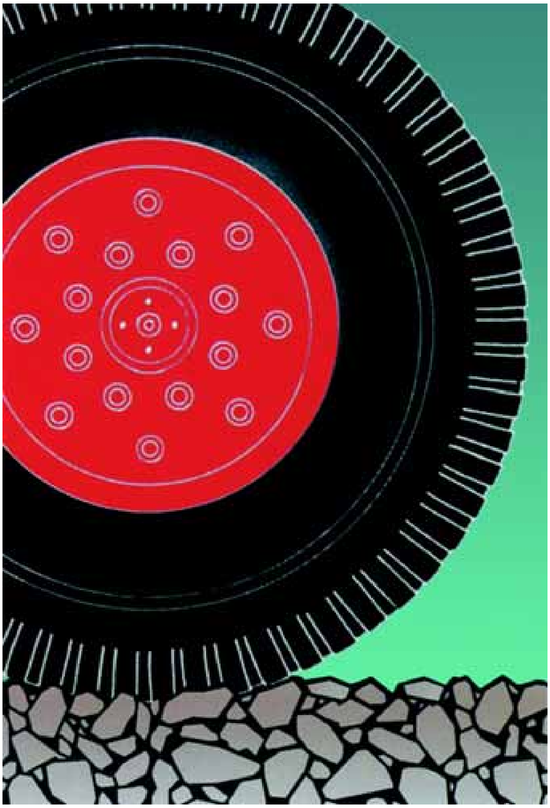
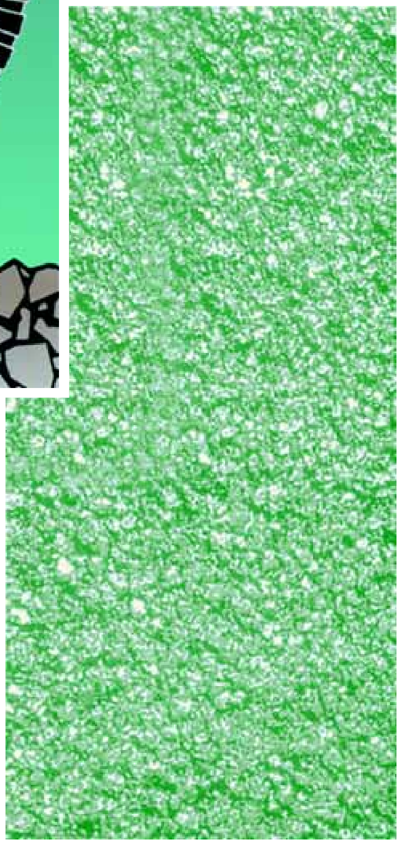
Stone Mastic Asphalt





asphalt
Asphalt Guide

Stone Mastic Asphalt

Lothar Drüschner and Volker Schäfer

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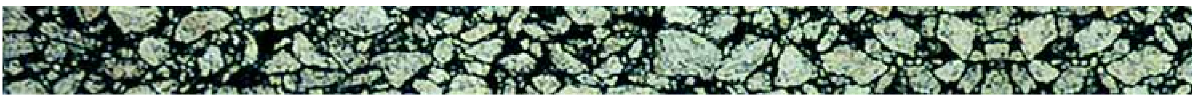

Appendix

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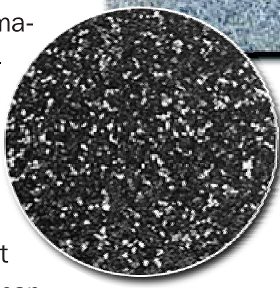
1. Preface

This guide, **Stone Mastic Asphalt**, was put together by the DAV Asphalt Technique Working Group and is based on Section 4 of the ZTV (Supplementary Technical Conditions of Contract, Specifications, and Guidelines) Asphalt Road Construction 2001 (ZTV Asphalt-StB 2001. The guide gives practical advice for customers, mix manufacturers and contractors which goes beyond and supplements the technical guidelines. Using this guide helps ensure that **stone mastic asphalt** can be produced and paved correctly.



Stone mastic asphalt 0/8 in Wilhelmshaven after 20 years wear.

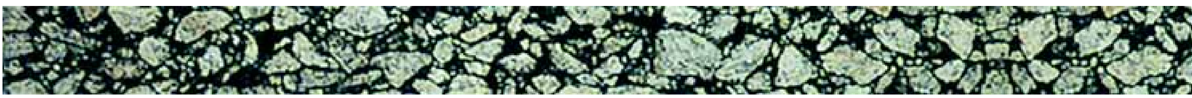
Over 30 years experience has shown that wearing courses made with **stone mastic asphalt** have an above average useful lifetime due to their special design; based on the one hand, on a high amount of chippings and on the other, high binder and mortar content.

Preface

The first **stone mastic asphalt** designs used a binder content of over 7 % by weight using asbestos fiber or rubber powder as stabilizing additives.

The type and characteristics of the stabilizing additives were of special importance when using this high amount of binder.

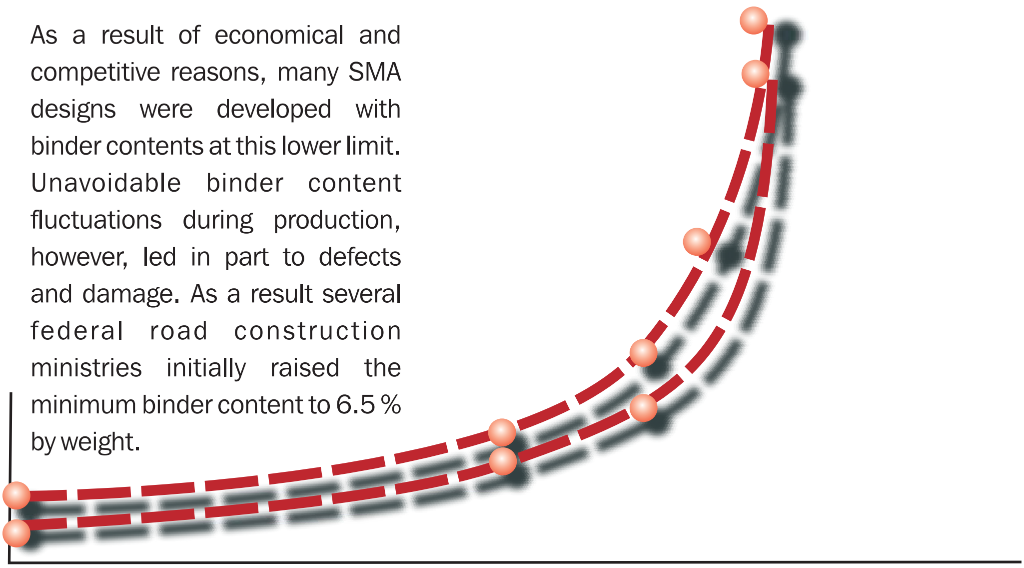
In the years following, the original **stone mastic asphalt** design underwent a series of changes for technical, economical and ecological reasons. Today, for example, other stabilizing additives are used such as cellulose and mineral fibers, thermoplastics and silica. With some of these additives, the high binder content could not always be added into the mixture without damaging it. That meant that some wearing courses with lower binder contents and in part, less coarse aggregate and mineral content were produced and called **stone mastic asphalt** by their manufacturers. These wearing courses were, however, closer in character to asphalt concrete.



These developments also had an effect on the general conditions in the ZTV bit StB-84 where **stone mastic asphalt** was first included in the technical guidelines. Irrespective of the maximum aggregate size, the minimum binder content of 6.0 % by weight was given for the stone mastic asphalt.

As a result of economical and competitive reasons, many SMA designs were developed with binder contents at this lower limit. Unavoidable binder content fluctuations during production, however, led in part to defects and damage. As a result several federal road construction ministries initially raised the minimum binder content to 6.5 % by weight.

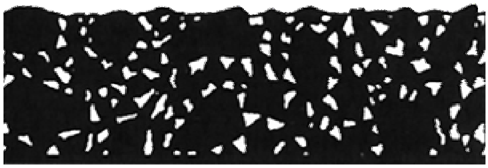
This value was included in the revised edition of the 1990 ZTV bit StB-84 and continued in the ZTV Asphalt StB-94. It was deemed adequate for the production of a **stone mastic asphalt 0/11 S** with its typical properties. There are higher minimum binder contents given for **stone mastic asphalt** 0/8 S, 0/8 and 0/5.



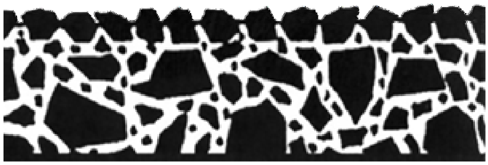
2. General comments

Stone mastic asphalt was designed as a wearing course with especially high resistance to studded tires in the mid sixties. It was a more developed and mechanized form of asphalt mastic wearing courses made according to TV bit 6 where the asphalt mastic was applied to the surface by hand or with distributor boxes. High quality chippings 5/8 or 8/11 were then spread and compacted into the surface (see illustration). Stone mastic asphalt has a comparable good durability and stability like gussasphalt but can be transported and paved like asphalt concrete.

Basic construction



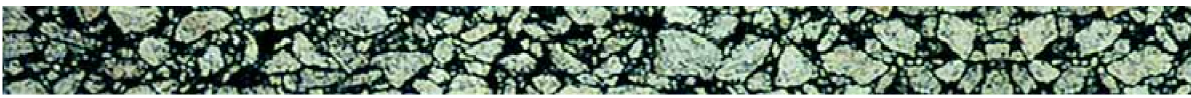
Asphalt concrete



Gussasphalt

Stone mastic asphalt

According to the definition found in the ZTV Asphalt StB, stone mastic asphalt is made from a mineral mixture which is gap-graded, has bitumen as a binder and uses stabilizing additives.

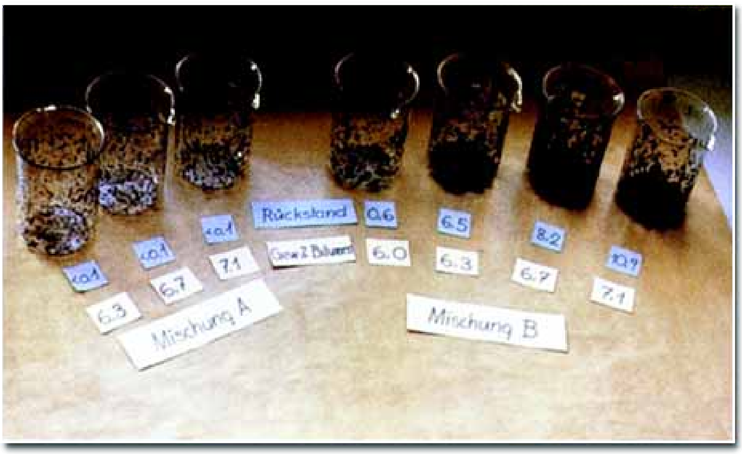


The main characteristics of stone mastic asphalt's composition are found in this definition:

- **high amount of chippings**
- **high amount of the coarsest particle size**
- **high binder content**
- **stabilizing additives**

The mixture which is made with a high amount of the coarsest particle size category, forms a coarse aggregate skeleton. The air voids in this skeleton are filled for the most part with bituminous mortar.

The stabilizing additives here act as binder carriers. They should stabilize the high binder content needed for the mastic-like mortar composition during the various working phases of mixing, transporting, paving and compacting. In this way they prevent the binder from draining off the minerals. Additionally the thick binder films achieved through the use of stabilizing additives positively affect the fatigue and aging behavior.



The binder drainage test (see appendix) shows if a stabilizing additive can prevent the drain-off of asphalt mortar from the minerals.

3. Properties and areas of application

Wearing courses made with stone mastic asphalt are especially stable and durable. They have proven their superior performance even in areas with heavy traffic and independent of any climatic influence.

A wearing course made from stone mastic asphalt with the correct design and mix production as well as proper paving shows the following characteristics due to the high chippings content together with the mastic-like mortar:

- **better resistance to permanent deformation**
- **high wearing resistance**
- **less cracking due to cold or mechanical stress**
- **coarse surface texture**
- **good macro roughness**
- **good long-term behavior**

SMA has proven itself even on surfaces where containers sit with their extreme demands. The photo shows SMA in a brightened version in Hamburg (for reasons of temperature).

Stone mastic asphalt can be used as wearing course for roads, paths and other traffic surfaces. It is a standard method of construction on motorways, federal roads and city streets with heavy and very high demand (cf. Steinhoff, Pätzold in "asphalt" No 1/98, page 20: Long-term preservation of asphalt courses, a documentation).

For maintenance of traffic surfaces, stone mastic asphalt 0/5 and 0/8 are specially suited for thin layers (ZTV BEA-StB 98). One of stone mastic asphalt's special advantages is that within limits it can be paved in different thicknesses in order to even out a surface without worrying about possible different postcompaction.

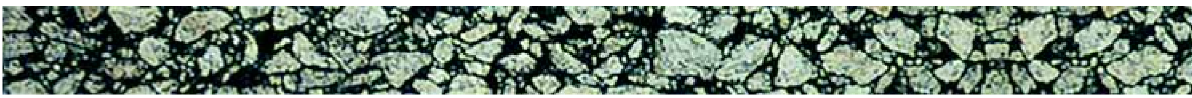
Paving a thin SMA wearing course on a through street in a town.

4. Mixture composition

Mineral Aggregates

In addition to the general valid demands on the minerals for wearing courses, the stability and polishing resistance of the chippings when using stone mastic asphalt are of great importance. Due to the low amount of sand used, the micro-roughness of stone mastic asphalt wearing course surfaces is almost completely achieved by the roughness of the chippings surface. For roads in the construction categories SV, I and II and for roads in the construction category III with special loads, the chippings used must therefore have high polishing resistance, i.e. a PSV value of at least 50. On surfaces with special polishing stresses or other high loads or requirements, minerals or mineral mixtures with an even higher PSV value are recommended. By using different mineral types with differing polishing factors in the fine chippings fractions, longlasting skid re-sistance can be achieved.

For the void content in stone mastic asphalt wearing courses (see the section **“Mix design and Type testing"**), especially with stone mastic asphalt 0/8 S and 0/8, the aggregate shape is a very important factor. The TL Min.-StB does not make demands on the aggregate shape of high quality chippings having a particle size fraction of 2/5 mm. This can negatively affect void content, degree of filling, etc. of the compacted asphalt when the aggregate shape is extremely flaky or elongated.



Binders

As a rule, road construction bitumen 50/70, made according to DIN EN 12591, is used for stone mastic asphalt. Thin wearing courses made with stone mastic asphalt can be produced using road construction bitumen 70/100 or 160/220. Under certain conditions, such as on surfaces with special demands or on bridges, the use of a polymer-modified bitumen should be considered.

NB: *As of 2005, the German Asphalt Association recommends the use of PmB for high trafficked areas only, because of reasons of skid resistance.*

Stabilizing additives

To achieve the desired high binder content with a relatively low specific aggregate surface in stone mastic asphalt, stabilizing additives must be added. The additives should act as binder carriers so that the drain-off of the binder from the aggregates is prevented during production, storage, transportation and paving. In practice, cellulose fiber has proven its good performance as a stabilizing additive.

In addition powdered, granulated or liquid materials can be used if a satisfactory, stabilizing effect can be proven (see appendix: Binder drainage test). Natural and artificial silicic acid, rubber powder or polymers have, in part, shown good results.

Mixture composition

Mix design and Type testing

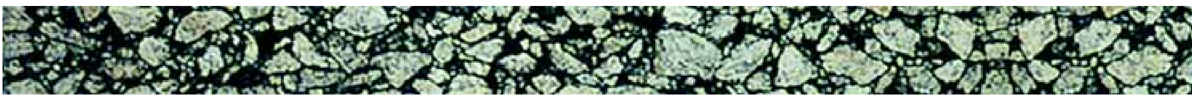
Marshall specimens should be produced using road bitumen 50/70 according to DIN 1996 Part 4 at a compaction temperature of 135 +/- 5°C. If PmB 45 is used, the ZTV Asphalt StB recommends a compaction temperature of 145 +/- 5°C for stone mastic asphalt. A void content of approximately 3.5 Vol. % should be targeted for traffic surfaces with construction categories of SV and I. In all other cases as well as when using PmB, a value of around 3.0 vol. % should be targeted. For mixes to be used for thin courses, a targeted void content in the Marshal specimen of 2.0 and 2.5 vol. % is recommended, depending on the amount and type of traffic.

The adjustment of the void content by changing the binder content only makes technical sense within very limited parameters. If greater changes are desired in the void content of the Marshall specimen, is it advisable to make changes in the following order:

- **total chippings content**
- **ratio of the individual chipping fractions**
- **filler content**
- **binder content**

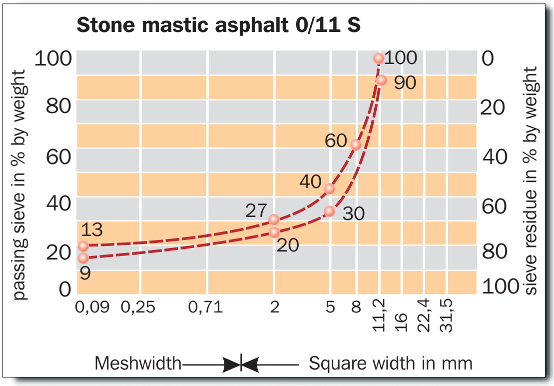
Recommended distribution of the individual particle size categories dependent on the total chippings content.

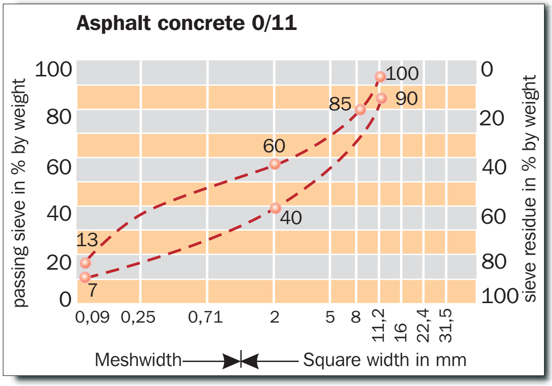
	SMA 0/11 S	SMA 0/8 S	SMA 0/8
Particle size class 2/5	1 part	2 parts	2,5 parts
Particle size class 5/8	2 parts	5,5 parts	4,5 parts
Particle size class 8/11	4 parts	-	-



The total chippings content over 2.0 mm can only be varied in a very limited manner. For heavy duty road surfaces, it should be oriented to the lower limit of the grading curve. This lowers the risk of differing void contents in the SMA wearing course that are due to unavoidable production fluctuations.

In the revision of the ZTV-Asphalt StB 2001, the lower limit for the total chippings content was lowered from 75 (issue 1998) to 73 % by weight (see table, page 12). The gradation of the respective chipping fractions themselves should lie in the table on page 10 (left).

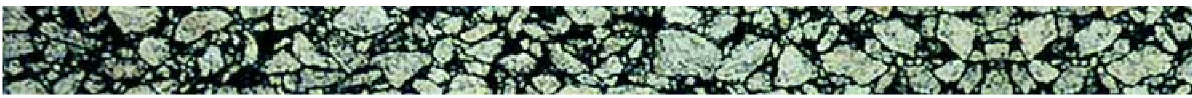




Gradation for SMA 0/11 S (above) compared to asphalt concrete 0/11 (below).

Stone mastic asphalt		0/11 S	0/8 S	0/8	0/5
1. Mineral Aggregate		high quality chippings, high quality crushed sand, mineral filler		high quality chippings, high quality crushed sand, mineral filler	
Particle size fraction	**mm**	**0/11**	**0/8**	**0/8**	**0/5**
Aggregate content < 0.09	% by weight	9 - 13	10 - 13	8 - 13	8 - 13
Aggregate content > 2.00	% by weight	73 - 80	73 - 80	70 - 80	60 - 70
Aggregate content > 5.00	% by weight	60 - 70	55 - 70	45 - 70	≤10
Aggregate content > 8.00	% by weight	≥ 40	≤10	≤ 10	-
Aggregate content > 11.20	% by weight	≤ 10	-	-	-
Crushed sand : natural sand ratio		1:0	1:0	≥1:1	≥1:1
2. Binders					
Binder type		50/70 (PmB 45)[1]	50/70 (PmB 45)[1]	70/100	70/100 (160/220)[1]
Binder content	% by weight	≥6.5	≥ 7.0	≥7.0	≥ 7.2
3. Stabilizing additives					
Content in mixture	% by weight	0.3 - 1.5			
4. Mixture					
Marshall specimen compaction					
Temperature[2]	°C	135 +/- 5			
Void content	vol. %	3.0 - 4.0	3.0 - 4.0	2.0 - 4.0	2.0 - 4.0
5. Course					
Paving thickness	cm	3.5 - 4.0	3.0 - 4.0	2.0 - 4.0	2.0 - 3.0
or					
Paving weight	kg/m²	85 - 100	70 - 100	45 - 100	45 - 75
For exceptions, e.g. with uneven foundations					
Paving thickness	cm	2.5 - 5.0	2.0 - 4.0	-	-
or					
Paving weight	kg/m²	60 - 125	45 - 100	-	-
Degree of compaction	%	≥ 97			
Void content	vol. %	≤ 6.0			

[1] only in special cases (*As of 2005, the German Asphalt Association recommends the use of Pm B for high trafficked areas only, because of reasons of skid resistance*). [2] The Marshall specimens should be produced at 145 +/- 5°C when using PmB 45.



Mixture composition

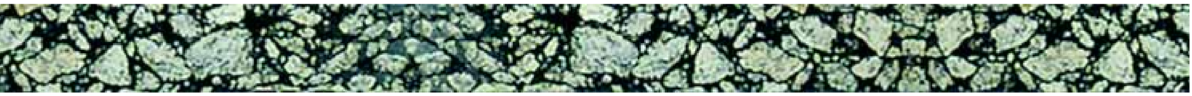
Marshall stability and flow values are not at all suitable for the evaluation of stone mastic asphalt's deformation behavior. The relatively low Marshall stabilities of stone mastic asphalt can lead to a misinterpretation of the deformation resistance when compared with asphalt concrete. Nowadays, rut formation testing is done using the wheel tracking test according TP A-StB(*) part: "Determination of the rut depth in a water bath". It is well suited for the internal evaluation of differing stone mastic asphalt compositions and their anticipated deformation properties. Because there is still no adequate evaluation information, no general, valid threshold values can be listed for stone mastic asphalts rut depths.

Besides the wheel tracking test the cyclic compression test (acc. to TP A-StB(*) part: "uni axial cyclic compression test - determination of the deformation behavior of rolled asphalt") is used to evaluate the deformation resistance. For this test, again, there are not enough adequate, general testing results available.

In each case when using a testing procedure to evaluate deformation resistance, it is very important to pay attention to the production method used for the specimen including the production of the specimen and the evaluation of the results.

(*) Technische Prüfvorschriften für Asphalt im Straßenbau (Technical testing guidelines for asphalt in road construction).

(left: Table 4.1 "SMA" from the ZTV Asphalt StB 2001)



5. Mixture production

Mixture production is similar to that of asphalt concrete. Due to the high amount of the coarsest aggregate fraction, it makes sense to use two cold bins for this. The upper level of the hot screen unit can become overloaded due to the high coarse aggregate content affecting the sieving. The paving capacity must therefore be adjusted to the capacity of the mixing plant (hot bins, cold bins). Because of the lower sand content in the minerals as compared with other mixture types, the chippings are heated more in the drying drum. This occurs because the flame acts directly on the chippings and not on a thick sand layer. The burner rating should therefore be adjusted so that the mineral temperature is not too high and remains constant during the entire production period. The temperature of the finished mixture is critical. It must not exceed 170°C.

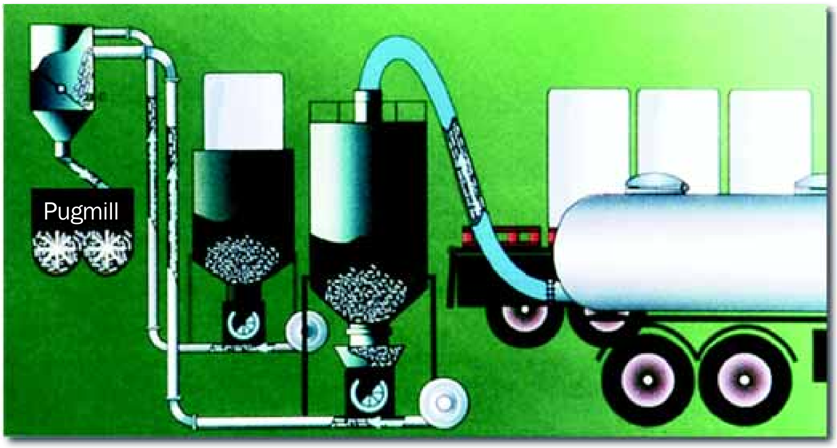
The stabilizing additives must be exactly dosed or added in pre-measured units (bags) depending on their type and form of delivery.

Due to the great effectiveness of the stabilizing additives, fluctuations in the amounts added and in the distribution of properties cause large changes in the stone mastic asphalt and the courses produced with it. That is why only those additives should be used which are delivered in a homogenous state and which retain their homogeneity during storage and processing.

The following production described is based on the addition of fibers. When adding granulates, liquids or additives using fillers, the special properties of these additives must be considered.

When using bags, their size and batch size must be coordinated. Organic fiber should not be subjected to moisture during storage and use. This can cause clumping and adds to the risk of uneven distribution in the mixture.

Mixture production



Automated addition of stabilizing additives.

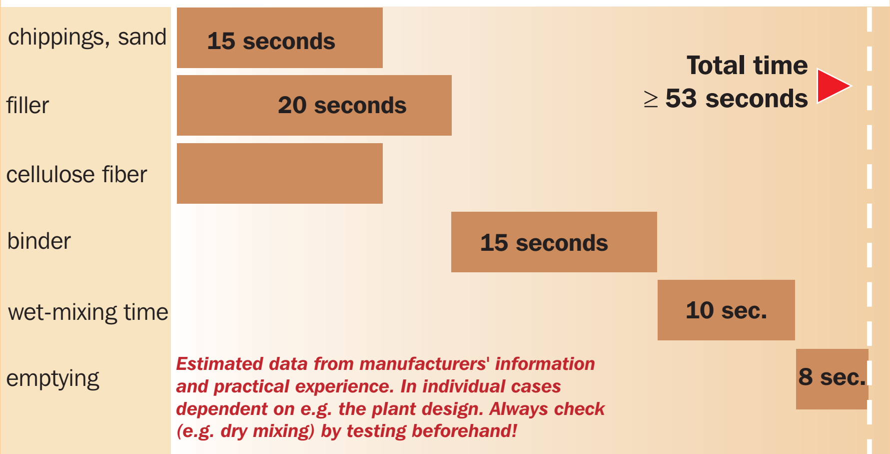
Stabilizing additives are usually added automatically using the corresponding dosing equipment. Many producers of these additives offer dosing devices that are specially adjusted to the materials used. In special cases (for example small quantities) the additives can be added manually through a lid cover at the pugmill. When using this method, the industrial safety regulations as well as the BG/BIA recommendations in "Production of Asphalt" should be followed as required. Because the binder accumulates on large surface areas, a homogenous mixture can only be obtained through the even distribution of the stabilizing additives. Special attention should be given to the additive manufacturers' information if available. When using fiber additives, it should be noted that homogeneous distribution in the mix first takes places in the "wet-mixing time" (i.e. during and after the addition of the binder).

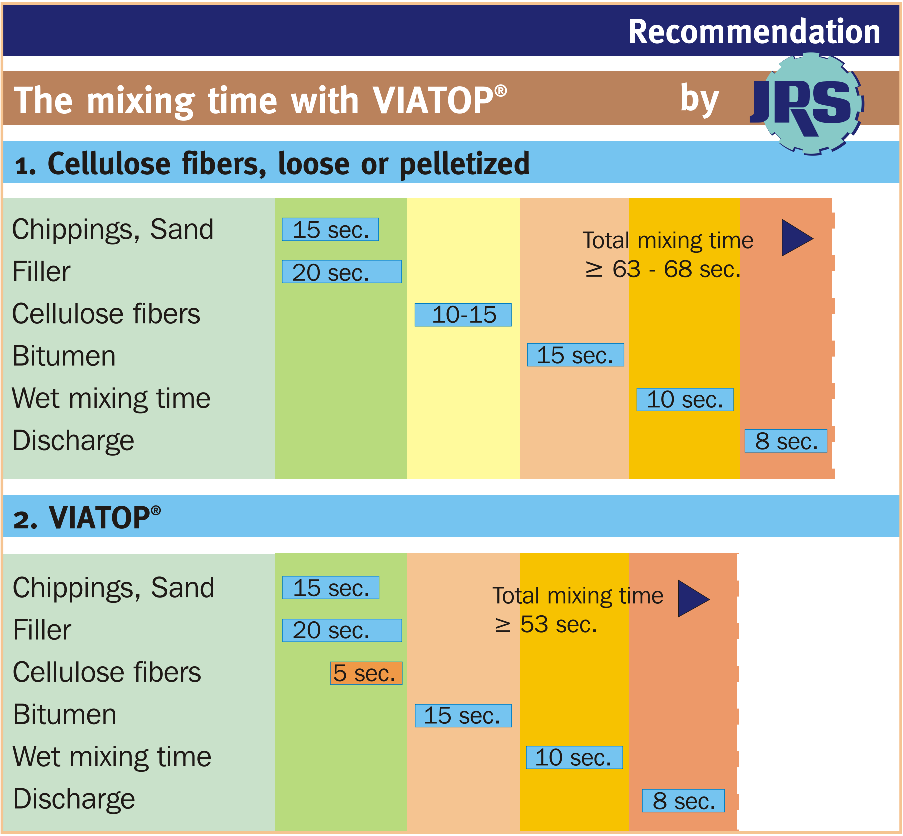
A dry pre-mixing time that is too long can result in the fibers being pulverized to filler. In some cases when using pelletized organic fibers, pellets do not break up adequately. This can be due to differing pressing during the pellets' production or to a dry mixing time that is too short. It is a good idea to check the breaking up and homogeneous mixing in of the pellets from time to time.

It should be noted that the required pre- and wet-mixing times can result in a reduction of the mixture output.

During the mixing of stone mastic asphalt, the mixing plant should not be switched over to the manufacture of other types of mixtures especially base course or binder mixes (changes in the burner adjustments, production rate…).

Recommendations for the addition of individual components and the total mixing time when using cellulose fiber (loose or pelletized, without or with bitumen coating)




Recommendation
The mixing time with VIATOP®
by JRS
1. Cellulose fibers, loose or pelletized
Chippings, Sand
Filler
Cellulose fibers
Bitumen
Wet mixing time
Discharge
15 sec.
20 sec.
10-15
15 sec.
10 sec.
8 sec.
Total mixing time
≥ 63 - 68 sec.
2. VIATOP®
Chippings, Sand
Filler
Cellulose fibers
Bitumen
Wet mixing time
Discharge
15 sec.
20 sec.
5 sec.
15 sec.
10 sec.
8 sec.
Total mixing time
≥ 53 sec.

6. Mixture - Interim storage and transport

Delivery of a red-colored SMA in a thermal container

Like other asphalts, stone mastic asphalt should not, as a rule, be stored for long periods of time in loading silos. This is to prevent damaging changes in the binder.

The truck beds must be clean. They should only be cleaned by spraying with a separating agent suitable for asphalt or a thin water film.

Diesel fuel should not be used due to quality considerations and industrial safety regulations. The transport vehicles must be covered with windproof blankets even in summer to prevent cooling off of the mixture and a damaging binder hardening from oxidation caused by contact with oxygen in the air.

With smaller areas to be paved (less mix) and slow work progress (e.g. in city road construction or road maintenance and repair), trucks with thermally insulated attachment containers (hold small amounts) or thermal tractor-trailers/articulated lorries with horizontal belt conveyors (see photo right) have proven valuable.

It is a mistake to try to counteract the cooling off effects of the mix during longer transport distances by overheating the mixture temperature. The result is mix segregation drain-off of the binder or mortar during transport and paving as well as hardening of the binder resulting in a poor paving and compacting behavior of the mix.

Mixing, transport and paving work must be coordinated. With good job organization and timing, there are shorter waiting times for the transport vehicles with less temperature loss of the mix and less down time for the pavers resulting in fewer compaction problems and better longitudinal evenness. The continuous feeding of mix to the paver is an important prerequisite for the smoothness of texture and compaction as well as for the evenness of the paved asphalt course.

7. Paving and compacting

Paving a SMA wearing course for a storage area

Stone mastic asphalt can easily be paved using a paver. During paving and especially during compacting, the following rules should be followed:

Rules:

- The mix temperature in the paver hopper should be evenly distributed and when using road bitumen 70/100, 50/70 or PmB 45 (without additives for improved processing) never fall below 150°C. Consistent temperature distribution means that, for example, no cold spots can build up in corners or at edges.

- The paver used should be operated dependent on the paving speed so that an appropriate i.e. not too high precompaction is achieved (check with e.g. Isotope probes) so that no bumper vibration (structural loosening) occurs.

- As a rule, compacting should be done as soon as possible, i.e. as close as possible to the paver.

- At least two rollers are required for each lane that is to be paved.

- The roller compaction should be done using a tandem or three-wheel roller (operating weight > 9 tons).

- Vibratory compaction should only be done with adequately high mix temperatures and only after a static pressing/compaction.

Rules:

- If layer temperatures fall below 100°C, vibration cannot be continued. With a rigid base course (e.g. concrete and stone paving), and with course thicknesses below 2 cm, vibration cannot be carried out because this can lead to breaking up and smashing of the aggregates.

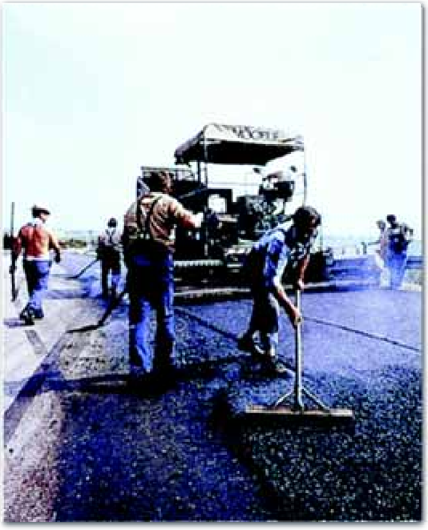
- Rubber-tire rollers are ineffective when used for SMA compaction. They are even counterproductive for the surface properties and are no longer used.

- Necessary, supplemental manual paving of stone mastic asphalt must be done quickly and if possible, at the same time as the paver work. The roller compaction must be done immediately after the paving. The missing pre-compaction by the paver will result in a higher neccessary paving thickness (roller dimension) which must be taken into consideration.

Paving thickness and weights for SMA are listed in Table 4.1 of the ZTV Asphalt StB 2001 (see page 12) and in Table 3.2 of the ZTV BEA-StB 98. The lower values should be viewed critically, based on experience, and limited only to special cases. For normal use, it should be ensured that no part of the layer falls below the minimal thickness.

Special attention should be given to the paving of seams and joints (see DAV guidelines "Course connections, seams, joints, edge finishing").

(NB: *Available only in german language)*



SMA manual paving on rounded surfaces and edges always simultaneously with the paver.

8. Treatment of the surface and opening road to motorists

In order to increase initial skid resistance, sanding measures (acc. to ZTV Asphalt StB) should be included in the tender to be carried out. The amount of gritting/sanding material is usually 1 to 2 kg/m^2. Next to the aggregate size 1/3 mm, a dedusted and possible lightly pre-coated (bituminous) crushed sand 0.25/2 mm has also proven satisfactory. Chippings 2/5 should not be used due to possible increased noise emissions.

The gritting material can be applied either directly behind the paving plank or between the first roller passes. It must in any case be applied onto the still adequately hot and adhesive surface. In order to obtain an even, consistent surface image, use of mechanical spreading is essential (photo left).

After paving, the compaction and final treatment, there must be a time period of at least 24 hours so that the wearing course can cool off before opening the road to traffic. If the wearing course surface is driven on too soon, it can lead to ruts in the wheel tracks.

Non-sanded (above) and sanded (below) surfaces of a stone mastic asphalt wearing course

1. Binder drainage test according to Schellenberg/von der Weppen

(cf. ALP A StB Part 2: "Testing the binder drain-off": EN 12697part 18)

The binder drainage test according to Schellenberg/von der Weppen is ideal for evaluation of the mixture stability and homogeneity during mixing, storage, transport and paving. Using this test, the tendency to segregate during the production phase can be assessed very precisely. Great test-technological effort is not required to carry out the testing.

Place approximately 1 kg of the mixture in a beaker (DIN 12332, 800 ml). Leave it covered for 60 min at 170°C, in a drying oven. Set the drying oven to circulating air (not supply air). Preheat the empty beaker in the drying oven at 170°C before. The length of time from the removal of the beaker to the weighing of the test specimen to the placement of the specimen in the oven should not exceed 20 seconds. The initial temperature of the mixture should be 135 +/- 5°C (see temperature for the production of Marshall specimen). Any deviations in heating times must not be longer than +/- 1 min. and in the heating oven temperature not more than +/- 1°C. After the heating period, empty the beaker by turning it upside down without shaking or knocking it. Weigh the specimen. The entire process should not exceed 10 seconds.

The segregation measurement is the difference between the mixture weight before and after heating taken as a percentage. Record any deviations in the heating period and/or heating temperature. Be sure to note and include in the assessment any unusual occurrences such as any chippings sticking to the beaker or more than just a minimal (dotted) adherence of the asphalt mortar. The difference (pure mortar) should be less than 0.15 % by mass, but even better, less than 0.10 % by mass.

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Translation kindly provided by

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