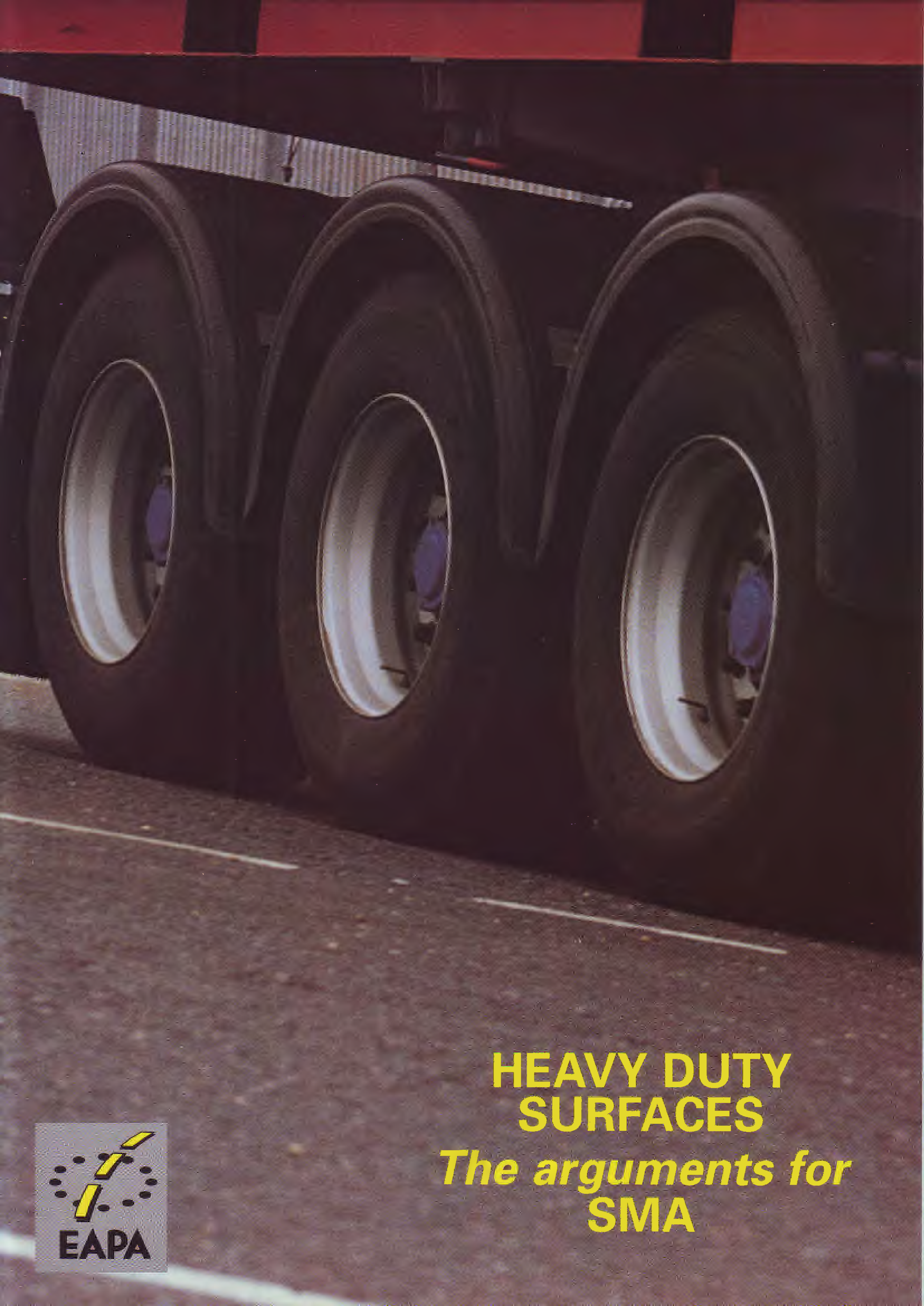

HEAVY DUTY SURFACES

The arguments for SMA

EAPA

HEAVY DUTY SURFACES:

THE ARGUMENTS FOR SMA

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Contents

IMPORTANT NOTICE

Summary

Stone Mastic Asphalt (SMA) has become a popular asphalt for the surfacing of heavily trafficked roads, airfields and harbour areas in Europe and its use is spreading across the world. The even surface that can be obtained using SMA provides comfortable riding characteristics whilst its texture gives good skid resistance with relatively low traffic noise. The strong aggregate structure provided by the coarse aggregate particles gives excellent resistance to permanent deformation and the rich mastic, which fills the voids between those particles, makes SMA highly durable. Due to the high binder content a drainage inhibitor is needed to prevent binder drainage. Modified bitumen can be used to further enhance the mechanical properties of SMA and also to reduce the use of a drainage inhibitor. The specific mixture composition allows thin layer application, which means that less of this high quality asphalt needs to be used in the surface course of pavement construction. As a result SMA has proved to be cost effective even though it requires a high binder content and the use of high quality aggregates. A well designed SMA requires extremely low maintenance when applied in a properly designed construction. The additional advantages of quick application, and ease of use in maintenance operations can contribute to lower pavement whole-life costs.

Longer road life, thinner construction and reduced noise levels impart sustainable environmental benefits.

Several individual countries now have a national standard for SMA, and CEN is in the process of developing a European product standard. In the USA, where SMA is called Stone Matrix Asphalt, and elsewhere in the world, its use is increasing in popularity amongst road authorities and the asphalt industry.

This report covers all the above points and highlights the key areas that must be satisfied to ensure success when producing and laying SMA. It is envisaged that it will be of use to producer, layer, contractor and specifier alike.

Résumé

L'enrobé Stone Mastic Asphalt (SMA) est devenu un enrobé d'usage très courant pour la réalisation des chaussées fortement circulées, des aéroports et des zones portuaires tant en Europe qu'ailleurs dans le monde.

Son squelette minéral grenu à base de granulats de qualité lui permet de bien résister aux déformations permanentes. Son mastic, riche en liant, assure une bonne longévité.

En raison d'une teneur en liant élevée, il est nécessaire d'utiliser des additifs destinés à fixer le bitume et éviter ainsi tout égouttage.

Afin de résoudre ce problème et d'augmenter les performances du SMA, il est également possible d'utiliser des liants modifiés.

La formulation des SMA permet une utilisation en couche mince, réservant cet enrobé de qualité aux couches de roulement.

La surface obtenue rend la conduite agréable tout en assurant une bonne adhérence ainsi qu'une nuisance sonore relativement basse.

Le SMA est un produit compétitif qui nécessite peu d'entretien et qui apporte un gain durable en terme d'environnement.

Certains pays ont déjà une norme nationale (voir Annexe C) et une norme européenne est en préparation au CEN. Le SMA est aussi appelé Stone Matrix Asphalt aux USA, Splittmastixasphalt en Allemagne, et en France l'enrobé qui s'en approche le plus est le BBM (thin bituminous concrete).

Le présent rapport développe tous les points évoqués ci-dessus et souligne les conditions essentielles à respecter pour une réussite complète au niveau de la fabrication et de l'application des SMA. Il est destiné aux fabricants d'enrobés, aux entreprises applicatrices ainsi qu'aux maîtres d'oeuvre.

Zusammenfassung

Splittmastixasphalt (SMA) gewinnt als Deckschicht für die Befestigung stark beanspruchter Straßen, Flugplätze und hochbeanspruchter Lagerflächen in Europa zunehmend an Bedeutung und seine Anwendung nimmt weltweit zu. Die gleichmäßige Oberfläche, die durch den Einsatz von Splittmastixasphalt erreicht werden kann, bietet angenehme Fahreigenschaften, wobei durch die Textur eine gute Griffigkeit bei relativ niedrigen Rollgeräuschen erzielt wird.

Das stabile Mineralstoffgerüst, das durch den hohen Splittgehalt entsteht, ist äußerst beständig gegenüber Verformungen. Durch den hochwertigen Asphaltmastix, der die Hohlräume im Mineralstoffgerüst teilweise ausfüllt, ist SMA ausgesprochen dauerhaft. Wegen des hohen Bindemittelgehalts ist der Einsatz von stabilisierenden Zusätzen erforderlich, die ein Ablaufen des Bindemittels von den Mineralstoffen verhindern. Zur Verbesserung der mechanischen Eigenschaften von SMA kann modifiziertes Bitumen eingesetzt werden.

Die Eigenschaften des SMA ermöglichen auch sein Auftragen in dünnen Lagen. Das heißt, daß auch eine dünne Schicht dieses qualitativ hochwertigen Asphalts als Deckschicht einer Fahrbahnkonstruktion ausreicht. SMA ist daher trotz seines hohen Bindemittelgehalts und des Einsatzes qualitativ hochwertiger Mineralstoffe preiswert. Darüber hinaus erfordert ein richtig konzipierter und hergestellter Splittmastixasphalt nur geringen Unterhaltungsaufwand, wenn er Bestandteil einer ausreichend bemessenen Konstruktion ist.

Insbesondere der problemlose und schnelle Einbau und der geringe Unterhaltungsaufwand tragen bei SMA zu geringen Gesamtkosten über eine lange Nutzungsdauer der Fahrbahnbefestigung bei.

Die lange Lebensdauer dieser Asphaltbefestigung, die dünne Konstruktionsdicke und der niedrige Rollgeräuschpegel bringen auch dauerhafte Vorteile für die Umwelt mit sich.

In verschiedenen Ländern liegen zum Teil seit vielen Jahren technische Regelwerke für Splittmastixasphalt vor und CEN erarbeitet zur Zeit eine entsprechende europäische Mischgutnorm. Sowohl in den USA, wo SMA "stone matrix asphalt" genannt wird, als auch in anderen außereuropäischen Ländern erfreut sich seine Anwendung wachsender Beliebtheit bei Straßenbaubehörden und in der Asphaltindustrie.

Der vorliegende Bericht behandelt die o.g. Punkte und gibt Hinweise für die richtige Zusammensetzung, die Herstellung, den Einbau und die Verwendung von Splittmastixasphalt. Er kann den Asphaltherstellern und den Asphalteinbaufirmen, aber auch den Planenden und den Baustofflieferanten wertvolle Hilfestellung sein.

Resumen

En Europa el Stone Mastic Asphalt (SMA) se ha convertido en una mezcla asfáltica muy utilizada en la pavimentación de carreteras de alto nivel de tráfico, pistas de aeropuertos y zonas portuarias, y su uso se está extendiendo por todo el mundo. La superficie homogénea que proporciona el SMA aseguran unas condiciones de conducción muy cómoda, y la textura que se obtiene da una muy buena resistencia al deslizamiento con un nivel de ruido relativamente bajo. La fracción gruesa del árido proporciona una gran resistencia a la deformación permanente mientras que el mástico rellena los huecos que quedan entre las partículas, lo que hace que el SMA sea una mezcla asfáltica de gran duración. Por su alto contenido en ligante se puede producir escurrimiento del mismo, por lo que se hace necesario utilizar un inhibidor de este escurrimiento. El uso de betún modificado está indicado para aumentar las propiedades mecánicas del SMA y también para impedir el escurrimiento. Las característícas de la mezcla permite su utilizacíon en capas finas, lo que simplifica una reducción del consumo de este ligante de alta calidad en la construcción de pavimentos. Por todo esto, el SMA ha demostrado ser rentable a pesar de requerir un alto contenido en lígante, así como la utilización de áridos de gran calidad. Un SMA estudiado adecuadamente requiere niveles mínimos de conservación, siempre que se utilice en carreteras bien diseñadas. Las ventajas adicionales de una rápida aplicación y la facilidad de uso en las operaciones de conservación pueden contribuir a una reducción de costes durante la vida de un pavimento.

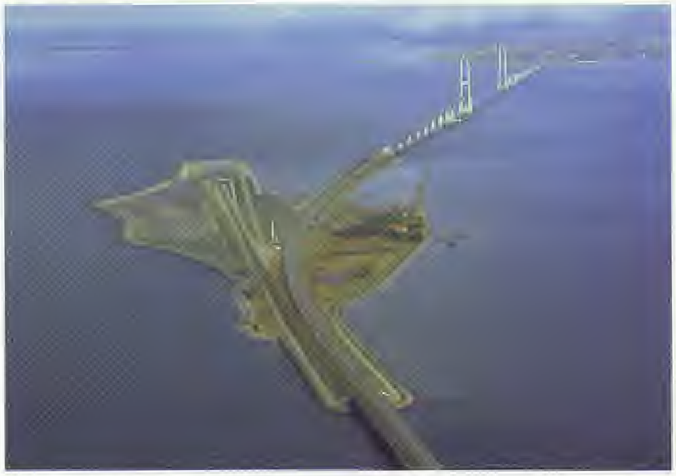
Alargar la vida de las carreteras y reducir los niveles de ruido constituye una gran contribución a la mejora del medio ambiente.

Varios paises estan aplicando normas nacionales para la utilización de los SMA y el CEN está desarrollando una norma europea. Tanto en Estados Unidos, donde el SMA se conoce como Stone Matrix Asphalt, al igual que en el resto del mundo, el uso del SMA está utilizándose cada vez más en los departamentos da carreteras y en la industria del asfalto.

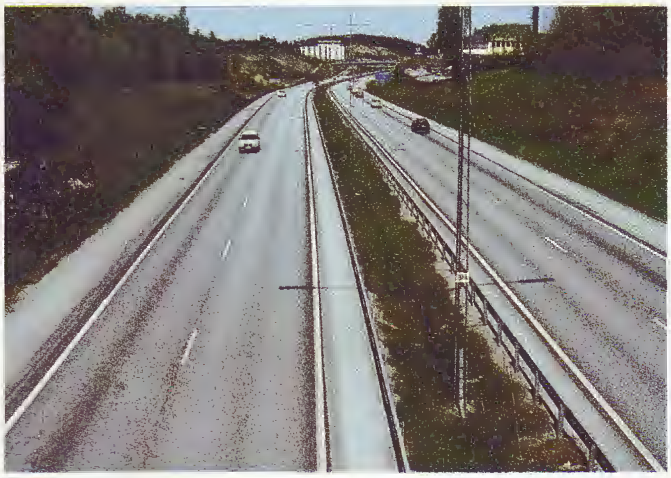
Este informe trata todos los puntos mencionados anteriormente y pone de relieve las áreas clave a las que se debe prestar atención, con el fin de asegurar una producción y una aplicación satisfactorias de los SMA. Se quiere con ello que, tanto los fabricantes, los utilizadores, los contratistas y los redactores de especificaciones encuentren beneficios en su utilización.

Czech Republic

The Netherlands



Denmark



Sweden

Germany

Spain

Hungary

United Kingdom

In many countries Stone Mastic Asphalt (SMA) has become a very attractive asphalt for the surface course of roads, airfields and other pavements. SMA possesses important functional, economic and technical advantages compared to conventional mixtures for surface courses: providing excellent riding characteristics; combining high stability with high durability and capable of being applied in thin layers. Recently the environmental benefits of its quieter surface have been recognised.

SMA was developed in Germany in the mid 1960s and proved extremely effective in combatting wear, and resisting damage from studded tyres. In recognition of its excellent performance a national standard was set in 1984. Since then it has spread throughout Europe and across the world. In France and Spain a type of asphalt (BBM – thin bituminous concrete) is used, which is very similar to SMA.

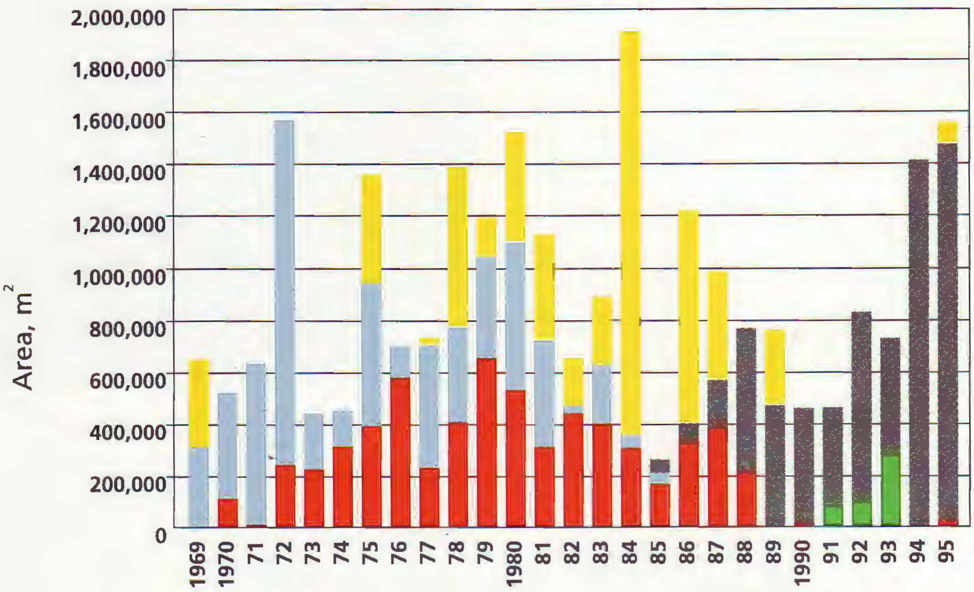
The area of SMA laid in Europe, and as a percentage of asphalt production, is set out by country in Table 1.

As countries gain experience with SMA they have found that to achieve the optimum performance from this excellent material the mixture has to be well designed and a high standard of production and contracting maintained.

This status report provides a survey of the use of SMA in a number of European countries and EAPA hopes that it will be of assistance to road authorities and asphalt contractors/producers who are looking for methods to further increase the life of asphalt pavements.

	Total area million m²	% of asphalt production 1996	Area applied in 1996 million m²
Belgium	4.0	8	
Czech Republic		6	
Denmark	14.1		1.1
Finland	6.0		
France (BBM)	18.0		4.0
Germany	>100.0	8	
Hungary	6.5		2.6
Netherlands	32.0	8	
Norway	12.0	3	
Poland	12.0		
Portugal	3.0		1.0
Slovenia	0.1		
Spain (BBM)	69.0		4.5
Sweden	50.0	18	

Table 1: Production of SMA, Europe, 1996



Increase in use of SMA in Bavaria (Germany) over recent years

- ZB Concrete
- SMA Stone mastic asphalt
- GA Gussasphalt (mastic asphalt)
- DA porous asphalt
- AB asphalt concrete

The main consideration when choosing a type of asphalt for the surface course is the functional characteristics provided by alternative materials in relation to the (whole life cycle) costs of the pavement. The main functional surface characteristics are:

- skid resistance (safety)
- evenness – transverse and longitudinal (driver comfort)
- noise level (environmental and driver comfort)
- durability (pavement performance)
- visibility (safety)

In addition, the recyclability of the material is becoming a greater consideration.

2.1. Skid resistance

SMA can be designed to achieve the levels of skid resistance required on most road applications. The skid resistance achieved will depend on two principal factors:

selection of aggregate type
design of surface texture

Coarse aggregate with a Polished Stone Value appropriate to the site should always be used. Higher PSV aggregates will resist polishing under traffic, and ensure maintenance of skid resistance (SCRIM) for a longer period. Regulations exist in most countries concerning acceptable PSV levels, determined by local aggregate availability and experience of use. Various studies have indicated that the performance of SMA will be equal to or better than that of conventional asphalts with the same aggregate.

Surface texture is important in both the dispersal of surface water at the tyre/road interface and in the provision of grip through the penetration of tyre rubber into surface depressions. It is possible to design different levels of texture into SMA surfaces. This design is a factor of both aggregate size and of the degree of mortar filling of the voids. Larger aggregate (0/14, 0/16) will give texture depths of 1.5 - 2.0 mm, the smaller sizes rather less. It is thus possible through mix selection and design to meet the surface texture regulations for high speed and low speed traffic in most countries. In design it is also important to ensure that mixes are not overfilled with mastic as this can result in 'closing up' or loss of texture under traffic.

SMA mixes, when new, have a rather thicker binder film on the surface than most other conventional asphalts. This has led to concerns in some countries that early life skid resistance during the first few months of trafficking may be lower than expected. There is however little experimental evidence to support this conjecture and indeed studies in the UK conducted using SCRIM have produced contrary indications. However, it is the practice in several countries to apply crushed grit 0-2/5 to the surface during laying to overcome any possible problem.

2.2. Evenness / rutting

Because of its strong aggregate structure the initial even finish from the paver determines the riding quality of the pavement to a greater extent than is the case with asphalt concrete, so additional compaction by the roller is limited. As a result even higher comfort levels for the driver can be achieved when compared to those already provided by other asphalt surfacing.

Due to SMA's high resistance to permanent deformation this initial evenness remains largely unaltered, both in the longitudinal and transverse direction (although the longitudinal evenness is mainly dependent on the bearing capacity of the lower pavement construction). This means that SMA has a high resistance to rutting.

The resistance to permanent deformation of SMA containing non-modified materials has been measured in triaxial compression tests and found to be approximately 1.5 – 4 times the resistance to permanent deformation of asphalt concrete (see also Tables 3 and 4). Tests using the UK wheel tracking device at 60°C generally show wheel tracking rates of around 1mm/hour using unmodified binders; well within the most rigorous UK limit of 5mm/hour for deformation resistant asphalt.

2.3. Noise

Noise level reductions reported from several countries are given in Table 2 (negative values indicate a noise level increase).

As can be seen from Table 2, the noise level from SMA must be judged against the standard alternative in the country of use. In situations where high textured surfaces are used to ensure certain friction characteristics (e.g. HRA, grooved or brushed concrete) SMA will prove much quieter at the same texture level. In comparison with smoother and lower textured asphalt concretes the noise reduction will be more limited, although of course the SMA texture will generally be greater.

Country	SMA type	Reported reduction, dB(A)	Reference
Germany[a] v = 50 km/h	0/5, 0/8	+2.0 to -2.0[b]	AC 0/11
Italy v = 110 km/h	0/15	+5.0 to +7.0	AC 0/15
Netherlands v = 60 – 100 km/h	0/6 0/8 0/11	+1.4 to +1.6 +0.2 to +0.6 0.0 to -2.0[b] 0.8 to -0.5 1.0 to -3.0[b]	AC 0/16
UK v = 70 – 90 km/h	0/6 0/10 0/14	+5.3 to +5.2 +3.5 to +3.2 +2.7	HRA

a.) Calculation values
b.) When the surface is treated with uncoated chippings > 2 mm.

Table 2: Noise levels of SMA compared to other mixture types
(negative values indicate an increase in noise level)

The application of grit to improve friction will increase the noise level for a period, possibly over a year.

2.4. Surface durability

The original reason for developing SMA was the need to improve the resistance to permanent deformation of pavement surfaces and to wear from studded tyres. This goal was achieved and SMA has proved to be a very durable, wear-resistant material. It was found that stripping, surface cracking (temperature and traffic induced) and ravelling are failure mechanisms that do not tend to be relevant to SMA. The excellent durability of SMA derives from the impervious nature of the mastic mortar. The mortar is very binder-rich and voidless, and consequently the rate of deterioration of the binder is extremely low.

The first SMA-type pavement sections were built in the mid sixties. Some of them, now approximately 30 years old, are still in use without extensive maintenance. Application in other countries started from the mid eighties and the same excellent performance has been experienced. For pavement engineers this poses a problem as the lack of significant failure makes it difficult to estimate the real performance life of this material!!

2.5. Visibility

The high surface texture of some SMAs compared to low texture asphalt concrete means that more water can be held within the material, rather than on the surface, resulting in reduced glare at night from the reflection of lights of oncoming vehicles, increased visibility of road markings, and reduced spray.

2.6. Summary

The main advantages of SMA are:

- Surface characteristics giving a safe and comfortable ride
  - high friction level
  - improved evenness/resistance to rutting
  - reduced noise level (under certain conditions)
  - improved visibility characteristics in wet weather
- Durability
  - increased resistance to surface deterioration giving a longer service life
  - reduced need for maintenance
- Speed of maintenance
  - the relatively thin layer construction means that it can be planed and replaced easily
  - less disruption to traffic during maintenance

SMA pavements have proved in practice to perform better than other pavements when comparing mechanical characteristics and durability. That optimum performance requires optimum pavement and mixture design as well as quality laying.

SMA has been very successfully used in heavy duty pavements. To ensure success the following conditions should be observed.

- Given the same loading on the pavement, the contact pressure between the particles in SMA is greater than in AC, so the possibility of abrasion increases. In the case of heavy duty pavements (industrial sites, heavily trafficked roads etc.) this requires a high quality aggregate (abrasion resistance, particle shape) and, as this effect is especially significant during compaction, the compaction procedure should be adapted (avoidance of over-rolling, no vibrating rolling).
- For heavy duty pavements it is not only the SMA that requires to be carefully designed; the layer thickness also needs careful selection. The applied layer thickness of SMA has a close relation to the aggregate size. The selection of the thickness is even more important if high contact pressures occur. The (nominal) layer thickness should be at least 2.2 x nominal aggregate size. For new construction maximum layer thicknesses have been reported to be between 20mm for a SMA 0/6, to 50mm for a SMA 0/16. For heavy duty pavements a reduction of at least 5mm is often applied to these figures.
- In the road sufficient friction between the surface layer and the second layer is required; no sliding plane should occur (which might be the case e.g. when applying a Stress Absorbing Membrane Interlayer [SAMI]).
- The failure risks related to overfilling the aggregate structure, insufficient stability of the aggregate structure or the large number of degrees of freedom for displacement of the aggregate particles can be reduced by using a binder with a relatively high viscosity at performance temperatures (e.g. a modified or multigrade type bitumen).

- The selection of the sand is a balance between stability and workability, and this also determines the percentage of crushed rock fines.

In cases where the intrinsic resistance to permanent deformation is not sufficient, an increase in resistance can be obtained by using a modified binder, though in Germany good results have been obtained with standard bitumen. In Table 3 the results of cyclic triaxial compression tests carried out on several surface course materials in The Netherlands are shown. (Tests carried out at 50°C, σ_v = 0.0 – 0.9 MPa, σ_h = 0.0 – 0.3 MPa, load (square wave form) 0.2 s, unload 0.8 s. Specimen size Ø100 mm, height 200 mm.) (For reference: even under the most severe traffic conditions porous asphalt pavements showed on average less than 0.2 mm rut increase per annum.)

Mixture	Slope of deformation curve, dε/dt	Relative improvement in resistance to permanent deformation
Asphalt concrete 0/16		
bitumen pen 45/60	0.12	Reference = 1.0
SMA 0/11		
bitumen pen 80/100	0.07 - 0.09	≅1.5
bitumen pen 45/60	0.03	4
modified binder	0.01 - 0.02	5 -10

Table 3: Deformation of several bituminous mixtures in the triaxial compression test

The effect of using a modified binder is also shown in Table 4, which gives results from the USA using the Couch Wheel Tracker at 55°C, (comparable to the Hamburg wheel track device, but with a solid rubber wheel), showing improvements by a factor 1.6 – 4.2 compared to SMA containing 60-pen bitumen.

The improvement is of the same order of magnitude as found in the triaxial tests.

Note 1: To obtain effective reduction in rutting, the underlying asphalt courses and the total construction must have sufficient resistance to deformation.

Note 2: In some countries modified binders are used for additional reasons: e.g. to reduce drainage; for additional increase in life span related to the pavement management policy, etc. In these cases the additional increase in rutting resistance can be seen as an extra advantage. See also Section 5.

Mixture type	Rutting rate, mm/h	Relative improvement in resistance to permanent deformation
SMA 0/12.5 – 60-pen (reference)	0.55	Reference = 1.0
Rubber modified binder	0.43	1.3
Polymer modification 1	0.34	1.6
Polymer modification 2	0.13	4.2

Table 4: Deformation of several SMA mixtures in the Couch Wheel Tracker test

In Annexe C the practice of using SMA in a number of EAPA member countries and in the USA is described. From this survey the following trends can be distinguished:

- All countries report very positive experience with SMA, especially its surface characteristics, durability and riding comfort. Its performance on heavy duty pavements is excellent and on lower volume roads the service life of SMA compares favourably. These excellent experiences are obtained when the technological requirements of SMA are fully met.
- The major SMA types used are 0/5, 0/6, 0/8 and 0/11, the latter for heavy duty and highway applications though sometimes 0/8 is chosen. There are national preferences due to the different aggregate grading used and as a result France uses BBM 0/6 and 0/10; Hungary, SMA 0/8 and 0/12; Portugal, SMA 0/9.5 and 0/12.5; and the UK SMA 0/6, 0/10 and 0/14. The Nordic countries use SMA 0/16 to withstand the heavy loading at industrial sites and to give increased resistance to studded tyres.
- Generally, crushed aggregates are recommended for both the coarse and fine mineral fractions though for the fine fractions partly uncrushed aggregate (natural sand) is sometimes used. For heavy duty applications there is a move towards higher quality aggregate: all crushed aggregates, only crushed rock, coarse aggregates with a lower flakiness index (e.g. USA: maximum elongation preferable 1:2 to 1:3).
- Bitumen B60 is generally used, however bitumen B80 is chosen for SMA 0/6 on lower volume roads. For heavy duty pavements harder grades of bitumen or modified bitumens are advised or required.

SMA type	V_s, (%)[a]
0/5-0/6	2 – 4
0/8	2 – 5
0/9.5-0/10	3 – 6
0/11-0/12	1 – 5
0/14	2 – 5
0/16	2 – 5

a.) Voids in the specimen

Table 5: Variation in the volumetric mixture design requirements

- The balanced technological concept of SMA requires that only virgin aggregate is used and that for all sizes a constant level of oversize and undersize is critical.
- For the mixture composition the allowed percentage of aggregate passing sieve 2 mm and binder contents vary according to Table 6. (Note: data "translated" to CEN-sieve series). The table summarises the ranges in target compositions, based on different experiences throughout Europe.

  Note: Controlling the grading viz. the "gap in the grading" could be improved by using control sieves at the lower and upper side of the gap. Viz. for SMA 0/8 that could be ISO-sieves 2.8 mm and 4.0 mm; for SMA 0/11, sieves 2.8 mm and 5.6 mm.
- The mixture design is generally based on the volumetric properties of impact compacted specimens (Marshall compaction). Denmark has requirements for VMA, VFB and Vs ("voids in the mineral aggregate", "voids filled with binder" and "voids in the specimen" respectively). Other countries have only specifications for Vs. The variation in the requirements for the latter are given in Table 5. It should be indicated that the basis for the voids calculation might be different for different countries.

SMA type	Percentage passing sieve 63 µm	Percentage passing sieve 2 mm	Binder content, % on 100% aggregate	Binder content, % "in" mixture
0/5-0/6	6 – 12	27 – 40	5.6 – 8.0	5.3 – 7.4
0/8	6 – 12	20 – 35	6.5 – 7.5	6.1 – 7.0
0/9.5-0/10	6 – 11	21 – 32	5.3 – 6.8	5.0 – 6.4
0/11-0/12	6 – 11	18 – 32	5.3 – 7.5	5.0 – 7.0
0/14	6 – 11	15 – 30	6.5	6.1
0/16	5 – 10	15 – 30	6.4	6.0

Table 6: Variation in mixture composition requirements

- The USA advises a maximum VCA ("Voids in the Coarse Aggregate"); this parameter (which is not yet quantified) fits well with the technological concept of SMA.
- Several countries have additional mechanical requirements, varying from Marshall properties (Norway) to (semi-) functional (France, Hungary).
- Advised layer thickness varies. General experience shows that Heavy Duty Pavement (HDP) applications require relatively thin layers.
- In general the requirements for the mixture in the road allow higher voids contents: generally between 6 and 12 %. Some countries require a specific degree of compaction (e.g. Norway, Netherlands: ≥98%). Comparison with these values is not possible at present due to the differences in establishing the reference density. It is expected that the new CEN standards will suggest the number of gyrations to use for compaction to compare with the Marshall Test.

The reasoning behind the differences between countries can be found in the climate and higher legal maximum axle weights, for instance in southern Europe 130kN versus 100kN in the northern part of Europe. In wet and cold regions a lower voids and higher bitumen content is used (often requiring both drainage inhibitor and modified bitumen), whilst in the drier and warmer regions the voids content is relatively higher and the binder content lower with a stiffer binder. Voids content ranges from 1% to 12% (for special mixtures). These percentages might be theoretical as voids below 3% are considered to be risky, due to potential problems with stability, and generally 6 – 8% after laying is considered to be 'normal'. Differences in aggregate grading are limited in Europe other than the very coarse SMA 0/16 mm laid in areas where studded tyres are used in Scandinavia.

SMA is a relatively new product in many countries, and continues to be developed across the world. Some of the areas of development are commented on in this section.

5.1. The European standardisation

Based on European experience to date, CEN TC 227/WG 1 "Bituminous Mixtures" is developing a product standard for SMA. A pre-CEN draft is expected to be available by the end of 1998, a short description of which is given in Annexe D.

The European standardisation process is a harmonisation of existing practices. New developments will be incorporated: a procedure based on rational performance related characteristics will be presented together with a procedure based on empirical performance related parameters.

5.2. Further product development in France

The French BBM mixture has been included within the SMA product group in this document as it is a further development of the concept. The principal differences are in deviating voids and binder content, deviating grading and specific pavement construction requirements. In addition specific experience with very thin layers has been reported on in France.

5.3. Drainage inhibitors

Due to the thick binder film required in SMA a drainage inhibitor is necessary. In general fibres are used, such as cellulose, rock wool and specific organic materials. Most drainage inhibitors are active during the storage, transport and laying of hot SMA; after compaction they should not influence the performance of the mixture. However, some proprietary inhibitors have been found to give improved resistance to plastic deformation at higher temperatures, reduced ageing of the bitumen, increased fatigue strength and further increases in durability giving longer service life. Fibres can be added loose or in pelletised form and can be blown into the mixture through a pipe to give better distribution and sometimes reduced mixing time.

The required amount of inhibitor is based on practical experience. However, in The Netherlands a test method for measuring the drainage inhibiting capacity of several materials has been developed and in Germany the Schellenberg test is used and has been found to give good results.

5.4. Modified binders

Modified binders are used for several reasons:

- to increase the resistance to permanent deformation
- to increase the life span of the pavement surface
- to reduce application and damage risks especially in cases of very thin layers
- to reduce the need for a drainage inhibitor (though this can still be necessary with some PMB's).

The potential advantages of using a modified binder in heavy duty pavements have already been discussed in section 3.

In Southern Europe there is a preference for using modified binders in SMA, especially in combination with relatively high voids content and low binder content. In some countries the use of a modified binder in SMA is mandatory; in others it is optional.

Modified binders include the following: polymer modified bitumen (such as EVA and SBS), and multiphalte-type bitumen.

Note: in practice a drainage inhibitor is necessary with higher binder contents, however with lower binder contents it might not be necessary if the appropriate modifier is used.

5.5. Mixture design

Starting from defined grading envelopes and binder limits, the mixture designer adjusts the required mixture composition to achieve the required volumetric properties. Specimens are generally prepared by impact compaction (Marshall hammer). However, a number of countries report that the impact compactor does not provide realistic specimen densities compared to those obtained in the road. In Denmark, USA, South Africa and The Netherlands it has been found that the slab compactor and/or the gyratory compactor give much more realistic density results.

The essential characteristics of the concept of SMA are the volumetric parameters: the quality of the mixture is essentially determined by the right volumetric proportion of the constituent materials viz. the right distribution of skeleton voids (VCA) and mastic portions. A higher voids content in the aggregate structure can be achieved by constructing a larger gap in the aggregate grading – lowering the grading curve at the lower end of the coarse aggregate section. This principle lies behind the development of 'Real SMA' i.e. in Sweden. 'Real SMA' is evidently also based on a self supporting stone skeleton of crushed high quality coarse aggregate. It is not acceptable for gradations to vary by more than 5% oversize and 15% undersize. In SMA 0/11, the 8/11 fraction is the dominant part by weight of the plus 2 mm aggregate (33-37% only passing the 8mm sieve); and the 2/5 fraction must be as small as possible, (only 19-23% passing the 2mm sieve), with 0.45% drainage inhibitor in pelletised form added by weight.

In The Netherlands a full volumetric mix design is being developed, based on the concept of 'under filling the coarse aggregate structure with mastic' and 'overfilling the fine aggregate with bitumen'.

The USA is carrying out research to implement SHRP findings for optimising SMA compositions. Using the Bending Beam Rheometer, and the Dynamic Shear Rheometer, the optimum mastic composition and constituent materials choice can be investigated.

5.6. SMA for binder and base courses

In Sweden SMA type mixtures are being developed for use in layers other than surface courses. There is currently some doubt as to the benefit that can be gained in these applications versus the additional cost. The main advantages of SMA are its high quality surface characteristics and durability in combination with its excellent resistance to permanent deformation and crack resistance. In binder and base courses surface characteristics are not relevant whilst high resistance to permanent deformation is. However, SMA will only give high deformation resistance when lateral support of the aggregate skeleton is given. This is only the case above the neutral line in the construction, and even then lateral support decreases with depth. The proposed mixture contains a high proportion of mastic (a relatively high binder content of appr. 5.0%) in combination with a reduced aggregate surface specification. This could result in the mixture having a low resistance to shear. The required performance of these layers can be more easily achieved using other asphalts, but SMA type mixtures could be used for stress absorption or crack reduction. These theoretical advantages need to be proved in practice.

6. Environmental benefits

SMA offers substantial environmental benefits to the road user, and to the community at large.

Both in the initial application, and in the long term, SMA has a lower requirement for aggregate, due to its thinner construction and its durability.

Its longer service life and lower maintenance needs provide a reduction in user delays and congestion (with their implications for higher levels of pollution). Furthermore, since the frequency of accidents is higher during maintenance operations, SMA is likely to prove to be a safer type of construction for both road user and maintenance operatives.

Safety is further improved by the nature of the SMA surface. In wet weather it can accommodate more water than many other surfaces, so the risk of aquaplaning is reduced. And because water is held within the material, rather than on the surface, there is less surface spray, and at night there is less glare reflected from the road surface and better visibility of road markings.

The even running surface, with its high resistance to rut formation, also contributes to safer driving, as well as improving ride comfort and thereby reducing driver fatigue. SMA surfaces also generally offer low levels of road noise, as shown in section 2.3 of this publication.

Recycling

SMA is 100% recyclable as asphalt, although the use of recycled material in SMA is not possible, due to the need for very accurate control of the grading, and the requirement to use high quality aggregate.

The initial material costs per tonne can be higher than those of standard AC due to the higher binder content, the need for high quality aggregates, the requirement for a drainage inhibitor and modified bitumen, and the reduced production capacity, if extra mixing time is required to incorporate the drainage inhibitor. Nevertheless, in practice SMA surfacing is found to be a cost effective answer when evaluated on the final life cycle cost of the pavement for the following reasons:

- SMA can be applied in thinner layers than AC. Where 35-50 mm AC is applied a 25-35 mm SMA can be used. This means that to maintain the same construction thickness a part of the AC surface course thickness can be replaced by less expensive binder or base course material. So the difference between construction prices will be less than expected when comparing the price of SMA and AC.
- Longer performance life than AC. Experience from Germany has shown that a performance life of 20 – 30 years is not exceptional, including its use on heavily trafficked roads.

  In 1997 the rut depth of nearly 450 km of the inside lane on German motorways in each of Bavaria, Baden-Wuerttemberg and Lower Saxony was investigated. The majority of these SMA stretches were built between 1987 and the mid 1990's and carry between 10,000 and 12,000 commercial vehicles per day. Despite the long and extremely hot summer of 1995, less than 10% showed rutting of greater than 6 mm, and under 1% showed rutting of more than 10mm.

  In The Netherlands where the average performance life of AC on highways is approximately 12 years, and for other main roads approximately 15-20 years, an extra performance life for SMA of 5 – 10 years (or more) is expected.
- The cost of maintenance of the surface course is lower for SMA than for AC because of SMA's higher resistance to ravelling, cracking and wear, giving longer service life.
- Due to the longer service life and reduced maintenance, the user delay costs are lower too. These costs can easily exceed the cost of the maintenance operations!
- SMA can be used in place of less durable materials. For instance SMA 0/6 is a very attractive alternative to surface dressing.

Individual projects should be evaluated to validate these advantages, but that is outside the scope of this report. An impression of the potential advantages of SMA can be gained by a simplified approach based on initial product costs.

The theoretically required life span for SMA to obtain equal annual capital costs for SMA and AC surfacing at 5% interest level, is 25% longer, assuming the price of SMA laid as 120% of the price of AC per m^2.

Given that a life span increase of at least 5 – 10 years can be obtained, and that additional advantages covered earlier are gained, it is clear that the choice of SMA can be a good investment!

8. Conclusions

SMA is a bituminous mixture that provides a number of advántages compared to other materials, specifically in the areas of surface performance, durability, environmental and whole life costs.

SMA has been successfully applied on heavy duty pavements, lower volume roads, racing circuits, bicycle tracks etc. In all these fields the main advantages are proven:

- high resistance to permanent deformation
- high resistance to wear by traffic and climatic changes
- superb riding characteristics (evenness, smoothness, skid resistance)
- under specific conditions SMA also provides a lower noise level than alternative materials.

SMA's longer service life gives it a better return on investment than most alternative materials even though the initial costs may be higher.

The limited differences in specification across Europe are a result of different climatic conditions, or legal maximum axle loads, and relate to voids, binder content and binder stiffness. In wet and cold regions a lower void content and higher bitumen content is used whilst in drier and warmer regions the void content is generally higher and the binder content lower with a stiffer binder. However, aggregate grading remains fairly consistent other than in exceptional cases such as the resistance to studded tyres.

To gain the maximum benefit from SMA it is important to ensure that the mixture is well designed and a high standard of production and laying is maintained. Then an economic and environmentally attractive solution will be obtained!!

Longer road life, thinner construction (less use of aggregate) and reduced noise levels impart sustainable environmental benefits.

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A. The volumetric characteristics of SMA

B. Production and laying

C. Practical experience in individual countries

1. Czech Republic
2. Denmark
3. France
4. Germany
5. Hungary
6. Italy
7. The Netherlands
8. Norway
9. Portugal
10. Sweden
11. United Kingdom
12. USA

D. The European Draft Standard for SMA

E. Bibliography/Abbreviations

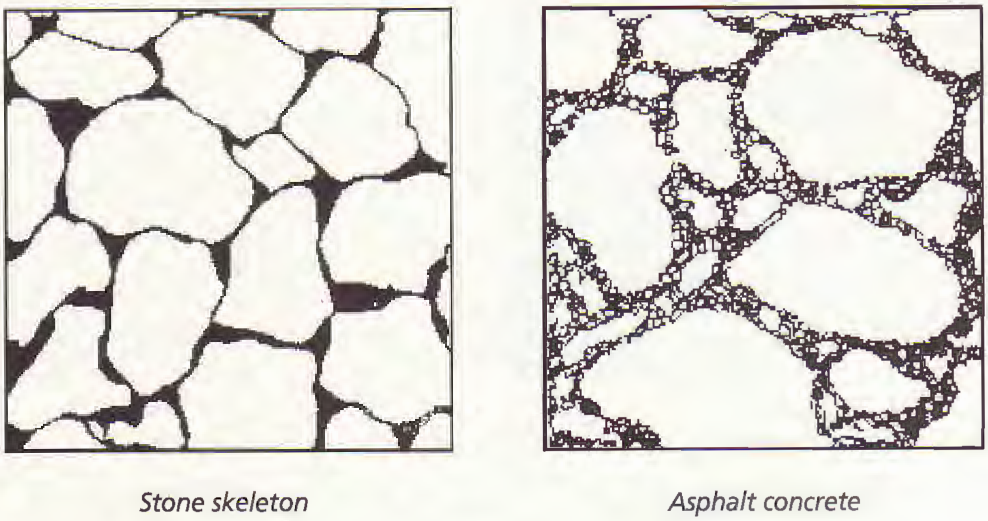


Figure 1

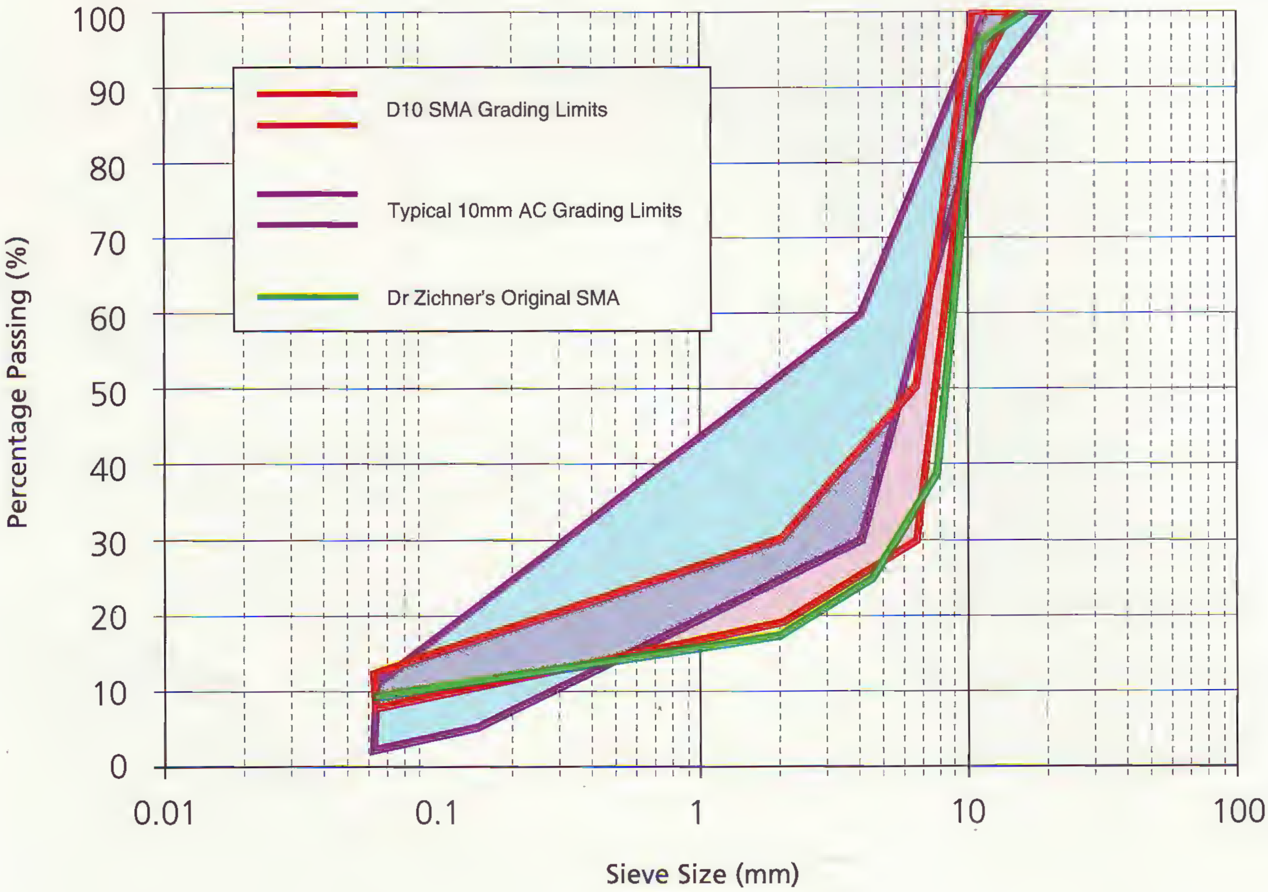


Figure 2

The specific qualities of SMA can best be understood by looking at the volumetrics of the mixture.

SMA is a gap graded bituminous mixture with an aggregate skeleton, formed by relatively coarse aggregate particles, which is filled by a mastic of bitumen, filler and fine aggregate (sand), see figure 1. Depending on the type of SMA the structure is built on aggregate with size 2-6 mm; 4-8 mm; 6-11 mm or 8-16 mm. The mastic is a filler-sand mixture which is overfilled with binder hence the need for a drainage inhibitor (see Annexe B). The remaining void content in the final SMA mixture generally lies between 3 and 6% (by volume).

In continuously graded mixtures such as AC the fine aggregate forms part of the aggregate structure. The remaining voids in such a structure are filled with a mortar, made up of very fine aggregate/filler and binder. To obtain a workable and durable AC mixture a kind of "gap" must exist. Generally this gap lies somewhere between 200 and 500µm. The main aggregate structure is built by the aggregate which is larger than 500 µm/1 mm.

The principal difference between SMA and (continuously graded) asphalt concrete mixtures is that the gap in the grading curve is higher and wider, resulting in a significantly larger voids level in the aggregate structure. The gap approximately exists between 1 and 2 mm (SMA 0/6), 2 and 4 mm (SMA 0/8), 3 and 6 mm (SMA 0/11) or 3 and 8 mm (SMA 0/16). The coarse aggregate provides the structure, the fine aggregate is part of the mastic and has in principle no role in building the aggregate structure. See figure 2 for a comparison of the grading curves of asphalt concrete and SMA.

From the volumetric point of view SMA is similar to porous asphalt which also consists of an aggregate structure built by coarse aggregate. In porous asphalt however the voids are only filled with a mastic to such a level that a voids content of approximately 20% remains in the mixture; in the SMA aggregate structure the voids are filled to such a level that the remaining voids content in the asphalt mixture is approximately 3-6%.

The volume of voids in the compacted coarse aggregate should be greater than the mastic volume.

A consequence of the volumetric concept of SMA is that the number of contact points between the structural aggregate particles is limited (compared to AC).

This has the following consequences:

- To obtain a stable aggregate structure the aggregate quality must be sufficiently high especially with regard to particle shape, viz. a low flakiness (see figure 3.a) and a high surface texture (see figure 3.b).
- Due to the large number of degrees of freedom for aggregate particle displacement, sufficient lateral support is required to provide the internal stability of SMA. This mechanism is significant both in the road and when testing. Tests without lateral support (as e.g. Marshall, uniaxial compression, bending tests, indirect tensile tests etc.) executed at relatively high temperatures are not suitable for this mixture, and wheel tracking and triaxial compression tests are recommended. In the case of heavy (static/concentrated) loading on the pavement the layer thickness must not be too large, see figure 4.
- Excess of mortar through insufficient drainage inhibition may lead to fat spots in the road surface with a resulting loss of friction.

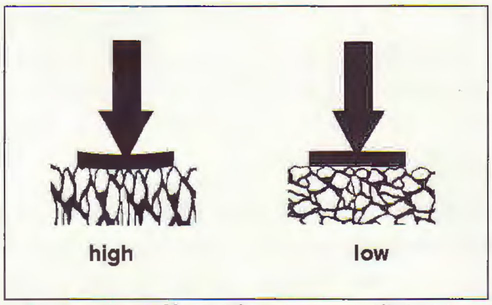


Figure 3a. Effect of aggregate flakiness

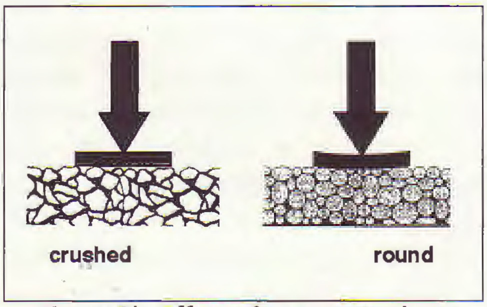


Figure 3b. Effect of aggregate shape

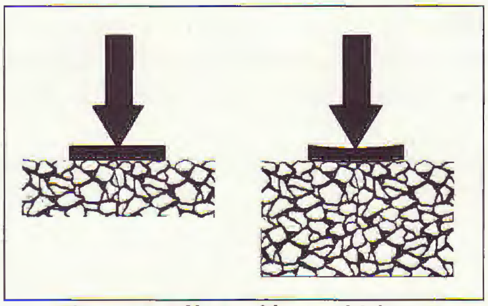


Figure 4. Effect of layer thickness

SMA is produced and laid with standard equipment for hot mixed asphalt. However, both the production and laying processes for SMA require specific care.

Batch plants and drum mixers can be used provided adequate attention is paid to aggregate supply control. As its specific performance is based on a strong gap graded aggregate composition, variations in the proportion of the "structural" and "filling" aggregate (viz. in the proportion coarse-fine aggregate) have an almost linear effect on the voids in the mixture. In principle this requires accurate control (consistency) of the amount of material passing/remaining on the sieves at the upper and lower side of the gap viz. a limited variation in the difference between the amounts of material on those sieves. In practice this means that the voids in SMA vary linearly with variation in the proportion of aggregate on the 2mm sieve (whereas the voids in AC show a more limited effect of variation on this sieve). This requires a well controlled production operation viz. the use of constituent aggregates with very limited grading variation. SMA is very sensitive to overfilling of the aggregate structure with mastic. When such an overfill does occur, the mastic bears the loading. As an unmodified mastic has almost no deformation resistance this will result in a collapse of the aggregate structure leading to premature rutting.

Because of the rich mastic and the relatively low aggregate surface area the mastic may drain from the aggregate at low binder viscosity (at high mixture temperature, during storage, hauling and laying). For this reason the viscosity of the mastic has to be increased and a drainage inhibitor, generally cellulose or other fibres, is normally incorporated. However, for thinner layers, heavy duty pavements and in Southern Europe, the use of modified bitumens at relatively low binder content, or a combination of modified bitumen and fibre, is preferred. After laying most drainage inhibitors have little significant effect (except modified binders). However they must be mixed sufficiently to prevent concentrations of fibres in the pavement.

The addition of the fibres can take place in several ways. Mechanical methods, which are preferred as they are not prone to operator error, incorporate loose or pelletized fibre.

If difficulty is found in achieving the correct air voids the following rule of thumb is recommended (SMA 0/11):

- To increase air voids, decrease the 4-8 mm material and increase the coarse fraction by the same amount. Do not change the fines.
- To reduce air voids, increase the 4-8 mm material and decrease the coarse fraction. Do not change the fines.

Laying by paver and compaction of SMA are relatively easy. Due to the strong aggregate structure, the contribution of the roller to the final compaction is limited. That means that the initial high evenness obtained by the paver will stay intact. The high precompaction achieved by the paver is useful.

Thin layer application rolling requires specific attention, especially on a cold substrate when cooling will be rapid and early compaction essential. However too heavy rolling (e.g. with rollers which provide a high pressure, vibratory rollers etc.) may introduce extensive aggregate crushing. In general a roller factor (calculated as P/LD^2, where P = wheel load, L = wheel length and D = wheel diameter *per wheel*) of approximately 22 is advised; however for less stable or "softer" mixtures a lower factor may be required.

Due to the high internal cohesion of the mixture (provided by the high binder content, reinforced by applying a binder with increased viscosity) laying by hand is not recommended as it is difficult to obtain the optimum evenness, durability and density of the mixture. For best results the layout of the site should allow paver laying for all trafficked areas.

1. CZECH REPUBLIC

C 1.1. Application

Since 1991 the scope of application and popularity of SMA has been growing. In 1995, 230,000 tonnes were produced, equivalent to about 2.5million m^2.

The following types are mainly used: AKMS (SMA 0/11), AKMJ (SMA 0/8) and exceptionally AKMH (SMA 0/16).

C 1.2. Requirements

Czech Standard ÈSN 73 6121 (1994)
Types and required composition: (see table below)

C 1.3. Specific material requirements:

- Filler : Limestone
- Drainage inhibitor: Cellulose fibres or granules (0.3%); effectiveness checked by Schellenberg test
- Aggregate: Coarse crushed aggregate with a perfect shape index, LA ≤ 20%, PSV < 0.55

C 1.4. Mixture design:

A two-step mixture design procedure is recommended:

1st step: optimisation of composition of the aggregate mixture to ensure a strong aggregate structure in the compacted material. Usually 4 to 5 mixtures are prepared with different coarse crushed aggregate content. The optimum composition of the aggregate mixture is usually characterised by a sudden change in the volume relationships during a Marshall test..

2nd step: verification of mixture properties by the Marshall test performed on specimens with (usually 3) different asphalt contents.

The job mixture formula must be verified by rutting tests on plates or rotating Marshall specimens. The method is under revision at present. Dynamic test with NAT apparatus (Nottingham Asphalt Tester) was also found to be useful.

SMA Mineral aggregate	AKMS (SMA 0/11) Crushed aggregate[a]	AKMJ (SMA 0/8) Crushed aggregate[a]
% (mm) passing:		
< 0.009 mm	10 – 13	10 – 13
< 2.0 mm	20 – 26	22 – 30
< 4.0 mm	26 – 38	28 – 42
< 8.0 mm	45 – 60	90 – 100
<11.0 mm	90 – 100	100
Binder type	AP-65 PmB 45, (PmB 65)	AP-65 PmB 45, PmB 65
Binder content, % [bcd]	6.5 – 7.0 (7.0 – 7.5)	6.8 – 7.2 (7.3 – 7.8)
Marshall test [efg]		
Stability	≥ 6kN	≥ 6kN
Voids % vol.		
2 x 50 blows	3.0 – 4.5	3.0 – 4.5
2 x 100 blows	2.5	2.5
Layer		
Thickness (mm)	34 – 45	(25) 30 – 40
Degree of compaction	min 97%	min 97%
Voids content, %	3.0 – 6.0 (7.0)	3.0 – 6.0 (7.0)

a) Crushed aggregate with good adhesion to bitumen used
b) In the case of modified binder the lower limit can be decreased by no more than 0.3%
c) Binder content "in" mixture. In brackets: binder content "on" 100% aggregate
d) Addition of modifying agents into mixer also led to successful products
e) In mixture design and during production the resistance against rutting must be checked
f) Compaction temperature depends on the type of bitumen used (usually 140 – 150°C)
g) Calculation of a voids content is based on the "bulk" density of an uncompacted mixture, determined using solvent

C 1.5. Production and laying

SMA is produced in batch asphalt plants with manual or automatic dosing of the drainage inhibitor. Extra care must be taken when adjusting dry and wet mixing time. Attention should be also given to precise grading of the aggregate ("sharp fractions") and dosing of aggregate components. The deviation from design composition of the aggregate mixture must be smaller than that in mixtures of asphalt concrete.

Laying with modern pavers has achieved good surface evenness without segregation. Two stage compaction is preferred. After the first compaction, the asphalt mixture of aggregate 2/4 with bitumen (1-2 kg/m²) is applied on the surface. Compaction is done by heavy or vibratory rollers. However, vibratory rollers are normally used only the 1st stage compaction with low amplitude of vibration and a limited number of runs (about 2).

C 1.6. Problems with SMA

- Variation of voids content due to the high sensitivity of SMA to deviation from the design aggregate grading.
- Difficult compaction of mixtures, especially those with modified binder, and therefore difficulties in achieving the optimum voids content after compaction (3.5 – 5.5% vol.).
- Sensitivity to the type and quality of the underlying binder course. The most suitable appears to be asphalt concrete dense graded mixtures 0-22 and 0-16, having voids content of 4.5 – 6.0 %.

- Low voids content (about 2%) results in decreased skid resistance.
- Difficult laboratory assessment of resistance to permanent deformation.

C 1.7. Conclusion

Considering mixture design, verification of design properties and mixture production, SMA cannot be held as a simple technology. However, if properly designed, produced and laid, SMA provides an even, rugous and durable surface with a high resistance to rutting. Current experience with SMA indicates increasing use of this technology in the Czech Republic.

2. DENMARK

C 2.1. Application

Since 1982. Wearing course used on high volume roads carrying a high proportion of heavy vehicles, industrial areas, airfields and other areas with heavy loading.

SMA 11 (SMA 0/11) is the standard material whilst for extremely heavy loading SMA 16 (SMA 0/16) is sometimes used. SMA 8 (SMA 0/8) is used when a thinner layer is preferred.

C 2.2. Requirements

Types and specific composition: (see table below)

Grading	% passing, m/m		
	SMA 8	SMA 11	SMA 16
16.0 mm	–	–	> 90
11.2 mm	–	> 90	< 90
8.0 mm	> 90	< 90	–
5.6 mm	90	30-50	24-45
2.0 mm	21-35	18-30	15-25
0.074 mm	> 4	> 4	> 4

C 2.3. Specific material requirements

Bitumen: B60 or PmB (B85 optional for low volume roads only).

Mineral aggregates: 100% crushed materials. Crushed gravel is only permitted in the fine fraction.

C 2.4. Mixture design requirements

Volumetric properties (Marshall 2x50 blows):

VMA: >16.0%

VFB: 78 - 93%

Voids in specimen (V_S): 1.5 - 4.0%

C 2.5. Construction (see table below)

Type	SMA 8	SMA 11	SMA 16
Layer thickness; mm	20-30	30-40	40-50
Voids, %(v/v)			
Average	< 6.0	< 6.0	< 6.0
Tolerance [a]	< 8.0	< 7.0	< 7.0
Compaction, %			
Average	> 97.0	> 97.0	> 97.0
Tolerance [b]	> 95.0	> 95.0	> 95.0

a.) Tolerance = $A + t.s / \sqrt{n}$

b.) Tolerance = $A - t.s / \sqrt{n}$

where: A = Average

s = standard deviation

n = Sample size

t = Statistic number

For α = 0.10 (single side):

n = 6 9 12

t = 1.48 1.40 1.36

C 2.6. Performance

In Denmark SMA is designed with a low air void content and is expected to have at least a 30% increase in service life compared to regular dense graded AC.

The experience with SMA is very good. Stripping and rutting problems have only been observed on a few occasions. If air voids are too high (e.g. in areas of hand work), there may be a risk of premature stripping, and if the proportion of fine aggregates is too high rutting may develop.

Significant amounts of SMA have been used at Copenhagen Airport.

3. FRANCE

Although some SMA is applied in France, the preferred material is a type of bituminous mixture very similar to SMA: "Béton Bitumineux Mince" (BBM). Both mixtures are gap-graded; however they differ on a number of principal technological points:

- The amount of mastic in BBM is lower than that in SMA: minus 3-5% fines, minus 0.5-1.3% binder. For this reason a drainage inhibitor is not necessary for BBM.
- The voids content of BBM in the road is approximately 6-12%. Therefore BBM is permeable to water: the impermeability of the construction must be obtained by applying a thick tack coat, generally of modified binder.

Due to the high voids content, BBM is very rugous; no special measures to assure a high skid resistance are necessary.

Two types of BBM: BBM 0/6 and BBM 0/10.

C 3.1. Application

Since 1986. Due to its thin layer possibilities, high performance quality (high evenness, high rugosity, high durability etc.) BBM is very popular for highways.

Because of the very thin layer application large areas can be covered within a short time. As a result BBM is very suitable for surface maintenance on heavily trafficked roads.

C 3.2. Requirements

NF P 98 137/132

Types and specific composition:

Type	BBM 0/10			BBM 0/6
Mineral aggregate, % passing	a	b	c	
80 µm	8	11	8	8
2.0 mm	35	38	38	38
4 mm	–	53	53	53
6.3 mm	35	53	53	97
10 mm	97	97	97	–
Binder content [a]	> 5.6 (5.3) %			

a.) Binder content on 100% aggregate.
In brackets: binder content "in mixture" = (binder content on 100% aggregate) : (1.00 + 0.01 x binder content on 100% aggregate)

C 3.3. Specific material requirements

- Aggregate: All crushed
- Binder: unmodified or modified

C 3.4. Mixture design requirements

BBM 0/10	Type a1	Type a2	Type a3
Compression/ immersion ratio	> 0.8		
Rutting	–	≤15% 3000 cycles	≤15% 10,000 cycles
Complex modulus	–	≥5400 Mpa	
Fatigue	–	≥100/10^{-6}	

Type a1 is used for lightly trafficked roads; types a2 and a3 for other roads

C 3.5. Construction

- Layer thickness: 30-40 mm
- Voids at 40 mm layer thickness: 6-12%(v/v)
- Texture (sand patch): > 0.6 mm

C 3.6. Performance

BBM provides an excellent surface performance – rugous, even, durable etc....

4. GERMANY

Inf.: European Asphalt Magazine 3/96

C 4.1. Application

Since 1965-1970. Four types: 0/8, 0/5 and 0/11S, 0/8S for Heavy Duty Pavements.

C 4.2. Requirements

"Empfehlungen für die Zusammensetzung, die Herstellung und den Einbau von Splittmastixasphalt", FGSV 1996 (incorporated in the National Standard ZTV Asphalt-StB, 1998).

Types and required compositions: (see table below)

C 4.3. Specific material requirements

- High quality chippings only.
- Requirements for drainage inhibitor, drainage test for mixture.
- Drainage inhibitor 0.3 – 1.5 %(m/m), depending on type; cellulose fibres generally 0.3% depending on binder content.

C 4.4. Type testing procedure

Marshall specimen

C 4.5. Specific production & application requirements:

- Maximum temperature at production is 180°C with a minimum laying temperature of 150°C.
- Pneumatic rollers not permitted; great care should be taken with vibratory rollers.
- Blinding/gritting necessary for early life skid resistance.

C 4.6. Performance in practice

A growing use for various applications (including most heavily trafficked areas) is expected. SMA is already the most commonly used type of asphalt mix on German motorways.

SMA	0/11S[a]	0/8S[a]	0/8	0/5
Mineral aggregate %(m/m)	Crushed aggregate, crushed sand, manufactured filler		Crushed aggregate, crushed & natural sand, manufactured filler	
< 90 µm	9-13	10-13	8-13	8-13
> 2.0 mm	75-80	75-80	70-80	60-70
> 5.0 mm	60-70	55-70	45-70	≤ 10
> 8.0 mm	≥ 40	≤ 10	≤ 10	–
> 11.2 mm	≤ 10	–	–	–
Binder type	B 65 (PmB 45)	B 65 (PmB 45)	B 80	B 80 (B 200)
Binder content [b]	≥ 6.5 (6.95)	≥ 7.0 (7.53)	≥ 7.0 (7.53)	≥ 7.2 (7.76)
Type testing requirement (Marshall specimen): voids content, % (v/v)	3.0-4.0	3.0-4.0	2.0-4.0	2.0-4.0
Layer thickness, mm	35-40	30-40	20-40	15-30

a.) S: Heavy Duty Pavements. The ratio of crushed sand versus normal sand is 1:0

b.) Binder content in mixture. In brackets: binder content on 100% aggregate =100 : (100 – binder content in mixture) x (binder content in 100% mixture)

5. HUNGARY

C 5.1. Application

Since 1983; since 1992 approximately 120 km motorways

C 5.2. Requirements

Útépítési aszfaltalapok és-burkolatok", ÚT 2-3.302 (national standard)
Types and required composition: (see table below)

	ZMA-8	ZMA-12
Mineral aggregate	Crushed rock, crushed sand and manufactured filler	
Passing sieve:	% (m/m)	% (m/m)
0.09 mm	8 - 13	8 - 13
0.20 mm	11 - 18	11 - 18
0.63 mm	14 - 24	14 - 24
2.00 mm	20 - 30	20 - 30
5.00 mm	30 - 50	30 - 53
8.00 mm	90 - 100	50 - 70
12.50 mm	100	90 - 100
16.00 mm	–	100
Binder type	B - 50, B - 65, PmB - 80A, PmB - 80B	
Binder content, %[a]	6.5 - 7.5 (6.1 - 7.0)	6.0 - 7.5 (5.66 - 7.0)
Filler content	8	8
Voids content Marshall, %	2.5 - 4.5	3.0 - 4.5
Wheel tracking test: LCPC method: ε (%), max	15	15 (10)[b]
Dynamic creep: N_k/ε_k, min	4000	4000
Layer thickness (mm)	25 – 30	30 – 50

a.) binder content on 100% aggregate.
In brackets; binder content "in" mixture.
b.) when polymer modified binder is used.

C 5.3. Specific materials requirements

- Filler: limestone
- Drainage inhibitor: cellulose fibres

C 5.4. Mixture design procedure

Modified Marshall procedure

6. ITALY

Italy has two types of SMA: SMA 0/10 and SMA 0/15

C 6.1. Application

Since 1991. Wearing course used on high volume roads.

C 6.2. Requirements

"Norme Technique d'Appalto" Autovie Veneta S.p.a. – Motorway A4 "Venezia – Trieste"

Types and specifications (see Table C 6.1 below)

C 6.3. Specific materials requirements

Mineral aggregates: 100% crushed, high quality chippings only.

Binder: (see Table C 6.2)

C 6.4. Mixture design requirements

Marshall: - Stability: ≥ 13,000 N

- Stiffness: ≥ 2000 N/mm

Indirect tensile stiffness: ≥ 0.80 N/mm²

Indentation test (DIN 1996): ≤ 1 mm

Passing sieve (%)	SMA 0/10	SMA 0/15
15 mm	100	80 – 100
10 mm	80 – 100	46 – 66
5 mm	47 – 64	30 – 44
2 mm	30 – 45	20 – 36
420 µm	12 – 20	10 – 17
180 µm	10 – 16	9 – 15
75 µm	9 – 14	8 – 13
Binder type	PmB 50	
Binder content, %[a]	5.5 – 7.0 (5.2 – 6.55)	5.5 – 7.0 (5.2 – 6.55)
Voids content, %	1.0 – 4.0	1.0 – 4.0
Layer thickness, mm	20 – 30	40 – 50

a.) binder content on 100% aggregate.
In brackets; binder content "in" mixture

Table C 6.1. Composition requirements

		Original binder	After TFOT
Penetration (25 °C) x 0.1 mm		45 – 55	≥30
$T_{R\&B}$	°C	75 – 85	≤10[a]
Penetration Index		+1/+5	
Dynamic viscosity at 80 °C Brookfield @ SPDL 0.7, RPM 0.5	Pa.s	800 – 2000	≥2000
Tube test	°C	ΔT ≤ 3.0	

a.) $\Delta T_{R\&B}$

Table C 6.2. Requirements for binders used in Stone Mastic Asphalt

7.THE NETHERLANDS

C 7.1. Application

Since 1987. Annual quantity (1996, estimated): 0.6 million tonnes which equates with 8% of total production; 20% of surface course material (PA 25%, AC 40%).

C 7.2. Requirements

RAW-Standaard 1995 (national "standard")

Types and required compositions: (see Table below)

C 7.3. Specific material requirements

- Filler: limestone
- Drainage inhibitor: a special test method to establish the performance of drainage inhibitors was introduced in 1995. For cellulose fibres approximately 0.3% is added to the mixture. Other inhibitors are allowed with proven effectiveness.
- (Very) high traffic loading/high contact pressures: the use of crushed rock and modified binder is advised.

C 7.4. Type testing procedure

Dutch testing procedures deviate from the German approach. Marshall specimens are prepared at four levels of aggregate content on sieve 2 mm (4 specimens each). The mastic composition is adapted in such a way that the sand/filler ratio is constant at all coarse aggregate levels. In this way the viscosity of the mastic is kept (almost) constant. The aggregate content at which the voids level is 4.0% (0/11 type 2: 5.0%) gives the mixture formula.

Note 1: Due to the required test method for the bulk density (Bulk Density-SSD) in combination with the relatively large pores, the real voids content is higher than established by the required test method. Following the test method "Bulk Density by Measurement" the real voids content lies between 6.0 and 8.0%. This means that SMA is not water-tight.

Note 2: To allow a larger variation of aggregate/filler choice viz. to increase the SMA quality management a volumetric design procedure is being developed.

SMA	0/11 Type 2[a]	0/11 type 1	0/8	0/6
Mineral aggregate %(m/m)	Crushed aggregate, crushed sand, manufactured filler		Crushed aggregate, crushed & natural sand, manufactured filler	
< 63 µm	6-10	7-11	8-12	9.5-13.5
> 2.0 mm	72.5-82.5	70-80	67.5-77.5	62.5-72.5
> 5.6 mm	60-75	55-70	40-60	≤ 6
> 8.0 mm	40-55	35-50	≤ 6	–
> 11.2 mm	≤ 6	≤ 6	–	–
Binder type	B 80	B 80	B 80	B 80
Binder content [b]	7.0 (6.54)	7.0 (6.54)	7.4 (6.89)	8.0 (7.41)
Type testing requirement (Marshall specimen): voids content, % (v/v)	5.0	4.0	4.0	4.0
Layer thickness, mm	35	30-40	20-30	15-20

a.) Type 2: Heavy loading.

b.) Binder content on 100% aggregate. In brackets: binder content "in mixture" = (binder content on 100% aggregate) : (1.00 + 0.01 x binder content on 100% aggregate).

C 7.5. Performance in practice

- Application areas:

– 0/11 type 2: Extreme heavy loading (high number of slow driving trucks with high axle loads/high contact pressure tyre-pavement; harbour areas etc.). It is accepted that due to the high voids content the lifetime of this mixture is limited. The use of crushed rock and only crushed sand is advised; use of modified binder is optional.

– 0/11 type 1: General application on motorways, airfields etc. (Note: on highways PA is the standard material for surface courses, so this type is not used very much). Less suitable for turning traffic.

– 0/8: General application on motorways (speed limit 80 km/h), city roads, industrial areas etc. For heavy trafficked areas the use of crushed rock is advised; for very heavy loading/turning traffic also modified binder.

– 0/6: Thin layer application. Used for city roads and light trafficked rural roads.

- Performance:

SMA provides a very durable, even and rugous surface when applied properly. Problems did occur when:

– The gap between fine and coarse aggregate was too small. This occured in the beginning of standardisation when the aggregate grading was less steep in the specifications. Recently it occurred when during production the grading requirements were not kept. As a result rutting occurred on heavily trafficked roads.

– The layer thickness was too large (0/6: > 20 mm; 0/8: > 30 mm; 0/11: > 40 mm); problems on heavy trafficked roads (high contact pressure).

– Turning traffic. This problem occurs when SMA is freshly laid – first 24-72 hours and extreme turning (power steering/trucks, road crossings/turning heavy traffic, industrial floors, airports). Practical solution: apply some sand during first use.

- Noise:

Limited tests show noise level approximately 1-3 dB(A) below AC. Extended measurement programme is going on.

A very popular material for replacing surface dressings.

C 7.6. Specific production & application requirements

– SMA is produced with standard equipment. The grading control requires extra attention, see C 7.2. Due to difficulty, in controlling aggregate grading in hot silos, the production of SMA (0/8) in a tower plant requires extra attention viz. maximum quality management (larger variation in grading distribution within silos viz. within sieve sizes).

– The drainage inhibitor (generally cellulose fibres) was originally applied by hand; the number of plants equipped with an automated dosing device is increasing where fibres in pelletised form are used.

– SMA is also laid with standard equipment. The first compaction is obtained with steel rollers having a relatively low contact pressure (roller factor $P/LD^2 < 20$). The final compaction is obtained with steel rollers having a roller factor $P/LD^2 > 20$. Due to the high internal cohesion (high binder content of relatively high viscosity/thick binder film) laying by hand should be avoided.

8. NORWAY

Norway has two types of SMA: SKA 11 and SKA 16

C 8.1. Application

Since 1985. Wearing course used on high volume roads (ADT > 5000), industrial areas, airfields and other areas with heavy loading. SKA 16 is more used than SKA 11 (approx. 70% versus approx. 30%) because of its higher resistance to wear by studded tyres.

C 8.2. Requirements

The grading of the aggregate shall be within the limits given in Table C 8.1 taking care that the requirements of Marshall Test results, given in Table C 8.2, are fulfilled. The binder content shall be as high as possible and recommended values are given in Table C 8.4. When designing the binder content the requirement of the Marshall Stability should be carefully considered.

C 8.3. Specific materials requirements

The properties of the materials used in Stone Mastic Asphalt (SKA) shall comply with the requirements given in Table C 8.3.

C 8.4. Mixture design

The mixture design requirements are given in tables C 8.2 and C 8.4.

C 8.5. Production and laying

After laying the binder content and the aggregate grading of the mixture shall be in compliance with the job mixture formula and within the tolerances given in Table C 8.5 and C 8.6.

Passing sieve	SKA 11	SKA 16
22.4mm	–	100
16.0mm	100	80 - 100
11.2mm	80 - 100	46 - 66
8.0mm	47 - 64	30 - 44
4.0mm	30 - 45	20 - 36
2.0mm	20 - 32	15 - 30
1.0mm	16 - 27	12 - 24
500 µm	14 - 24	11 - 21
250 µm	12 - 20	10 - 17
125 µm	10 - 16	9 - 15
75 µm	9 - 14	8 - 13

Table C 8.1. Grading requirements

	Annual Daily Traffic (ADT)	
	ADT < 15000	ADT ≥ 15000
Number of blows	2 x 75	2 x 75
Stability (N)	≥ 4500	≥ 6000
Flow Value (mm)	1.5 – 4.6	1.5 – 4.0
Stiffness (N/mm)	≥ 1600	≥ 2300
Air voids (%)	1 – 5	2 – 5
Bitumen filled voids (%)	70 – 90	70 – 85

Table C 8.2. Mixture design requirements, Marshall Test

Property	Annual Daily Traffic (ADT)		
	3000	5000	15000
Class of Aggregate	1 – 2	1 – 2	1
Flakiness Index > 11.2 mm	≤ 1.45	≤ 1.45	≤ 1.45
Abrasion Value	≤ 0.55	≤ 0.45	≤ 0.40
Abrasion Value x √ Impact Value	≤ 3.0	≤ 2.5	≤ 2.0
% Crushed Particles (Particles > 4 mm)	≥ 80	≥ 100	≥ 100
Type of Binder	B 80 – B 180	B 60 – B 85 PmB	B 40 – B 85 PmB
Stabilising Agent (Weight % of Binder)	4 – 10		

Table C 8.3. Requirements for materials used in Stone Mastic Asphalt

Stone Mastic Asphalt (SKA)	SKA 11	SKA 16
binder content	6.3	6.0

Table C 8.4. Recommended binder content (weight %)

	Tolerances (weight %)			
Mixtures with maximum nominal size	One sample	2 samples	5 samples	10 samples
> 16 mm	± 0.60	± 0.45	± 0.30	± 0.20
≤ 16 mm	± 0.40	± 0.30	± 0.20	± 0.15

Table C 8.5. Tolerances from job mixture formula – binder content (average of samples)

Tolerances (weight %)				
Sieve size	One sample	2 samples	5 samples	10 samples
≥ 2 mm	± 6.0	± 5.0	± 4.0	± 3.0
1 mm	± 4.0	± 3.5	± 3.0	± 2.5
500 μm	± 4.0	± 3.5	± 3.0	± 2.5
250 μm	± 4.0	± 3.5	± 3.0	± 2.5
125 μm	± 3.0	± 2.5	± 2.0	± 1.7
75 μm	± 2.0	± 1.7	± 1.4	± 1.2

Table C 8.6. Tolerances from job mixture formula – grading (average of samples)

C 8.5. Production and laying (continued)

The temperature during production and laying shall be within the limits given in Table C 8.7.

After compaction the void content and the degree of compaction shall be within the limits given in Table C 8.8.

C 8.6. Performance

Experience with Stone Mastic Asphalt is very good. SMA has a very good resistance to wear by studded tyres and has no problems with rutting due to plastic deformation.

Type of Mixing plant	Grade of binder			
	B 40	B 60	B 85	B 180
Batch Plants Production temperature Laying temperature	 180 – 205 ≥ 165	 170 – 190 ≥ 155	 160 – 175 ≥ 145	 150 – 160 ≥ 135
Drum Mix Plants Production temperature Laying temperature		 150 – 170 ≥ 140	 140 – 160 ≥ 130	 130 – 150 ≥ 120

Table C 8.7. Mixing temperature requirements (°C)

Bituminous layers with thickness ≥80 kg/m²	Voids (Vol %)			Degree of compaction (%)
		Average of samples		
	One sample	5 samples	10 samples	
Wearing course Binder course	2 – 5 2 – 7	2 – 5 2 – 7	2 – 5 2 – 7	≥ 98 ≥ 98

Table C 8.8. Requirements for compaction

9. PORTUGAL

Two types of bituminous mixtures comparable to SMA can be distinguished:

- "Betão Betuminoso Rugoso" (0/12.5)
- "Microbetão Rugoso" (0/9.5)

C 9.1. Application

Since 1994. Application areas: Motorways and main roads.

C 9.2. Requirements

Specifications are given in:

"JAE / NORMAS PROJECTO (DSAT)"

"APORBET / PARTE 1 – Materiais e Misturas Betuminosas"

Types And Required Compositions:

SMA Types	0/12.5	0/9.5
Mineral Aggregate	Crushed coarse & fine aggregate, manufactured filler	
(%m/m)		
≥ 75 µm	6 - 10	7 - 12
≥ 2.0mm	70 - 78	68 - 78
≥ 4.75mm	58 - 68	58 - 70
≥ 9.5mm	25 - 40	10 - 20
≥ 12.5mm	10 - 20	–
Binder Type	Only modified Binder	
Binder Content[a]	≥ 5.0%	≥ 5.0%

a.) Binder content on 100% aggregate

C 9.3. Specific material requirements

- Aggregate: 100% crushed; LA < 20%; PSV > 0.55
- Sand: 100% crushed
- Filler: Limestone
- Binder: Always modified (SBS or EVA)

C 9.4. Type testing procedure

Marshall specimens are prepared with several binder contents and the same mineral aggregate. Usually, the aggregate content at which the voids level is 4.0% (0/12.5 type) or 4.5% (0/9.5 type) gives the job mixture formula.

Type Testing Requirement (Marshall specimens):

- Voids content:
  - SMA 0/12.5: 3 – 5 %(v/v)
  - SMA 0/9.5: 3 – 6 %(v/v)

C 9.5. Specific production and application requirements

Both types are produced and applied with standard equipment.

Layer Thickness:	SMA 0/9.5:	15-20 mm
	SMA 0/12.5:	20-30 mm

C 9.6. Performance in practice

SMA provides a rugous, even and durable wearing course.

10. SWEDEN

Four types of bituminous mixtures comparable to SMA can be distinguished: ABS 22, ABS16, ABS 11 and ABS 8

C 10.1. Application

Trials since 1974, standard on motorways and main roads since 1988.

C 10.2. Requirements

Specifications according to "VÄG 94"

Types and required composition: (see table below)

C 10.3. Specific material requirements

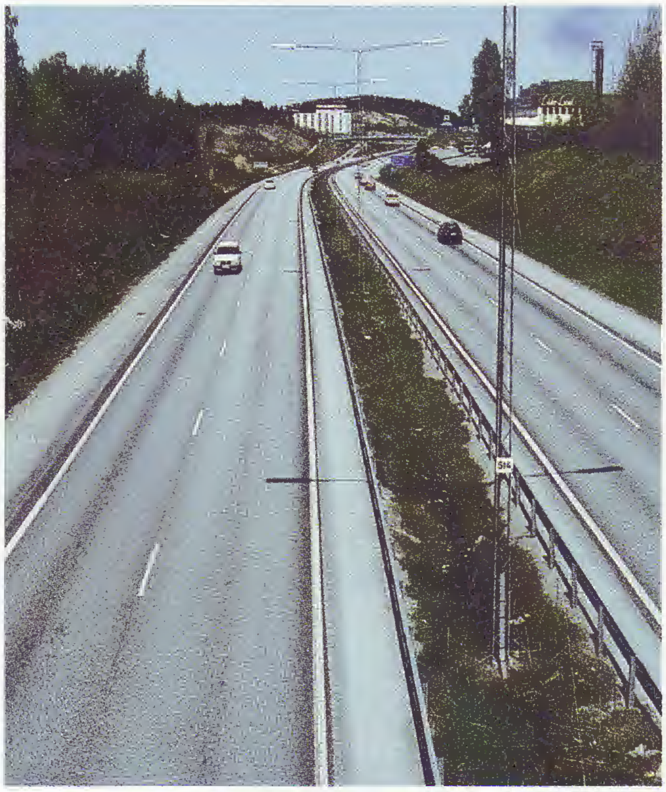
Aggregate: 90% crushed; Kulkvarnsvärde ≤ 6

C 10.4. Type testing procedure

Marshall specimen testing at several binder contents.

C 10.5. Performance in practice

SMA provides good wear resistance, deformation resistance, ageing properties, fatigue properties and some noise reduction.



SMA Types	ABS 22	ABS 16	ABS 11	ABS 8
Mineral aggregate	Crushed coarse & fine aggregate and filler (% min/max)			
75µm	8 - 13	8 - 13	8 - 13	8 - 13
2.0 mm	16 - 29	16 - 29	19 - 30	20 - 30
4.0 mm	20 - 33	20 - 32	24 - 35	28 - 49
8.0 mm	27 - 50	27 - 50	35 - 60	85 - 99
11.2 mm	35 - 65	34 - 70	85 - 99	98 - 100
16.0 mm	50 - 80	85 - 99	98 - 100	100 - 100
22.4 mm	85 - 99	98 - 100	100 - 100	
31.5 mm	98 - 100	100 - 100		
45.0 mm	100 - 100			
Binder type	B 85, B 120, B 180 or modified binders			
Binder content[a] min/max %	5.5 - 7.2	5.5 - 7.2	5.7 - 7.4	5.9 - 7.6
Void content[b] min/max %	2.0 - 4.2	2.2 - 4.4	2.7 - 4.9	3.2 - 5.4
Layer thickness min/max	48 - 88	36 - 64	24 - 44	18 - 32

a.) Binder content in mixture
b.) Marshall specimens

11. UNITED KINGDOM

Inf.: "Evaluation of Stone Mastic Asphalt (SMA): A High Stability Wearing Course material" TRL report PR 65

This report includes a draft clause which is expected to be included within the national specification for highway works.

C 11.1. Application

Since 1994 there have been a number of trials on major trunk roads and whilst these are being evaluated the use of SMA on non-trunk roads has increased substantially.

C 11.2. Requirements

Until now the UK has no specific requirements for SMA. Most applications are based on German specifications. In the TRL report mentioned above the results of a demonstration trial of a SMA variant derived from those specifications is described:

Aggregate Grading and Binder Content:

BS Sieve Size mm	% by mass of total aggregate passing Nominal Size 14 mm	10 mm
20	100	–
14	90 – 100	100
10	35 – 60	90 – 100
6.3	23 – 35	30 – 50
2.36	18 – 30	22 – 32
75µm	8 – 13	8 – 13
Binder[a] % by mass	6.5 – 7.5	6.5 – 7.0

a.) Binder content in mixture

12. USA

- *"Performance of Stone Matrix Asphalt (SMA) in the U.S." E.R. Brown, J.E. Haddock, R.B. Mallick and J. Bukowski, AAPT 1997*
- *Development of a Mix Design Procedure for Stone Matrix Asphalt (SMA) Mixtures" E.R. Brown, J.E. Haddock, R.B. Mallick, T.A. Lynn, AAPT 1997*

In the USA, SMA is named "Stone Matrix Asphalt" to prevent it being confused with mastic. (Mastic may contain tar in the U.S. or is applied for roofing at relatively high temperatures.)

C 12.1. Application

Since 1991. Experiments since then in most states (several hundreds of projects) and its use is becoming more and more common – it is the standard surfacing material in Georgia and Maryland.

Field of application: Surface course for heavy duty pavements (e.g. Interstate). Generally SMA 0/12.5 is used.

C 12.2. Requirements

No standard specifications for mixture composition or mixture design exist. Preliminary recommendations were derived from European practice. Based on those experiences and on an evaluation of approximately 100 SMA projects NCAT (the National Centre for Asphalt Technology) has recently developed the following recommendations:

- Grading: > 95 % passing sieve 12.5 mm
  < 30 % passing sieve 4.75 mm
  8 – 10% passing sieve 75 µm

  The required grading could be determined from the combined interpretation of the VMA and VCA values (" Voids in the Mineral Aggregate" and "Voids in the Coarse Aggregate": AASHTO T19).

- Aggregate characteristics: Preferred is a L.A. Abrasion value < 30. Elongation values should be 1:2/1:3 maximum (1:5 is too low).

  A good correlation exists between breakdown of aggregate and elongation value.

- Binder content: to be determined from the voids content in the mixture, which shall be 3.0 – 4.0 %(v/v). For heavy duty application a higher voids content (e.g. 5.0 – 6.0 %) may be required. After application the voids content shall be > 3.0 % to prevent premature rutting.
- Specimen preparation: Gyratory compaction preferred as density levels and aggregate abrasion in this device are comparable to practice. For density evaluations 100 gyratory revolutions are approximately equivalent to 2 x 50 blows by impact compactor (except for abrasion).
- A drainage inhibitor is required; fibres (cellulose and rockwool) perform better than modified binders.

SMA type	D4	D6(1)	D6(2)	D8	D10	D11	D14	D16	D20	D22
Percentages passing sieves (% m/m)										
31.5									100	100
22.4								100		90-100
20.0							100		90-100	
16.0						100		90-100		60-80
14.0					100		90-100		60-80	
11.2				100		90-100		45-75		35-60
10.0			100		90-100		50-75		35-60	
8.0		100		90-100		45-75		25-40		25-40
6.3			90-100		30-50		20-35		20-35	
5.6	100	90-100								
4.0	90-100			25-45		25-40		20-35		20-35
2.0	30-40	30-40	25-35	20-30	20-30	20-30	15-30	15-30	15-30	15-30
63 µm	8 -12									
Binder content "in" mixture	7.0-8.0	6.5-7.5	6.5-7.5	6.0-7.0	6.0-7.0	6.0-7.0	5.8-6.8	5.8-6.8	5.7-7.2	5.7-7.2
Additives	0.3 -1.5									
Layer thickness (mm)	12-25	15-30	15-30	20-40	25-50	25-50	30-55	30-55	40-70	40-70

Note: D6(1), D8, D11 and D16 to be used when the basic set + set 1 of the aggregate sieves according to EN 933-2 are in use; D6(2), D10 and D14 when basic set + set 2 of the aggregate sieves according to EN 933-2 are in use. For practical reasons the grading and binder contents are rounded off. Binder contents have to be adapted to the density of the aggregates.

In the draft European Standard for SMA (prEN 13108 – 6) the mixture group "Stone Mastic Asphalt" is defined as "the mix group (of bituminous mixtures) comprising gap-graded asphalt mixtures with bitumen as a binder, which are composed of a coarse aggregate skeleton bound with a mastic mortar". It is meant for application in surface courses of roads, airfields and other paved areas for all kinds of traffic and climates.

In the prEN the following types are distinguished: SMA (D4,) D6, D8, D10, D11, D14, D16, (D20, D22). Those between brackets are types not currently in use in Europe.

For the constituent materials a broad description will be given of aggregates, binders, manufactured filler, additives and reclaimed asphalt.

- Mixture design (type testing): requirements:

  Voids content: The type testing requirement still has to be established. First proposal: voids content of Marshall specimen 2.0-6.0 % (v/v), values for other compaction devices to be established.

  Permanent deformation: Requirements for wheel tracking (empirical procedure) and triaxial test (fundamental procedure) to be determined.

  Other requirements: requirements for the temperature of the mixture and the evaluation of conformity.

References:

The text in this document is based on the responses provided by the EAPA member associations to a questionnaire that was established by the EAPA Technical Committee. Furthermore the following literature was used:

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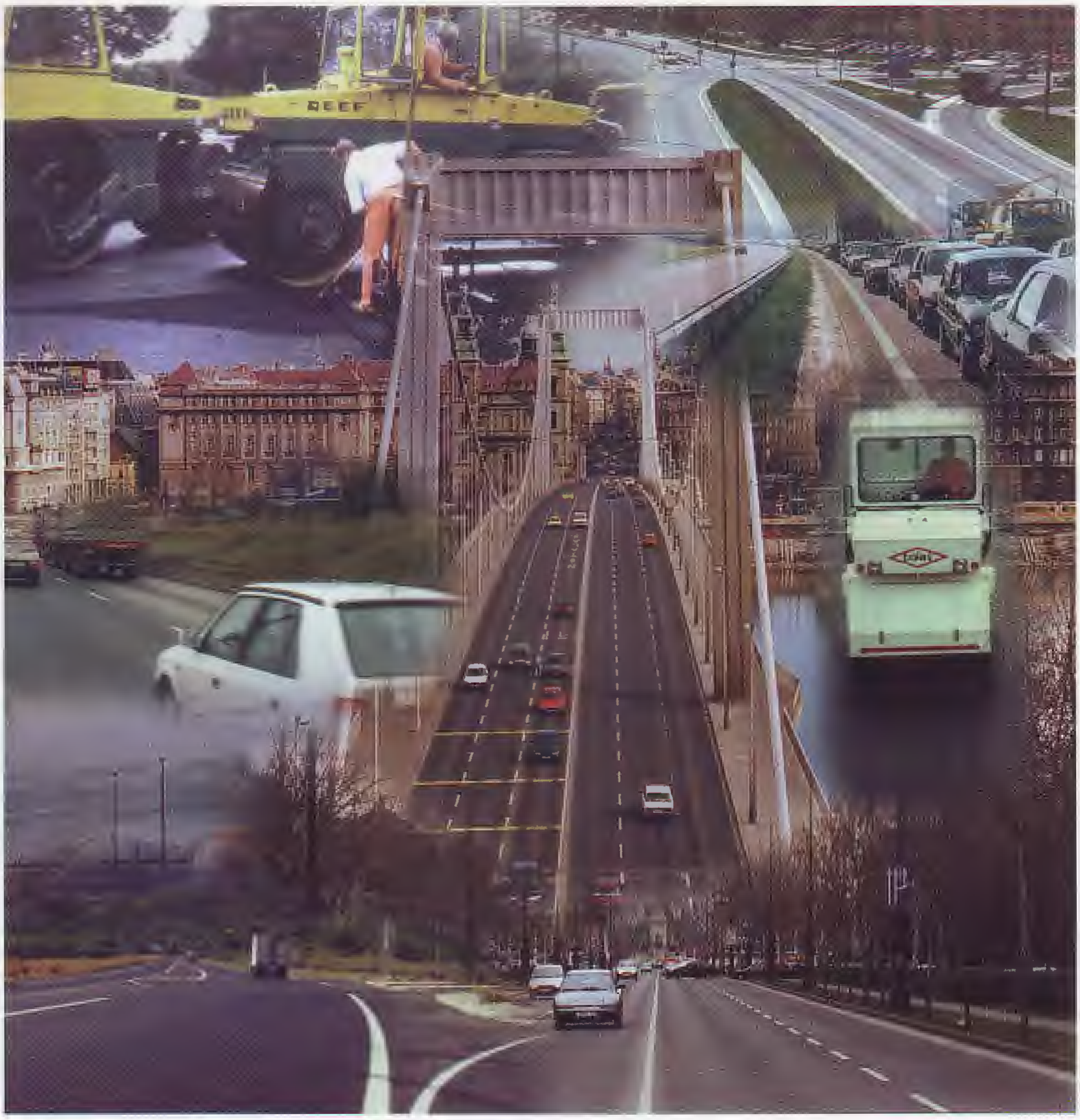
19. Asphalt Institute (SP-2), USA. Supersave Series No.2.

Abbreviations frequently used in this document

AC	Asphalt Concrete
AC+numeral	Asphalt Cement (US terminology for bitumen)
ADT	Annual Daily Traffic
BBM	Béton Bitumineux Mince (French). A type of bituminous mixture developed in France that has some similarities to SMA.
CEN	Comité Européen de Normalisation, the European standards body.
EVA	Ethyl Vinyl Acetate
HDP	Heavy Duty Pavement(s)
HRA	Hot Rolled Asphalt
PA	Porous Asphalt
PMB/PmB	Polymer-modified Bitumen
PSV	Polished Stone Value
SBS	Styrene Butadiene Styrene
SMA	Stone Mastic Asphalt/Stone Matrix Asphalt (US)
VCA	Voids in the Coarse Aggregate
VFB	Voids Filled with Binder
VMA	Voids in the Mineral Aggregate



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