An Investigation of the Skid Resistance of Stone Mastic Asphalt laid on a Rural English County Road Network

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ABSTRACT

The safety of SMA surfaces on high speed roads has come into question following an investigation by the BBC into concerns expressed by the police and others regarding dry road skid resistance following a number of fatal accidents on new surfacing materials. The information derived from the study reported in this paper is based on scientific data and provides an objective assessment of the wet road skid resistance performance of this material.

This paper seeks to establish the wet road frictional resistance of stone mastic asphalt surface courses laid in a county in England during the period 1999 to 2004. The change in skid resistance with time is examined together with the texture of the material to assess its suitability for use on the rural principal road network.

The early life skid resistance was similar to that of conventional bituminous surfacings and improved with time but this could take up to two years and in exceptional cases three years to achieve. Thereafter the material remained consistent before experiencing a decrease in skid resistance in the following years as the aggregates at the surface polished.

The texture of 14mm SMA measured in the twelve months following re-surfacing is below the optimum required for a new surfacing but is still above the recommended threshold level of 0.6mm. SMA surfaces with 10mm coarse aggregate give a higher skid resistance but have 25% lower texture.

There is a 30% chance that new stone mastic asphalt surfaces will not meet the investigatory level for wet road skidding resistance in the 12 months after laying.

Highway authorities are recommended to consider the use of ‘slippery road’ warning signs erected at the time of re-surfacing to warn motorists of the dangers of reduced skid resistance in the early life of the surfacing.

Work is required to investigate the high speed frictional resistance of stone mastic asphalt in the initial period before the binder rich mastic mortar has been abraded. Measurements are required to determine the thickness and consistency of the binder film covering the surface aggregate in relation to other bituminous materials and whether the absorptive fillers used in the mix have any impact on the skid resistance of the surface material.

1.0 INTRODUCTION

This paper examines the variation in wet road skid resistance of a number of stone mastic asphalt (SMA) surfaces laid on the principal road network in the County of Dorset England during the period 1999 to 2004.

The study was concerned with: -

a) The annual level of skid resistance measured by SCRIM and any trend in the recorded values;

b) The measurement of texture depth and the change in texture with time.

The skid resistance of SMA was called into question following an investigation of road safety by the Derbyshire Police following two fatal accidents in 2001 and a subsequent study undertaken for Derbyshire County Council by the Transport Research Laboratory. The Police investigation found the dry road skid resistance of the new surface was as slippery as the wet road skid resistance and was below that of conventional surfaces.

Considerable interest has been expressed recently in the media and the technical press [1] regarding the early life skid resistance of thin surfacings such as stone mastic asphalt. A recent documentary by the BBC highlighted concerns for the early life dry road skid resistance of this material and its continued use on high speed roads. Tests carried out in Ireland by the National Roads Authority (NRA) raised questions about the materials ability to provide enough friction for tyres at high speeds [2]. The NRA has decided to restrict its use to roads with a 30mph speed limit and has taken remedial action on other roads where the material has been laid**.** Concerns have also been raised in Germany where this material was pioneered in the 1960's as well as in Holland.

Although policy decisions have been made in regard to SMA by a number of highway authorities the evidence thus far is anecdotal. This paper attempts to provide information on the wet road skid resistance characteristics of SMA based on objective evidence from a scientific study.

Mean Summer SCRIM Coefficient (MSSC) readings derived from single run SCRIM readings seasonally corrected together with texture depths were examined on a number of sites over a period of three to five years and are shown in the accompanying tables and graphs. The variation in skid resistance is assessed in relation to the skidding standard set out in the Design Manual for Roads and Bridges 1994 [3] .

2.0 BACKGROUND

For the last 6 years Dorset County Council have monitored the skid resistance of their principal road network annually with Sideways-force Coefficient Routine Investigation Machine (SCRIM) surveys. Readings are collected in a single run and corrected for seasonal variation using a number of calibration sites situated in the County. These are surveyed three times a year during the preferred period. Data from the SCRIM surveys provides a measure of the wet road skid resistance performance of materials laid on the principal road network.

Machine surveys were also commissioned to monitor the profile and texture of the principal road network. These were run bi-annually until 2004 when they were replaced by TRAffic speed Assessment Condition Surveys (TRACS) which in addition provide cracking data. Texture depth of SMA surfaces has been recorded at intervals over a five year period and the results have been examined to determine the trend in texture with time.

In road trials undertaken by the Transport Research Laboratory (TRL) in 1995 [4] and 1998 [5] the early life performance of SMA and other thin surfacing materials was found to be satisfactory. The introduction of these materials met the increasing demand from maintenance engineers for thin surfacings which had the benefit of acceptable SCRIM Coefficients with relatively low traffic noise levels and a subjective reduction in spray. This resulted in the approval of a number of products by the British Board of Agreement *Highways Authorities Products Approval Scheme* for thin surfacings.

In April 2002 Dorset County Council instructed WDM to examine a number of sites where SMA had been laid during the period April 1999 to March 2002, Figure 1. The study reflected the national concern at the skid resistance of SMA and called for a review of the performance of this material with time. This was subsequently extended to include the results of surveys from 2003 and 2004.

Details of 61 sites where SMA had been laid since April 1999 were supplied by the Dorset Engineering Consultancy (DEC). These were used to amend the construction records held in the Dorset Pavement Management System (PMS) and provided a basis for the comparison of SCRIM results for SMA sites over the last five years. Details of the materials used are presented in Table 1.

The dry road skid resistance of SMA was called into question following routine locked wheel skid tests carried out by Derbyshire Police after two fatal accidents on a newly laid surfacing in 2001. Their primary concern was the dry skid resistance of the new surface which was found to be as slippery as the wet road skid resistance. The Sergeant undertaking the test indicated ‘it took 25% longer than normal to stop and that the skid resistance had not improved in two years’.

Derbyshire County Council subsequently asked the Transport Research Laboratory (TRL) to assess the risk that newly laid surfaces can be slippery when dry. The findings from the project have still to be released.

3.0 MATERIAL SPECIFICATION

Stone mastic asphalt (SMA) was developed from Gussasphalt used in Germany some 30 years ago to combat the detrimental effects of studded tyres. The tyres are now banned but the material has shown the ability to withstand the effects of heavy traffic loading. SMA used on the continent was not normally designed to have the texture required for UK high speed roads although this requirement has been accommodated in the mix design. SMA has a 'negative texture' where the void spaces below the initial binder level provide the texture. This is different from hot rolled asphalt and surface dressing both of which are used extensively in the United Kingdom where the aggregates protrude above the initial binder level and provide the positive texture for interaction with vehicle tyres.

SMA mix design produces a generally flat surface which together with negative texture provides a quieter surface than hot rolled asphalt and surface dressing systems and has been responsible for its popularity with the general public. A further unexpected benefit from the use of SMA was a reduction in spray from traffic.

Surfacing contractors welcomed the move to thin surfacings which increased the speed of laying and eliminated the need for a chipping spreader. New legislation for 'Safety at Road Works' effectively required the closure of most rural roads where hot rolled asphalt and pre-coated chippings were to be applied because of the width of the spreader. The removal of the Bristows chipping spreader and tractor units supplying the chippings also reduced the size of the surfacing gang by 25%.

The design of a SMA mixture produces a stone skeleton of interlocking crushed rock coarse aggregate comprising largely single sized stone of a size appropriate to the laying thickness. The single sized nature of the material leaves a relatively high void content between the aggregate particles which are partly filled with a binder rich mortar. This process involves adjusting the grading to accommodate the required binder and void content rather than the more familiar process of adjusting the binder content to suit the aggregate grading. Very high binder content is essential to achieve the durability and laying characteristics required and this can not be achieved with unmodified or unstabilised binders without binder drainage and hence the need for a fibre stabiliser, absorptive fillers or modified binders.

Material initially exposed at the surface of a SMA will be binder, filler and stabilising additives together with some fine aggregate. With the negative texture of the material surface aggregates will play an important part in determining early life skid resistance. It is essential therefore to ensure that care is taken in the specification and selection of both the coarse and the fine aggregate.

There are no exclusive requirements for the fine aggregate included in the Dorset specification and on a number of sites limestone fines were evident and these reflected in lower MSSC readings reported in the paper.

The Dorset County Council Term Maintenance Contract (TMC) for highway works specifies in Appendix 7/1: Permitted Pavement Options: -

Clause 942 'Thin Wearing Course Systems'
'The Contractor should note that only systems having British Board of Agreement HAPAS Roads and Bridges Certificate shall be used. Until such Certificates have been issued the approval of the Engineer shall be obtained prior to the use of any system.

(i) PSV 60 unless specified as 65 in the Works Order

(ii) Nominal thickness ranges - 15 to 20mm
21 to 30mm and
31 to 40mm'.

4.0 SURVEY DATA

4.1 SKID RESISTANCE

The SCRIM surveys undertaken in the last 6 years on the principal road network and B class roads together with High speed Road Monitoring surveys provide important data for the performance assessment of new surfacing materials. SMA has been universally used in Dorset since 1999 and has been well received particularly in urban areas due to the speed of operations and the reduced noise and spray.

MSSC and texture depth results have been compiled for a number of the sites shown in Figure 1 with a common coarse aggregate type. The data presented in Table 1 relates to the age of the surfacing for each of the sites and shows the average and standard deviation for each of the years. The average values of MSSC since re-surfacing are shown in Figure 2 and indicate an upward trend which is considered normal for any bituminous product which relies on the micro-texture of the coated aggregate for frictional resistance. It is recognised that the skid resistance of bitumen will be less than that of the coarse aggregate selected for surface courses but can still be greater than the investigatory skid resistance levels.

The MSSC values indicate a lower level of skid resistance in the initial year after re-surfacing. As the mastic mortar is abraded from the surface of the coarse aggregate skid resistance improves and continues to improve over the next two or in extreme cases three years under the trafficking experienced on rural roads in Dorset. On more heavily trafficked roads this process will be a lot quicker. After that phase the polishing action of the aggregates in the next two years caused a reduction in skid resistance which will continue until an equilibrium condition is reached [6].

The variation in MSSC values for each site is shown in Figure 3 and whilst the change with time is not uniform there is a general trend which indicates an overall improvement in performance of SMA with time.

The results show that: -

a) The initial skid resistance of all the SMA's in the study was similar to conventional surfacings. There was a 30% chance of SMA having a skid resistance value lower than the investigatory level for the site category in the 12 months after surfacing.
b) Skid resistance improved with time and in one year the MSSC values had increased approximately 11% and remained stable for the next two years before falling to 6% in the fifth year. The initial increase in skid resistance is generated by the surface binder being abraded exposing the coarse and fine surface aggregates which contribute to the ultimate skid resistance of the material.
c) If aggregates of the specified PSV are used the skid resistance of SMA after the binder film wears away should give acceptable values

for the general road category in Dorset. A SCRIM coefficient of better than 0.45 would be expected from aggregates with a polished stone value of 60.

4.2 TEXTURE DEPTH

Texture depth has a marked impact on the high speed skid resistance of a road surface. The average Sensor Measured Texture Depth (SMTD) on the 33 sections examined has an initial value lower than expected of a new surface. There is a marginal improvement in the year two before a gradual decrease in the following three years. The results are shown in Table 2 and the average values are plotted in Figure 4.

Friction on low textured surfaces falls more rapidly with speed than for high textured surfaces [7] and of the 14mm SMA sites considered all but one were above the specified threshold value of 0.6mm [8] but five had a SMTD value below 0.7mm in the year after re-surfacing.

The single sized nature of the aggregate skeleton in SMA produces a relatively high void content filled with binder rich mastic mortar. This mixture allows the coarse aggregate to be re-orientated during rolling and presents flat sided aggregates at the surface. This helps provide the noise reduction welcomed by many motorists and residents but reduces the materials ability to provide adequate texture. An important aspect in the manufacture of the material is to maintain a volumetric balance to avoid fatting up of the mastic mortar which exacerbates the problem of poor texture.

The sensor measured texture depth (SMTD) of the 33 sections of road examined in this study produced a mean value of 0.92mm with a range of 0.59 to 1.4mm. Texture is lower than specified and will contribute to the reduced early life skid resistance at high speeds and will also have an impact on friction loss at slow speeds.

Whilst texture depth seems to fluctuate over the five years the general trend is one of a slight decrease due in part to the contamination of the void space.

5.0 MAINTENANCE OPTIONS

A number of options have been considered by highway authorities in England to warn motorists of the early life skid resistance of SMA surfaces and to improve their performance. These include: -

1) ‘Slippery road surface’ signs erected at the time of surfacing with a supplementary plate indicating ‘new road surface’.
2) Grit spread over the new surface to allow traffic to abrade the mortar film and improve the early life skid resistance but this may have a detrimental effect on surface texture.

Alternatively the use of water re-texturing could be considered but this will increase the cost of the work.

6.0 CONCLUSIONS

All newly laid bituminous surfacings have slightly lower skid resistance levels compared with those obtained a few months after re-surfacing due to the binder film coating the stone. Initial values should be above the investigatory levels required for the roads in question or steps should be taken to warn motorists of the lack of skid resistance of the new material.

This study based on factual data from one County Council over a five year period indicated that SMA surfaces had a 70% chance of exceeding the investigatory level of skid resistance in the first year after laying. All sites showed some improvement in skid resistance in the succeeding two years and thereafter stabilised at a lower level. In year five 10% of the sites had some values below the recommended investigatory levels which emphasises the need to select materials with due regard to the site category.

The main concern has to be the overall level of skid resistance throughout the five year period. For lightly trafficked roads in Dorset with 14mm aggregate of Polished Stone Value (PSV) =>60 one would expect SCRIM readings in excess of 0.50 whereas the year on year average did not exceed 0.45. Either the erosion of the binder film is taking longer than expected to expose the coarse aggregate or inappropriate aggregates coarse and fine have been used in the materials supplied. Site inspections reveal the binder rich mastic mortar is slow to abrade under the volume of traffic using these rural roads. It is only on the more heavily trafficked roads that the skid resistance levels follow the conventional theory of improved frictional resistance and then polishing to a long term equilibrium value.

A separate examination of 10mm aggregate used in SMA indicates improved skid resistance due to the increase surface area of aggregate present at the surface but with a 20% decrease in texture.

The MSSC values shown in Table 1 show an 11% improvement in the first three years before falling by the fifth year to a 6% improvement on the level experienced in the year after laying. Continued monitoring of the SMA sites will help to establish the long term trend in skid resistance and would indicate the ultimate level of skid resistance achieved for the materials used.

The use of grit as an abrasive to remove the binder film on new SMA has been used successfully in some areas although this may have a detrimental effect on the surface texture of the material. Alternatively water re-texturing can be used to expose the aggregate without affecting the structure of the material.

A number of authorities have erected ‘slippery road’ signs at the time of laying the material with supplementary plates indicating ‘new surface’. This provides a warning to motorists of the likelihood of decreased skid resistance but with the popularity of this material the signs will soon become familiar and will be ignored.

7.0 RECOMMENDATIONS

A careful review of site categorisation and the risk rating for each site should be undertaken in relation to the accident data available to determine whether there is a case for reducing or increasing the risk rating thereby altering the intervention level.

Each site should be examined in relation to the information contained in the report and the appropriate action taken to maintain a safe environment for the travelling public. This should include careful consideration of both the coarse and fine aggregate used in the mixed material.

The use of slippery road signs should be considered where required. These are advisable not so much to absolve the authority from possible legal action in the event of an accident but to advise motorists of the need for extra care. The number of signs should be limited to maintain their impact and sites should be carefully monitored to enable the signs to be removed as soon as skid resistance reaches a satisfactory level.

Any sites exhibiting below investigatory values should be considered for remedial work and appropriateness for the erection of slippery road signs.

Further work is required to assess both the dry and wet road early life performance of SMA surfaces namely:-

a) High speed skid resistance measurements (100kph) to assess the performance of these materials when the binder film is still present on the surface aggregates.
b) Measurement of the thickness and consistency of the binder film coating the surface aggregate and its change with time.
c) Comparative tests for early life skid resistance on other thin surfacing materials in current usage.

8.0 REFERENCES

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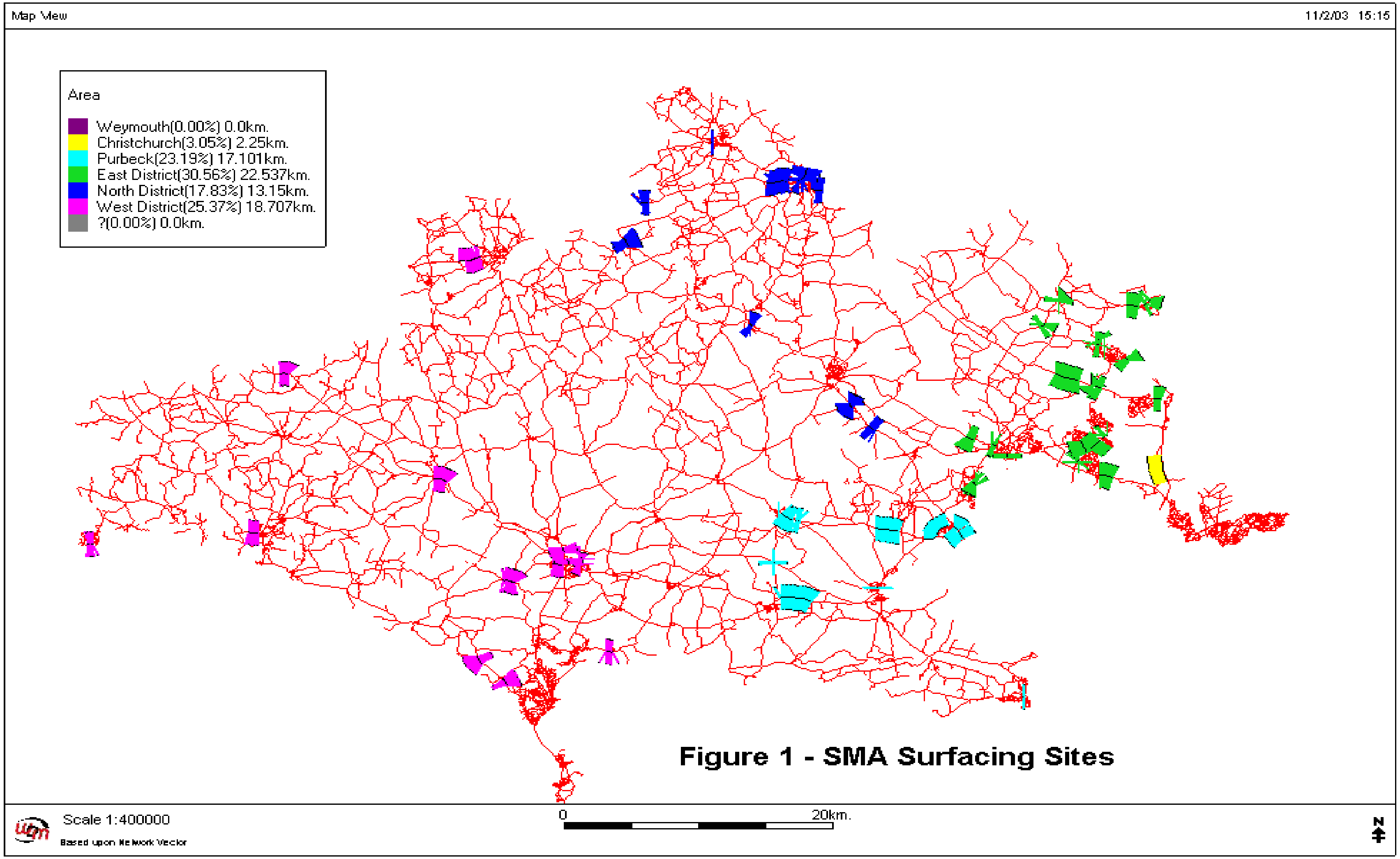

Figure 1 - SMA Surfacing Sites

Table 1 - Trend in MSSC Results

Stone Mastic Asphalt Performance Report 1999 to 2004

Note: - MSSC figures in bold represent values after SMA was laid

Project	Section	Chainage	Project Title	Lane	Traffic Flows	MSSC Results Age of Surfacing Year-4	Year-3	Year-2	Year-1	Year1	Year2	Year3	Year 4	Year 5	% Change	Date of Laying	Material Type (Gst = Gritstone) (PMB = Polymer Modified Binder)
South District																	
2011	A35/556	1218-1559	A.35 Improvement, Woodbury - Bere Regis (part)	CL1	Medium	0.40	0.39	0.40	0.48	**0.48**	**0.44**	**0.47**			**-1.1**	Oct-01	14mm Gst - 'Generic' SMA PSV 65
2011		1218-1559		CR1		0.40	0.38	0.40	0.47	**0.46**	**0.45**	**0.51**			**10.8**	Oct-01	14mm Gst - SMA & Cellulose Fibres PSV 65
2691	A35/556	0-1020	A35 Poole Hill, Bere Regis (Part)	CL1	Medium					**0.40**	**0.48**	**0.47**	**0.42**	**0.47**	**16.1**	Nov-99	14mm
2691		0-1020	A35 Poole Hill, Bere Regis (Part)	CR1						**0.39**	**0.44**	**0.48**	**0.43**	**0.45**	**15.1**	Nov-99	
2693	B3068/505	150-515	B3068 Blandford Road North	CL1	Light			0.45	0.46	**0.42**	**0.51**	**0.49**	**0.49**	**0.50**	**19.4**	Sep-99	14mm Gst PSV 65
2693		150-515		CR1				0.40	0.44	**0.43**	**0.50**	**0.48**	**0.48**	**0.50**	**15.7**	Sep-99	
2724	B3068/515	50-750	B3068 Blandford Road, Upton	CL1	Light		0.33	0.33	0.39	**0.41**	**0.37**	**0.34**	**0.36**		**-13.2**	Mar-01	14mm Gst PSV 65
2724		50-750		CR1			0.30	0.33	0.42	**0.47**	**0.40**	**0.35**	**0.38**		**-18.2**	Mar-01	
2751	A35/584	0-1093	A35 Upton Bypass	CL1	Heavy					**0.55**	**0.53**	**0.42**	**0.48**		**-14.0**	May-01	14mm Gst - SMA (PMB) PSV 63
East District																	
1529	B3074/460	0-478	B3074 Blandford Road, Corfe Mullen	CL1	Light					**0.47**	**0.48**	**0.48**	**0.49**		**3.0**	Jul-00	14mm Gst
1529		0-478		CR1						**0.46**	**0.49**	**0.49**	**0.53**		**16.9**	Jul-00	
1861	A348/434	1310-1480	The Angel, Longham: Traffic Signals	CL1	Heavy Urban			0.41	0.42	**0.38**	**0.39**	**0.43**	**0.40**	**0.37**	**-3.4**	Sep-99	14mm Gst PSV 68
1861		1310-1480		CR1				0.41	0.41	**0.39**	**0.45**	**0.43**	**0.38**	**0.39**	**-1.3**	Sep-99	
2447	B3072/423	226-276	Three Legged Cross Junction Improvement	CL1	Light	0.34	0.37	0.40	0.50	**0.50**	**0.52**	**0.48**			**-4.0**	Mar-02	14mm Gst PSV 68
2447		226-276		CR1		0.37	0.34	0.37	0.40	**0.56**	**0.47**	**0.49**			**-12.1**	Mar-02	
2703	B3081/482	2210-2632	Forestside to Hampshire Boundary B3081	CL1	Light		0.24	0.50	0.31	**0.45**	**0.47**	**0.54**	**0.55**		**22.1**	Jul-00	10mm Gst PSV 60
2703		2210-2632		CR1			0.32	0.49	0.33	**0.50**	**0.45**	**0.56**	**0.58**		**17.1**	Jul-00	
2758	B3078/416	1390-2245	B3078 Station Road, Alderholt	CL1	Light					**0.34**	**0.44**	**0.44**	**0.43**		**26.5**	Apr-01	10mm Gst PSV 60
2758	B3078/416	1390-2245	B3078 Station Road, Alderholt	CR1						**0.42**	**0.46**	**0.45**	**0.50**		**19.0**	Apr-01	
2758	B3078/417	392-631, 891--1080	B3078 Station Road, Alderholt	CL1	Light					**0.36**	**0.43**	**0.47**	**0.44**		**22.9**	Apr-01	10mm Gst PSV 60
2758		392-631, 891-1080		CR1						**0.39**	**0.43**	**0.49**	**0.49**		**27.5**	Apr-01	
2793	B3078/430	0-445	St Giles Park Wimborne St Giles	CL1	Light	0.50	0.47	0.46	0.51	**0.35**	**0.38**	**0.41**			**15.6**	Nov-01	14mm Gst PSV 60
2793		0-445		CR1		0.39	0.47	0.48	0.56	**0.42**	**0.44**	**0.49**			**16.7**	Nov-01	
2908	C2/480	1080-1670	C2 Horton Rd (St Ives Wood to Whitfield Pk) Ashley	CL1	Light					**0.35**	**0.40**	**0.44**			**26.3**	Nov-01	14mm Gst PSV 65
2908		1080-1670		CR1			0.37	0.37	0.45	**0.41**	**0.46**	**0.49**			**19.0**	Nov-01	

Ref: - (yellow highlight) 10mm Material

Table 1 - Trend in MSSC Results (Continued)

Stone Mastic Asphalt Performance Report 1999 to 2004

Note: - MSSC figures in bold represent values after SMA was laid

Project	Section	Chainage	Project Title	Lane	Traffic Flows	MSSC Results Age of Surfacing										Date of Laying	Material Type (Gst = Gritstone) (PMB = Polymer Modified Binder)
						Year-4	Year-3	Year-2	Year-1	Year1	Year2	Year3	Year 4	Year 5	% Change		
North District																	
2670	A30/338	1132-2606	A30 Causeway Garage to Church HillJunction	CL1	Heavy			0.38	0.41	**0.37**	**0.48**	**0.54**	**0.55**	**0.53**	**41.8**	Oct-99	10mm Gst PSV 65
2670		1132-2606		CR1				0.38	0.41	**0.42**	**0.53**	**0.55**	**0.57**	**0.58**	**38.3**	Oct-99	
2670	A30/375	0-90	A30 Causeway Garage to Church HillJunction	CL1	Heavy			0.34	0.37	**0.42**	**0.56**	**0.55**	**0.57**	**0.41**	**-3.2**	Oct-99	10mm Gst PSV 65
2670		0-90		CR1				0.40	0.37	**0.45**	**0.57**	**0.54**	**0.62**	**0.32**	**-29.7**	Oct-99	
2701	A350/305	0-357	Ivy Cross R/B to Wiltshire Bndy A350 Shaftesbury Prt	CL1	Heavy					**0.44**	**0.44**	**0.53**	**0.45**	**0.51**	**15.0**	Dec-99	14mmm Gst PSV 60
2701		0-357		CR1						**0.41**	**0.46**	**0.50**	**0.45**	**0.41**	**1.7**	Dec-99	
2701	A350/306	0-558	Ivy Cross R/B to Wiltshire Bndy A350 Shaftesbury Prt	CL1	Heavy			0.34	0.39	**0.39**	**0.45**	**0.51**	**0.43**	**0.45**	**17.0**	Dec-99	14mmm Gst - SMA & Cellulose Fibres PSV 60
2701		0-558		CR1				0.28	0.38	**0.42**	**0.45**	**0.49**	**0.42**	**0.40**	**-3.6**	Dec-99	
2757	A30/397	0-479	A30 Shaftesbury Town To Wiltshire Boundary	CL1	Heavy					**0.49**	**0.50**	**0.50**			**1.6**	Jul-01	14mm Gst PSV 65
2757		0-479	A30 Shaftesbury Town To Wiltshire Boundary	CR1						**0.48**	**0.53**	**0.49**			**1.3**	Jul-01	
West District																	
2696	A356/105	1695-2425	A356 Winyards Gap (Part)	CL1	Heavy			0.46	0.46	**0.39**	**0.52**	**0.51**	**0.50**	**0.49**	**24.8**	Dec-99	14mmm Gst PSV 60
2696	A356/105	1695-2425	A356 Winyards Gap (Part)	CR1				0.41	0.42	**0.36**	**0.49**	**0.55**	**0.49**	**0.47**	**31.9**	Dec-99	14mmm Gst - SMA & Cellulose Fibres PSV 60
2697	A356/179	200-636	A356 Maiden Newton (Part)	CL1	Heavy					**0.35**	**0.59**	**0.48**	**0.46**	**0.47**	**35.3**	Nov-99	14mmm Gst - SMA & Cellulose Fibres PSV 60
2697		200-636		CR1						**0.42**	**0.49**	**0.52**	**0.50**	**0.46**	**7.6**	Nov-99	
2697	A356/182	0-100, 320-645	A356 Maiden Newton (Part)	CL1	Heavy					**0.37**	**0.53**	**0.50**	**0.45**	**0.48**	**30.3**	Nov-99	14mmm Gst PSV 60
2697		0-100, 320-645		CR1						**0.37**	**0.47**	**0.51**	**0.51**	**0.46**	**24.0**	Nov-99	
2697	A356/185	0-90	A356 Maiden Newton (Part)	CL1	Heavy			0.42	0.42	**0.45**	**0.59**	**0.45**	**0.38**	**0.44**	**-3.9**	Nov-99	14mmm Gst PSV 60
2697		0-90		CR1				0.42	0.44	**0.44**	**0.48**	**0.47**	**0.45**	**0.44**	**0.3**	Nov-99	
Ref: -			10mm Material														
			Average for 14mm material			0.40	0.38	0.40	0.44	**0.43**	**0.47**	**0.47**	**0.45**	**0.45**			
			SD for 14mm material			0.05	0.06	0.05	0.05	**0.05**	**0.05**	**0.05**	**0.05**	**0.04**			
			Average for 10m material				0.28	0.42	0.37	**0.41**	**0.48**	**0.51**	**0.53**	**0.46**			
			SD for 10mm material				0.06	0.07	0.04	**0.05**	**0.05**	**0.04**	**0.06**	**0.12**			
			Count							33	33	33	23	18			
			% improvement								10.5	10.9	5.0	6.2			

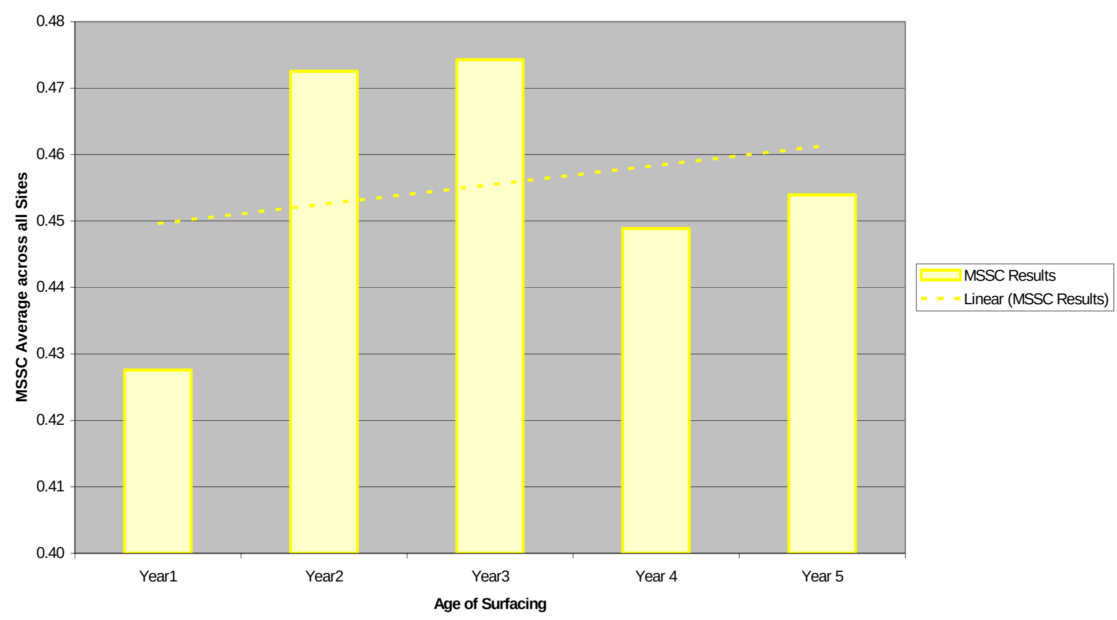

Figure 2 - Average MSSC Values for SMA

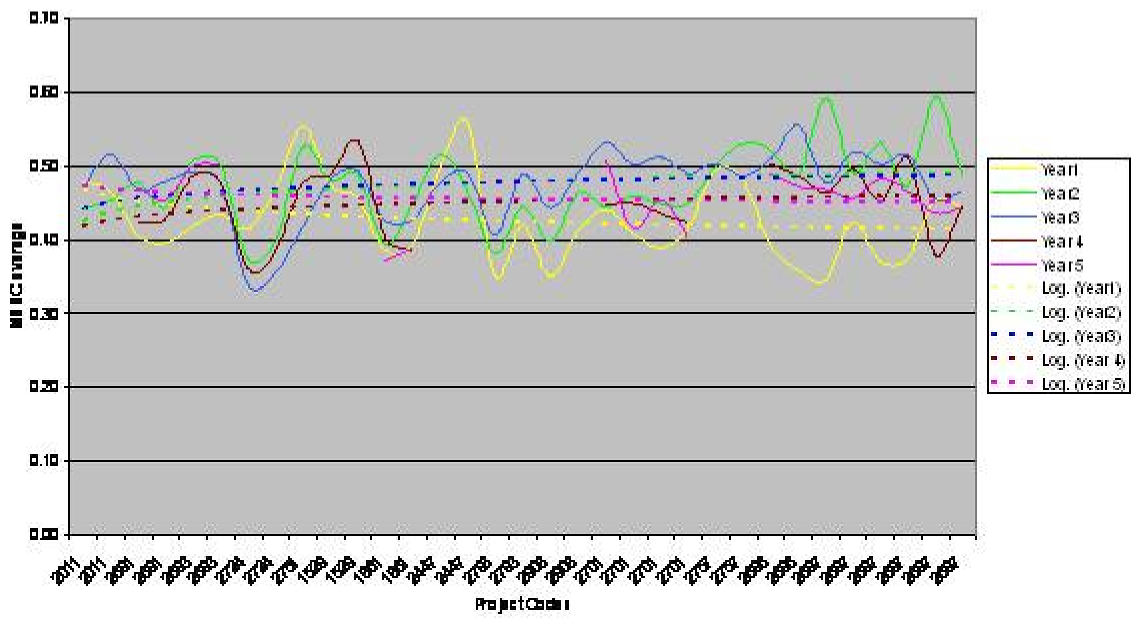

Figure 3 - Variation in MSSC Values for Each Site

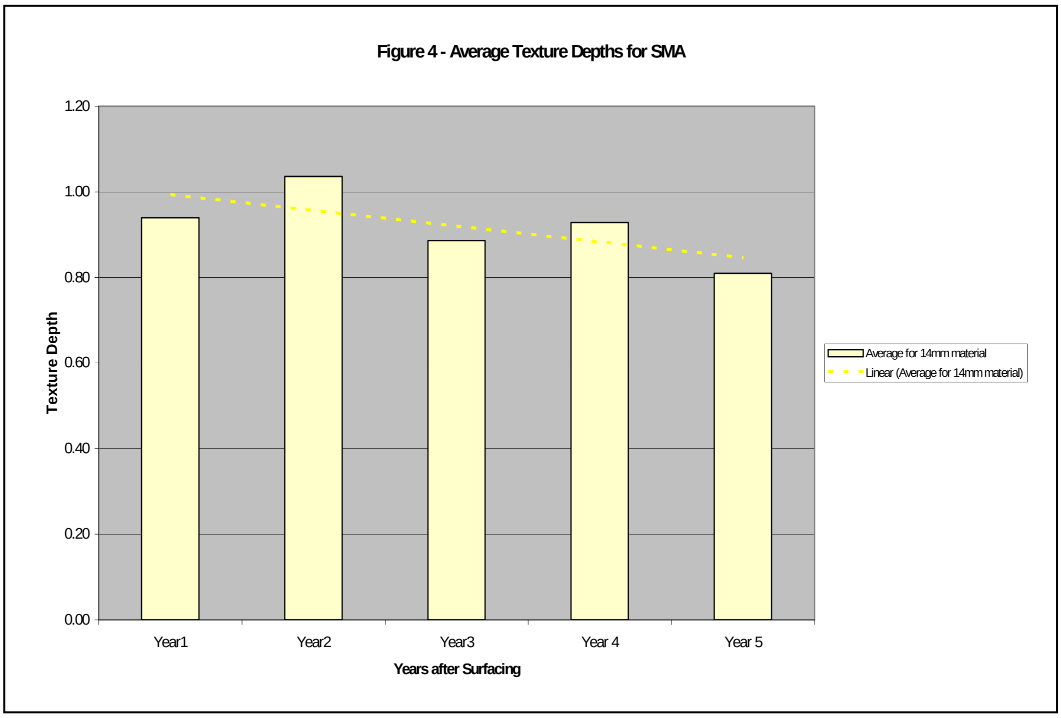
Figure 4 - Average Texture Depths for SMA
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Texture Depth
Year1
Year2
Year3
Year 4
Year 5
Years after Surfacing
Average for 14mm material
Linear (Average for 14mm material)

Table 2 - Trend in Texture Depth with Time

Stone Mastic Asphalt Performance Report 1999 to 2004

Note: - MSSC figures in bold represent values after SMA was laid

Project	Section	Chainage	Project Title	Lane	Traffic Flows	MSSC Results Age of Surfacing Year-4	Year-3	Year-2	Year-1	Year1	Year2	Year3	Year 4	Year 5	Date of Laying	Material Type (Gst = Gritstone) (PMB = Polymer Modified Binder)
South District																
2011	A35/556	1218-1559	A.35 Improvement, Woodbury - Bere Regis (part)	CL1	Medium		1.16				**0.99**	**0.92**			Oct-01	14mm Gst - 'Generic' SMA PSV 65
2011		1218-1559		CR1			1.19				**1.35**	**1.20**			Oct-01	14mm Gst - SMA & Cellulose Fibres PSV 65
2691	A35/556	0-1020	A35 Poole Hill, Bere Regis (Part)	CL1	Medium		0.90		0.86				**0.99**	**0.94**	Nov-99	14mm
2691		0-1020	A35 Poole Hill, Bere Regis (Part)	CR1			0.88		0.84				**1.17**	**1.13**	Nov-99	
2693	B3068/505	150-515	B3068 Blandford Road North	CL1	Light		0.83		0.70	**0.89**		**0.98**			Sep-99	14mm Gst PSV 65
2693		150-515		CR1			0.74		0.63	**0.90**		**0.97**			Sep-99	
2724	B3068/515	50-750	B3068 Blandford Road, Upton	CL1	Light		0.68		0.50	**0.68**					Mar-01	14mm Gst PSV 65
2724		50-750		CR1			0.59		0.42	**0.59**					Mar-01	
2751	A35/584	0-1093	A35 Upton Bypass	CL1	Heavy		0.90				**1.23**	**1.16**			May-01	14mm Gst - SMA (PMB) PSV 63
East District																
1529	B3074/460	0-478	B3074 Blandford Road, Corfe Mullen	CL1	Light	0.65		0.64	0.51	**0.89**					Jul-00	14mm Gst
1529		0-478		CR1		0.71		0.64	0.55		**0.93**				Jul-00	
1861	A348/434	1310-1480	The Angel, Longham: Traffic Signals	CL1	Heavy Urban		0.93		0.48	**0.64**		**0.62**	**0.64**	**0.58**	Sep-99	14mm Gst PSV 68
1861		1310-1480		CR1			0.94		0.60	**0.66**		**0.64**	**0.73**	**0.59**	Sep-99	
2447	B3072/423	226-276	Three Legged Cross Junction Improvement	CL1	Light	0.58		0.30		**1.32**					Mar-02	14mm Gst PSV 68
2447		226-276		CR1		0.75		0.68		**1.41**					Mar-02	
2703	B3081/482	2210-2632	Forestside to Hampshire Boundary B3081	CL1	Light	0.73		0.77	0.56		**0.63**				Jul-00	10mm Gst PSV 60
2703		2210-2632		CR1		0.79		0.81	0.84		**0.62**				Jul-00	
2758	B3078/416	1390-2245	B3078 Station Road, Alderholt	CL1	Light					**0.47**					Apr-01	10mm Gst PSV 60
2758	B3078/416	1390-2245	B3078 Station Road, Alderholt	CR1						**0.60**					Apr-01	
2758	B3078/417	392-631, 891--1080	B3078 Station Road, Alderholt	CL1	Light					**0.46**					Apr-01	10mm Gst PSV 60
2758		392-631, 891-1080		CR1						**0.47**					Apr-01	
2793	B3078/430	0-445	St Giles Park Wimborne St Giles	CL1	Light		1.33		1.26	**1.22**					Nov-01	14mm Gst PSV 60
2793		0-445		CR1			1.25		1.12	**1.25**					Nov-01	
2908	C2/480	1080-1670	C2 Horton Rd (St Ives Wood to Whitfield Pk) Ashley	CL1	Light		0.45		0.57	**1.13**					Nov-01	14mm Gst PSV 65
2908		1080-1670		CR1			0.71		0.62	**1.26**					Nov-01	

Ref: - (yellow) 10mm Material

Table 2 - Trend in Texture Depth with Time (Continued)

Stone Mastic Asphalt Performance Report 1999 to 2004

Note: - MSSC figures in bold represent values after SMA was laid

Project	Section	Chainage	Project Title	Lane	Traffic Flows	MSSC Results Age of Surfacing Year-4	Year-3	Year-2	Year-1	Year1	Year2	Year3	Year 4	Year 5	Date of Laying	Material Type (Gst = Gritstone) (PMB = Polymer Modified Binder)
North District																
2670	A30/338	1132-2606	A30 Causeway Garage to Church HillJunction	CL1	Heavy				0.66	**0.70**		**0.79**	**0.83**	**0.73**	Oct-99	10mm Gst PSV 65
2670		1132-2606		CR1					0.77	**0.69**		**0.80**	**0.79**	**0.75**	Oct-99	
2670	A30/375	0-90	A30 Causeway Garage to Church HillJunction	CL1	Heavy				0.56	**0.66**		**0.70**	**1.01**	**0.85**	Oct-99	10mm Gst PSV 65
2670		0-90		CR1					0.45	**0.53**		**0.73**	**0.90**	**1.09**	Oct-99	
2701	A350/305	0-357	Ivy Cross R/B to Wiltshire Bndy A350 Shaftesbury Prt	CL1	Heavy				1.00	**0.93**		**0.95**	**1.03**	**0.99**	Dec-99	14mmm Gst PSV 60
2701		0-357		CR1					1.00	**0.95**		**1.03**	**0.99**	**0.88**	Dec-99	
2701	A350/306	0-558	Ivy Cross R/B to Wiltshire Bndy A350 Shaftesbury Prt	CL1	Heavy				0.75	**0.94**		**0.91**	**0.92**	**0.89**	Dec-99	14mmm Gst - SMA & Cellulose Fibres PSV 60
2701		0-558		CR1					0.76	**0.98**		**1.01**	**1.06**	**0.63**	Dec-99	
2757	A30/397	0-479	A30 Shaftesbury Town To Wiltshire Boundary	CL1	Heavy		0.67		0.68	**0.86**	**0.86**	**0.77**			Jul-01	14mm Gst PSV 65
2757		0-479	A30 Shaftesbury Town To Wiltshire Boundary	CR1			0.62		0.65	**0.90**	**0.85**	**0.69**			Jul-01	
West Di																
2696	A356/105	1695-2425	A356 Winyards Gap (Part)	CL1	Heavy		0.80		0.89	**0.84**		**0.93**		**0.90**	Dec-99	14mmm Gst PSV 60
2696	A356/105	1695-2425	A356 Winyards Gap (Part)	CR1			0.95		1.01	**1.04**		**1.01**		**0.93**	Dec-99	14mmm Gst - SMA & Cellulose Fibres PSV 60
2697	A356/179	200-636	A356 Maiden Newton (Part)	CL1	Heavy				0.58	**0.97**		**0.88**		**0.87**	Nov-99	14mmm Gst - SMA & Cellulose Fibres PSV 60
2697		200-636		CR1			0.61		0.59	**0.91**		**0.86**	**0.84**	**0.82**	Nov-99	
2697	A356/182	0-100, 320-645	A356 Maiden Newton (Part)	CL1	Heavy		0.72		0.69	**0.94**		**0.90**		**0.82**	Nov-99	14mmm Gst PSV 60
2697		0-100, 320-645		CR1			0.72		0.86	**0.78**		**0.83**		**0.76**	Nov-99	
2697	A356/185	0-90	A356 Maiden Newton (Part)	CL1	Heavy		1.47		1.06	**0.68**		**0.53**		**0.69**	Nov-99	14mmm Gst PSV 60
2697		0-90		CR1			1.03		0.76	**0.83**		**0.82**		**0.56**	Nov-99	
			Average for 14mm material			0.67	0.88	0.56	0.75	**0.94**	**1.04**	**0.89**	**0.93**	**0.81**		Average Texture 0.92mm
			SD for 14mm material			0.07	0.26	0.18	0.21	**0.21**	**0.21**	**0.17**	**0.17**	**0.16**		
			Average for 10m material					0.79	0.64	**0.57**	**0.63**	**0.75**	**0.88**	**0.85**		Average Texture 0.74mm
			SD for 10mm material					0.03	0.14	**0.10**	**0.01**	**0.05**	**0.10**	**0.17**		