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STONE MASTIC ASPHALT IN THE UK

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Abstract

Development of Stone Mastic Asphalt (SMA) began in the 1960s in Germany and offered a more attractive solution than chipped Gussaphalt for the reduction of wear caused by studded tyres. The excellent resistance of the product to deformation was recognised and developments continued, leading to the publication of a German Standard Specification and to similar developments in a number of other countries in Europe, the Far East and the USA.

Typical applications include heavily trafficked roads, airport taxiways, bridge deck surfacing, container storage areas and bus stops. The surface texture of the installed product is greater than that of dense graded asphalt concrete but usually less than that currently considered suitable for high speed roads in the UK. The material has been re-designed, however, to provide high surface texture and evaluation of skid resistance is a matter of ongoing study.

The use of SMA is rapidly gaining the support of highway engineers in the UK and is, in particular, an intriguing, alternative solution to chipped hot rolled asphalt in many situations.

This paper examines the case for continued use of SMA in the UK.

Introduction

Development of Stone Mastic Asphalt (SMA) began in the 1960s in Germany and offered a more attractive solution than chipped Gussasphalt (a type of mastic asphalt) for the reduction of wear caused by studded tyres. The excellent resistance of the product to deformation by heavy traffic at high temperatures was recognised and developments continued, leading to the publication of a German Standard Specification[1] and to similar developments in a number of other countries in Continental Europe, the Far East and the USA.

Interest in the product has also been generated in the United Kingdom (UK) and a study tour was made by a DOT/BACMI/RBA collaborative research group to Germany in 1993. A demonstration of SMA quickly followed at the Transport Research Laboratory (TRL) test track and a report of an evaluation of the product was subsequently published in 1994.[2] The report included a draft specification for SMA wearing course that had been prepared by the Highways Agency for application to trunk roads on a trial basis.

The scope for producing and marketing the product in the UK for different roads and other paved areas in both public and private sectors was examined by a number of asphalt suppliers at the time. Although the product was viewed as essentially a heavy duty material, its general application was considered by one or two suppliers to be potentially immense and the suppliers proceeded to promote it actively. A major incentive was the possibility of its use as an alternative solution to chipped hot rolled asphalt (HRA)[3] where this was to be laid in difficult situations.

HRA is a high grade asphalt product with a wide range of applications and is the most common type of surfacing in the UK for major roads. In terms of both durability and surface friction, there has been none better than HRA. However, because of the need to apply coated chippings to the surface as a separate but concurrent operation during laying, the process necessarily takes up more room across the width of the road leading to greater traffic congestion and so, higher road user costs and where specified, high chipping spread rates applied to achieve high texture depth[4] can lead to subsequent loss of chippings after the road is opened to traffic.

Largely due to the endeavours of the few zealous contractors and the good judgement of various clients and engineers around the country, SMA began to gain rapidly in popularity from about 1995.

The product

SMA is a dense, gap-graded bituminous mixture with high contents of stone, filler and bitumen, modified with a suitable binder carrier such as cellulose fibre. The essential elements of mixture design comprise the formation of an interlocking stone skeleton that provides high resistance to deformation and the filling of the skeleton voids with a rich bituminous mortar to provide high durability. The conventional structure is illustrated in Figure 1 and compared with those of Porous Asphalt[5] and textured thin wearing course,[6] both of which also have high contents of aggregate coated with relatively thick binder films. In very general terms, however, shifting from Porous Asphalt to thin wearing course and on to SMA, the air voids content and surface texture are reduced, but each material still has a relatively quiet surface compared with that of chipped HRA.

Typical applications in mainland Europe have included heavily trafficked roads, airport taxiways and runways, bridge deck surfacing, container storage areas and bus stops. The surface texture of the installed product in Germany, for example, has traditionally been greater than that of dense graded asphalt concrete but less but less than that currently considered suitable for high speed roads in the UK [4]. Development of SMA in this country, however, has focused a lot on producing high texture without impairment of the other desirable properties of the material.

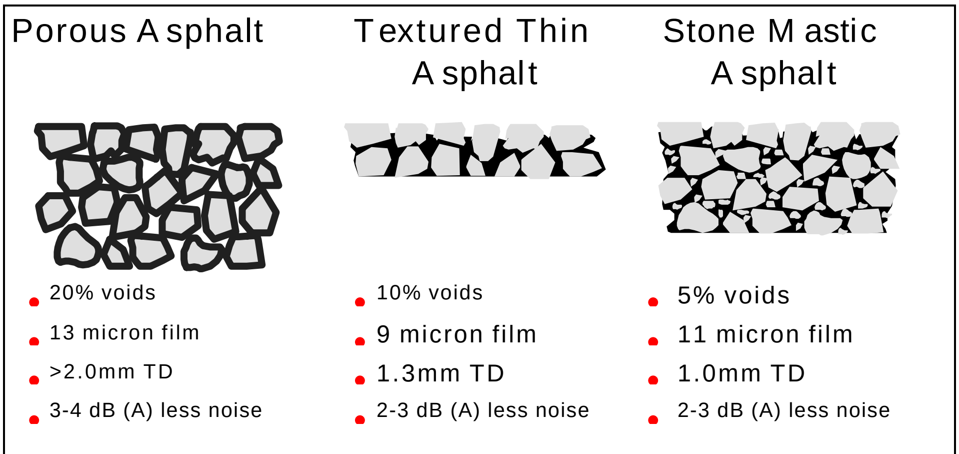

Fig. 1

The main benefits may be described as follows:

- high resistance to rutting [7]
- high resistance to cracking
- high durability
- wear and ravelling resistance
- insensitivity to water
- good skid resistance
- low surface noise
- superior surface finish

The principal attraction of the material, though, is the unique combination of deformation resistance and durability.

Joint DOT/BACMI/RBA study tour

The aim of the study tour made to Germany in 1993 by a collaborative research group comprising the Highways Agency of the Department of Transport (DOT), BACMI (now known as Quarry Products Association) and the Refined Bitumen Association (RBA) was to gain a better appreciation of the use of SMA in Germany. The itinerary included visits to the State of Baden-Wuttemberg and the Schellerberg Research Institute at Rotwiell, and inspections of an asphalt manufacturing plant, laying site and trafficked surfaces. Details of the tour are reported elsewhere,[2] but some of the salient points are described here.

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Up until the 1980s, the wearing course on German roads was generally continuously graded asphalt concrete. A relatively low content of hard grade bitumen became necessary to resist deformation by increasing traffic. As a result, cracking also became a common mode of failure. The development of SMA as an alternative surfacing hastened and a national specification was published in 1984.[1] It was reported subsequently that failure of the surfacing was rarely attributable to the breakdown of the SMA wearing course, but that the rutting that had occurred to date was more likely due to deformation of the basecourse underneath. Consequently, SMA can also be specified for use as a basecourse.

Despite the high binder content and high mixing temperature (up to 180°C when using 65 penetration grade bitumen), the discharged material does not slump in the wagon body and is devoid of any obvious segregation. This is largely due to the high capacity of the added cellulose fibre for carrying bitumen. SMA can be laid as thin as 20mm, but 40mm is commonly the preferred thickness to benefit more from the influence of the stone structure on performance. Compacted thicknesses corresponding to 2.5 to 5.0 times the nominal size of aggregate are also recommended. A very consistent and uniform surface appearance is produced at the paver screed and very little displacement of the material can be observed during rolling. Due to the high binder volume in the mixture, the compacted surface has initially a relatively thick binder film coating. To avoid vehicle skidding during service in the first winter period, uncoated grit is commonly spread and compacted into the surface at the time of construction. The surface appearance after considerable trafficking is quite reminiscent of a worn "Delugrip" high friction dense asphalt,[8] which was introduced in the UK on experimental sections in the mid 1970s.

TRL Demonstration

A demonstration of SMA was organised at the TRL immediately following the study tour. The main interest of the research group was the possible application on trunk roads. It was thought at the time that the optimum composition of the material for this case may lie somewhere between that of Porous Asphalt and that of SMA to obtain the right balance between high texture or porosity and high durability. Trial sections of thickness varying from 40mm down to less than 20mm were laid. The corresponding aggregate nominal sizes varied from 14mm down to 6mm and the bitumen grade varied from 50 to 100 penetration.[2]

The conclusions of the trials were that SMA should be a durable and rut-resistant material with a capacity for generating less tyre noise. It was also observed that there was scope for adjusting the surface texture to quite high values by raising the stone content even higher.

Application of SMA in the UK

Motorways and trunk roads account for 4.7% of the UK road network.[9] That leaves 351,700 km of other types of Public Sector road in addition to various types of paved areas in the Private Sector. For reasons of expediency, many of the earliest examples of SMA installations fall into the latter categories. Mixtures used for applications for which high texture depth was not an essential requirement were based closely on the requirements of German Standard Specifications. Some typical data for these early materials are given in Table 1. The low wheel tracking rate provided confirmation of good deformation resistance. A surface giving a tracking rate of less than 2mm/h would normally be considered good.[10] Subsequent testing on similar materials at the higher temperature of 60°C indicates that the rate is in general not markedly affected by this high temperature. The stiffness modulus may be considered to be comparable with that for HRA.

Table 1. Test results at the time of construction for early SMA in the UK

Indirect tensile stiffness modulus (20°C), MPa	2100
Wheel tracking rate (45°C), mm/h	0.55
Texture depth (sand patch), mm	1.0

Typical applications have included industrial sites; residential, town and country roads; and by-passes. In addition, some proprietary versions[11] have been installed as surfacing to motor racing tracks, tunnel toll plaza and access roads, airfield taxiways and runways.

In order that the material may be used as a surfacing on the trunk road network, it has been necessary to re-design it to suit the particular requirements.[4] Figure 2 illustrates the shift in aggregate grading away from the more traditional German type to one that will satisfy the high texture depth requirements in the UK (minimum average of 1.5mm by sand patch) that are considered to be necessary to minimise loss of skid resistance at high vehicle speeds ie >90km/h. Despite the coarser grading, some typical test data that are given in Table 2 indicate that other desirable properties are not impaired.

12.5km of the A1 in East Lothian have been upgraded to dual carriageway standard and this was the first section of trunk road in Scotland to include SMA wearing course. The project was a design and build contract and the use of SMA was part of the fully flexible pavement option. A further example is 8km of 2-lane dual carriageway that formed part of a design, build, finance and operate (DBFO) contract to upgrade the A417 and A419 in the South West of England. A proprietary mixture of SMA[12] was used in this case for the wearing course. A similar material has been used to overlay a cracked and seated concrete pavement as part of another DBFO contract to rehabilitate a section of the M40 motorway in Oxfordshire.

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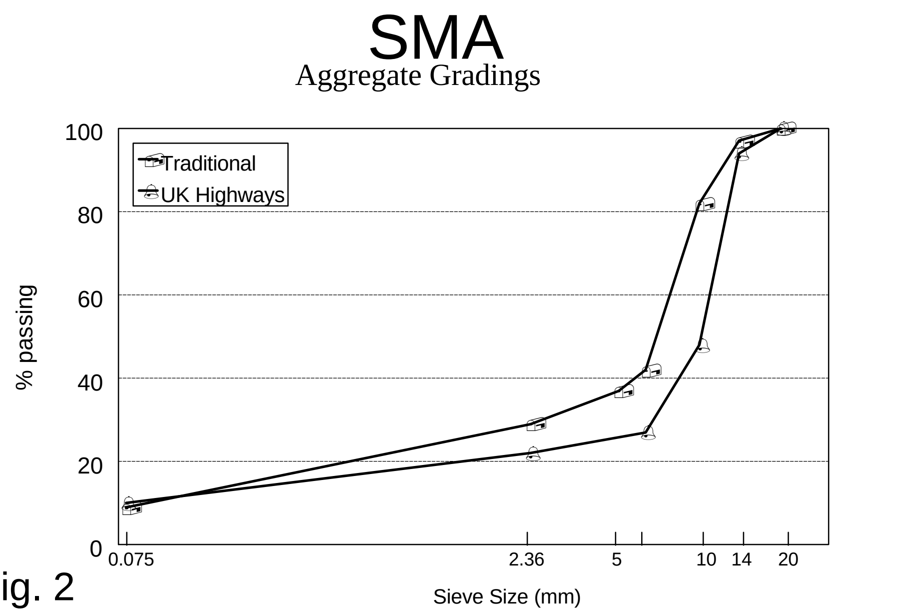

Fig. 2

Table 2. Test results for SMA used on high category roads

Wheel tracking rate @ 45°C, mm/h	0.25–0.9
Wheel tracking rate @ 60°C, mm/h	1.3
Wheel track depth @ 45°C, mm	1.5–1.8
Wheel track depth @ 60°C, mm	3.0
Texture depth (sand patch), mm	>1.5
Indirect tensile stiffness modulus (20°C), MPa	3200
Water sensitivity – stiffness ratio	1.0
Noise reduction (90 km/h), dB(A)*	3–5

*Compared with chipped HRA

Skid resistance measured by the Sideway-force Coefficient Routine Investigation Machine (SCRIM) and the Griptester has also indicated that a level can be achieved that is commensurate with that which would be expected of the aggregate used in those same site conditions for a traditional surfacing mixture. There is some anecdotal evidence of lower values in the early life of the material which can be offset to a certain extent by the application of grit particles onto the surface during laying. Lower early life skid resistance is also found on traditional road surfaces, however, which rather suggests that gritting should be rarely necessary. Any initial improvement due to gritting may be expected to be lost after only a few months of trafficking.

Gritting trials of SMA surfacing on a trunk road in 1995 demonstrated that the particles tend to collect in the voids in the surface and so effectively reduce the texture depth! As soon as the surface is opened to traffic, a high proportion of the grit particles are then picked up by vehicle tyres and dispersed to the sides of the road.

Figure 3 shows the change in texture depth that might be expected over the first few months of trafficking. So, an initial texture depth by the sand patch method of just over 1.5mm may reduce to around 1.1 or 1.2mm within the first twelve months, depending on the traffic density, before tending to level off during a further period of trafficking. Associated with this behaviour, the change in surface friction with speed is also of interest. Figure 4 shows the change in grip test number for a SMA mixture with an aggregate nominal size of 10mm that was laid on an airfield runway and that typically has an initial texture depth of between 1.0 and 1.5mm. The minimum friction level for the new runway in this case was 0.52 at 65km/h with 0.8 set as a target. The required friction level was achieved, but perhaps the more interesting feature shown on the graph is that the friction on the SMA surface does not appear to be influenced by speed to any great degree over the range examined. This might suggest that texture depth may not be quite so critical for this type of material, but further work would be needed to substantiate such a claim.

Evidence to date also suggests that SMA can tolerate application on a relatively irregular, existing surface without detriment to the regularity of the final surface. This may well be related to the need for a smaller surcharge of material for compaction by the paver screed and rollers.

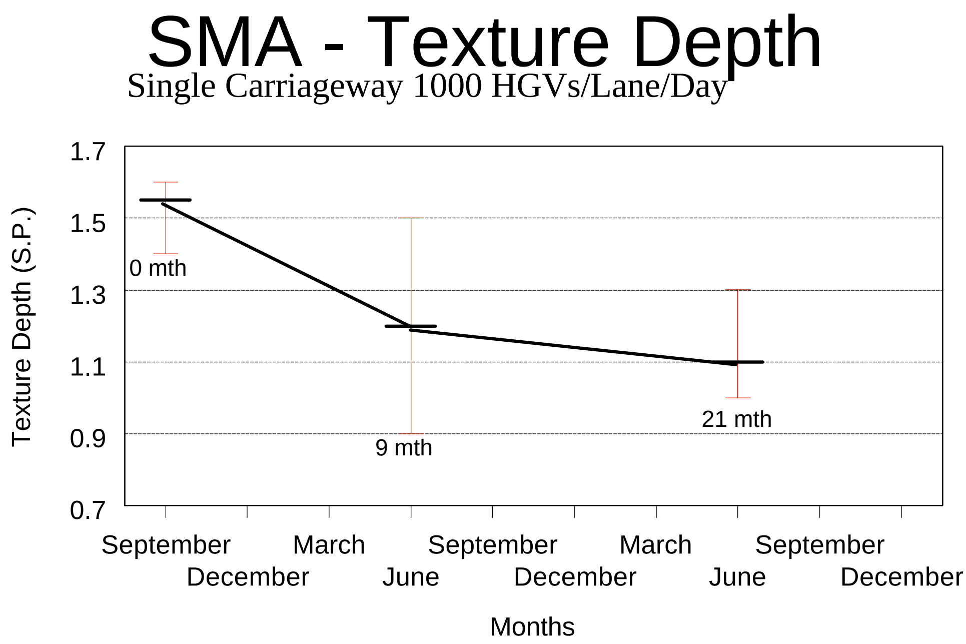

Fig. 3

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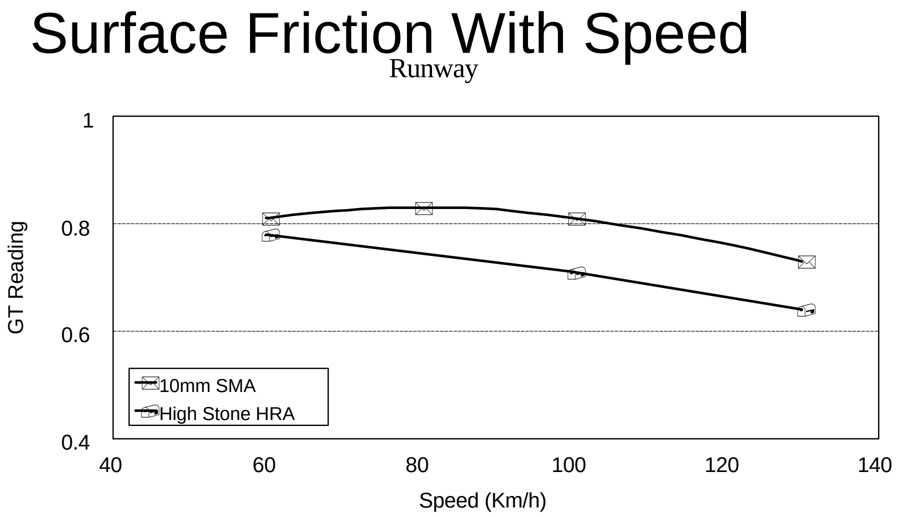

Fig. 4

It is traditional practice in the UK to cut the longitudinal joint of dense asphalt wearing courses to produce a tight, neat finish. Alternatively, joint heaters or paving in echelon may be employed, although these practices are less common. However, it can be argued that a similar treatment is not necessary for SMA because of its relatively high binder volume and thick binder film coating. There are now a lot of examples in the UK that appear to support this view. More care is needed, though, in the forming of the joint and, in some cases, the traditional method may be preferred to ensure a high quality of finish.

The German Standard Specification[1] includes mixture design criteria for SMA stipulating an air voids content in the range 2–4% (3–4% for HGVs/day>1800) when following a prescribed method of laboratory impact compaction. For UK conditions, however, it is suggested that this range may only be appropriate for the design of materials that are intended to be laid in thinner layers, up to, say, 35mm thick. Thicker layers are more prone to densification by traffic that may lead to unacceptable binder migration with consequent loss of texture and, at worst, surface deformation. A slightly higher range of design air voids contents would minimise the risk of such an occurrence in this case without impairment of the durability of the product in the field.

Conclusion

There has been increasing concern in the UK over the lack of resistance to rutting of asphalt wearing courses. This has led to a decrease in binder contents that has in turn resulted in a fear of possible loss of durability and of resistance to cracking. A dense material has now been made available that imparts to the road surface both high resistance to deformation and high durability through the design of a coarse graded aggregate structure having the capacity to accommodate a rich bituminous mortar by the incorporation of suitable binder carriers.

SMA has been re-designed to provide a high surface texture and to meet the requirements of surfacing for UK motorways and other trunk roads. In so doing, other desirable properties of

SMA have not been impaired. It has also been found to be a very versatile material and as such, some freedom, but also great care, is required in its design in order to satisfy the demand for its use in a variety of other applications.

The use of SMA is rapidly gaining acceptance in the UK and provides the highway engineer with a further option in the choice of surfacing materials. In particular, it has become a convenient alternative to chipped HRA in difficult situations.

Note

The views expressed by the author in this paper are not necessarily those of Tarmac Quarry Products.

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