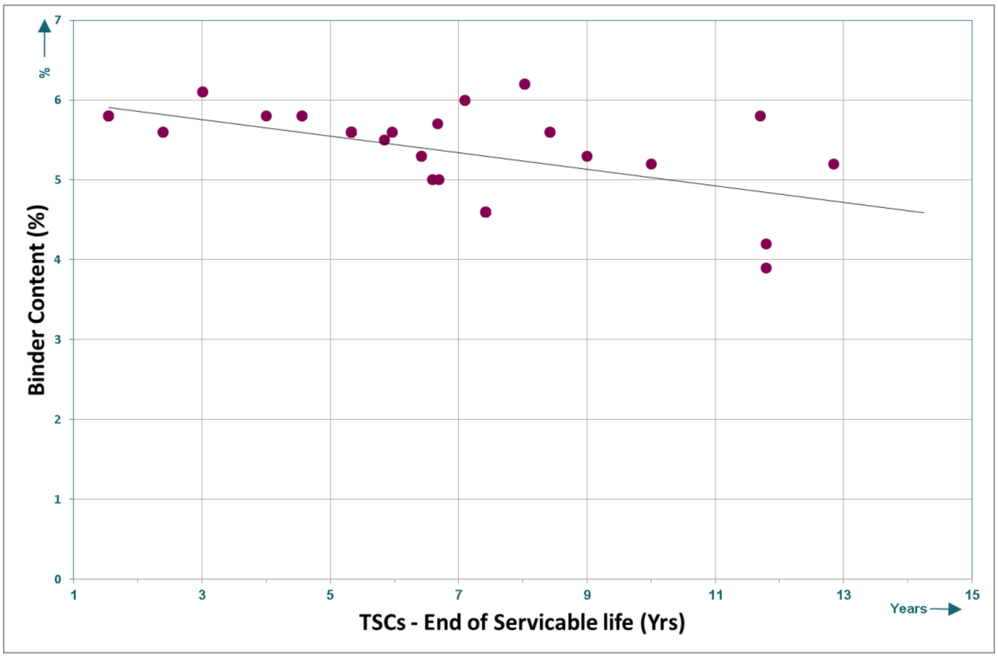

Figure 6 – Binder content versus Serviceable life of TSCs

2.7 Frequency-Temperature Sweep Test

A Dynamic Mechanical Analysis (DMA)/Frequency-Temperature Sweep test using a Dynamic Shear Rheometer over a range of different temperatures (5oC to 75oC) and frequencies (0.1Hz to 10Hz) was performed. All tests were performed in the Dynamic Shear Rheometer according to the procedure in BS EN 14770 using the following test parameters:

Stress/strain sweeps using both 8 mm and 25 mm diameter geometries to determine the linearity limits of the binders. Frequency sweeps (0.1 to 10Hz) using both 8 mm and 25 mm geometries from 10oC to 70oC to generate complex modulus and phase angles values for subsequent rheological analysis. The Phase Angle from the temperature equilibrated data at 5°C and at a frequency of 0.4 Hz. The Complex Stiffness Modulus at 25°C and frequency 0.4 Hz.

Due to lack of recovered bitumen from the cores, DSR testing was carried out only once for each site as the binders recovered from the individual cores were not enough for DSR testing to be carried out. However it is very likely that all the cores gathered from one site will represent one mixture laid at the specific site.

The mechanical properties of the binders were studied by investigating their rheological behaviour by performing the Frequency-Temperature Sweep test using a Dynamic Shear Rheometer (DSR) over a range of different temperatures (5°C to 80°C) and frequencies (0.1Hz to 10Hz). The test was performed in accordance with BS EN 14770:2012 [17]. It should be mentioned that the rheological behaviour investigations have been carried out for two main reasons. Firstly, to study the mechanical properties of the binder itself at different temperatures and loading frequencies and secondly, in order to have sufficient fundamental support to analyse and interpret the mechanical behaviour of the resulting mixtures at the operating temperatures. This will also allow the linking and finding of any correlations between the behaviour of the mixtures and the mechanical properties of their corresponding binders.

Figure 7 indicates a trend of increasing G* with age as expected due to ageing. However, a large degree of scatter was found in the measured G* values and no convincing correlation could be found. However all five sites at the upper end of the G* range had suffered some level of fretting and other defects such as potholes.

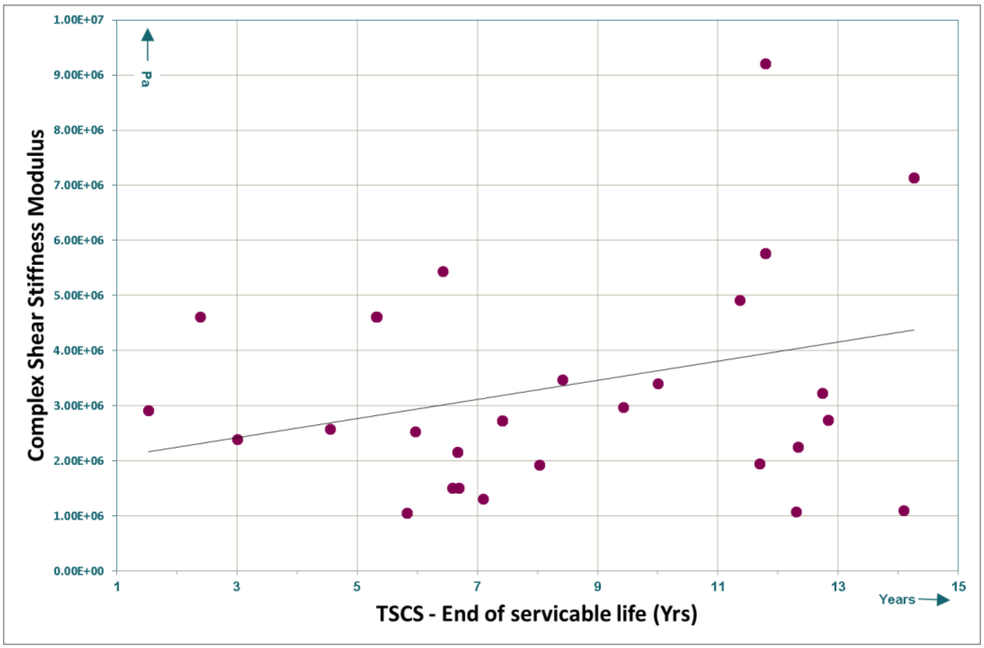

Figure 7 – Complex Shear Modulus versus Age of TSCS

Figure 8 shows a Master Curve comparison of three TSCS with different performance. As shown in Table 1, Samples A and B performed satisfactorily for more than 12 years before fretting commenced. Sample C started to fret at five years even though it had the lowest void content.

Table 1 – Core samples data

Sample No	Serviceable life (Yrs)	Void content (%)	Binder Content (%)	Season laid	Nominal Aggregate size (mm)
A	12.3	4.5	5.8	Winter	10
B	12.7	14.5	5.3	Not Winter	10
C	5.5	7	5.7	Not winter	10

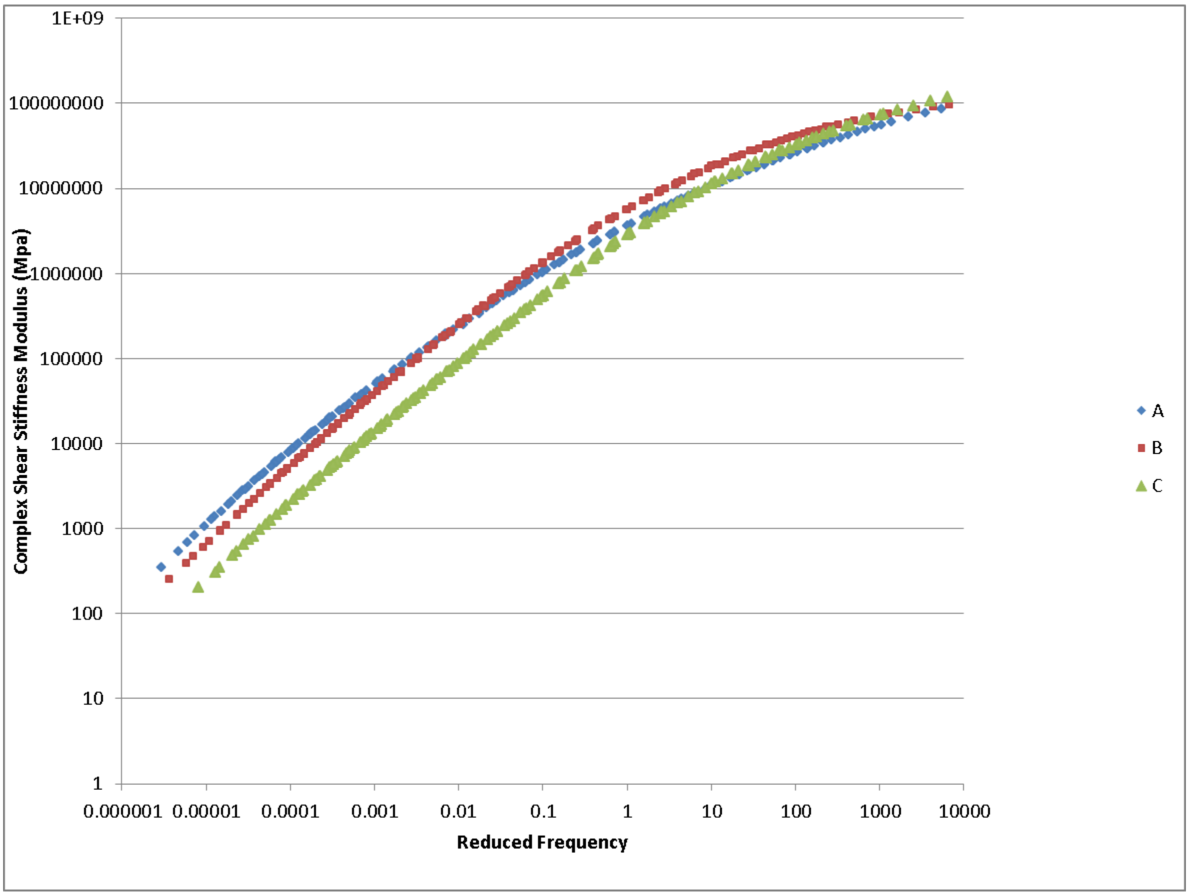

Figure 8- Comparative Master Curves for the Complex Shear Modulus

The Complex Shear Modulus was measured for the three samples and the results are shown in figure 8. The binders used in three samples are very different in terms of their complex shear modulus (G*). The binder from sample A has a higher complex shear modulus at the higher temperatures while binder B has a higher complex shear modulus at lowers temperatures. Binder C has a significantly lower complex shear modulus at higher temperatures.
The different shear modulus of sample C could be one of the reasons for its poor in-situ performance. The lower shear stiffness at higher ambient temperatures may have contributed to the early fatigue of the surfacing material on site.

3. CONCLUSION

- When considering the mixture properties, the reported air void contents measured from core samples were very high. The expected range for thin surfacing would normally be expected to be around 4% to 7%. Mixtures with less than 7% air voids are generally regarded as "dense" and therefore likely to be more durable. Mixtures with more than 7% are regarded as "open". Individual measurements of up to 21.7 % were reported and the overall average void content was 10.6%. In general the findings confirm that some level of fretting existed on most of the selected sites with an air void of higher than 8%. The percentage of air voids within the TSCS in England when compared to some other European countries is significantly higher.
- As indicated on figure 8, Lower shear modulus at higher temperatures may be related to the early onset of fretting on in-situ TSCs.
- As demonstrated by Figure 1, most Thin Surface Course Systems observed started indicating some areas of fretting and/or other defects after **five** years of being in service. This is interestingly in line with the warranty period required within the Highways England specifications. However it contradicts previous studies carried out in England where it was concluded that if a TSCS has performed well within the first five years then it would continue to perform well for up to 10 years in service.
- Samples with higher texture depth were found to have higher air void content. This is thought to be due to the loss of surface aggregates and the subsequent trapping of air pockets when wrapping the cores for bulk density measurement.
- 45% of materials were laid in the "Winter" period (November to March) when the laying conditions are less likely to be satisfactory (1).

4. RECOMMENDATIONS

Sites with higher void content suffered a higher level of fretting so it is recommended to consider introducing a maximum Design and In-situ air void criteria in any specification written for Thin Surfacing contracts. As was shown in Figure 8, the Binder properties and their behaviour may have a direct effect on the TSCS in-situ performance of TSCS. It is therefore recommended to carry out more binder rheology exercises for all other samples in order to be able to find any possible correlation between binder properties of mixtures and their in-situ performance. It is important to note that although the void content and binder properties of Thin Surface Course Systems are clearly very important factors affecting durability of TSCS, there are also factors such as weather conditions, Traffic Management, aggregate size, number and quality of construction joints, lack of compaction, drainage and level of supervision that will impact on the performance of the thin surface course and will need to be considered in order to be able to successfully produce a durable TSCS.

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