

# Abstract

of the results of a master's thesis submitted to the Beuth Hochschule für Technik, Berlin, bearing the title:

## **Study on the sustainability of heavy-duty mastic asphalt wearing courses on federal trunk roads**

with the support of



# 1. Initial situation

The network of federal trunk roads in Germany is one of the most frequented in Europe. It totals over 52,000 km in length, approx. 12,900 km of which are federal motorways.<sup>1</sup>

According to current statistics, today 71 % of goods in Germany are transported by road.<sup>2</sup> Therefore for economic reasons alone, it is extremely important to expand and maintain this road network. Every maintenance project, however, involves traffic restrictions through road closures that cause significant traffic disruption, particularly on federal motorways which account for only 6 % of the total road network but have to cope with 33% of the annual volume of traffic.<sup>3</sup> For the period from 2004 to 2025 forecasts predict an increase of approx. 79 % in freight transport on roads and an increase of approx. 84 % in long-distance goods transport on roads.<sup>4</sup> Besides this, there is a constant increase in permissible axle loads; over the past 50 years these have increased from 10 to 11.5 tons, representing a 75 % increase in pavement loads. If a loss of substance occurs as a result, road closures are then imminent.

The set goal must be to design federal trunk roads with high load-bearing capacity, without loss of substance under high and increasing pavement loads, and to ensure a long service life with long intervals between maintenance works. Mastic asphalt (MA) has been used to produce resistant and safe wearing courses on federal highways for over 50 years. Advantages offered by mastic asphalt wearing courses are their high resistance to deformation caused by traffic loads, as well as their long life. Examples of mastic asphalt wearing courses with a useful life of well over 20 years can be found all over Germany. When taking macroeconomic costs and congestion avoidance into account, mastic asphalt can generate even more benefits.

A comparison of the sustainability of rolled asphalt and mastic asphalt wearing courses has not been carried out in Germany so far. There is also no data available concerning the cost efficiency of mastic asphalt pavements in the light of their long service life. The main objective of a thesis on this topic was therefore to assess the sustainability of mastic asphalt wearing courses and to substantiate their durability, thus establishing the basis for a well-founded line of arguments in favour of mastic asphalt wearing courses on federal trunk roads.

<sup>1</sup> cf. BMVI, 2013, p. 168

<sup>2</sup> cf. Statistisches Bundesamt, 2015, p. 589

<sup>3</sup> cf. BMVBS 2010, p. 81

<sup>4</sup> cf. Ripke 2009, p. 1

## 2. Field-proven mastic asphalt wearing courses

For this master's thesis road sections across Germany were documented, these sections substantiating the deformation resistance and durability of a mastic asphalt pavement design.

The choice of road sections was based on a search carried out in all 16 federal states. In the course of this search federal trunk roads with mastic asphalt wearing courses and a service life of over 20 years were seldom found in the eastern states of Germany because asphalt road construction had been neglected there for decades. In central, western and southern Germany some of the roads with mastic asphalt wearing courses have been in service for 30 years and more. Stone mastic asphalt wearing courses (SMA) with such a long service life were, on the other hand, not to be found, in spite of intense searches. Another criterion when selecting the road sections was a high average daily traffic volume (DTV) with a high share of heavy vehicles (HV share). In this way, it was possible to identify and analyse a maximum service life in conjunction with a high traffic volume. The focus was on the federal states of Bavaria, Berlin, Hesse, North-Rhine Westphalia and Thuringia. Finding documentation on the construction projects - that sometimes went back 30 years - was a major challenge. With the support of specialists from the contracting authorities of the respective federal states and road construction companies it was, however, possible to gain access to very detailed information. The assessment of the current pavement condition was carried out by means of visual inspection in most cases. To determine the average daily traffic volume, figures from manual counts and permanent counting stations of the Bundesanstalt für Strassenwesen (BASt) (Federal Highway Research Institute) were used. In individual cases, figures were provided by the contracting authorities and departments of the federal states.

Several investigated road sections are presented below as examples.



### Berlin

Federal highway:	A100-AS Innsbr. Platz
DTV (SV-share):	144.000 (8.000)
Opened to traffic:	1994
in place:	<b>22 years</b>

During the visual assessment the mastic asphalt wearing course showed no defects, such as cracks, ruts, raveling or loss of material, in spite of the high traffic load.



### Thuringia

Federal highway: A4-AS Nohra  
 DTV (HV share): 56,000(10,100)  
 Opened to traffic: 1992  
 In place: **24 years**

Good visual condition of the wearing course.  
 Due to defects in the SMA hard shoulder this had to be repaired in 2008 after a service life of 16 years.



### North Rhine-Westphalia

Federal highway: A4-AK Cologne-West  
 DTV (HV share): 111,000(14,000)  
 Opened to traffic: 1985  
 In place: **31 years**

The road does not show any cracks, repair patches or significant deformations; there are no maintenance or repair works planned.



### Hesse

Federal highway : A7-AS Guxhagen  
 DTV (HV share): 73,000(15,200)  
 Openend to traffic: 1975  
 In place: **41 years**

The section has been in service for over 40 years .  
 Good visual condition of the wearing course.  
 Repair work has already been carried out on the SMA hard shoulder.



### Bavaria

Federal highway: A9- AK Nuremberg-East  
 DTV (HV share): 63,500 (9,000)  
 Opened to traffic: 1992  
 In place: **24 years**

No works are planned on the low-noise mastic asphalt wearing course .The SMA hard shoulder wearing course, however, is very much in need of repair.

### 3. Cost analysis

It is the set objective of road construction planners to design, build and operate federal trunk roads in a sustainable and efficient manner. It is therefore most important, particularly during the planning phase, to not only consider and compare investment costs for different pavement designs, but also to take into account maintenance costs and maintenance intervals during the period of use. In addition, macroeconomic costs and restrictions for road users due to roadworks have to be considered, because road maintenance and repair works are usually carried out with the roads still open to vehicle traffic.

The following gives a comparative cost analysis of mastic asphalt pavement design and stone mastic asphalt pavement design. For a successful cost analysis it is important to calculate the life cycle costs of the wearing courses. These cover the costs arising at the time of production, as well as maintenance and repair costs over a selected period of time.

In cooperation with construction estimators the current prices for the implementation of the individual designs and the respective maintenance and upkeep were calculated and compared with similar projects. The prices calculated are to be seen as reference values, because conditions and technical requirements can differ in the field. This concerns, for instance, the layer thickness or varying expenditure for securing traffic due to different traffic regulation plans. Since most influencing factors affect both construction methods, it is also possible to carry out an objective comparison of the life cycle costs. The road section used as a basis is a 1 km stretch of dual carriageway on a federal motorway with six lanes. This complies with the currently valid Richtlinien für die Autobahnen RAA (Guidelines for the Construction of Motorways) and corresponds to a standard cross section RQ 36 for heavy-duty motorways with a DTV of 60,000 to 100,000 vehicles per day and with a high share of heavy vehicles.

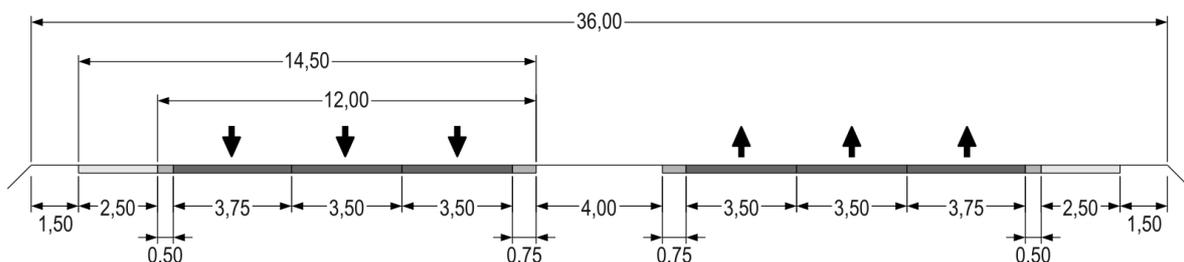


Fig.: RQ 36 according to RAA

Variant	Surface area	Thickness [mm]	Mix costs [€]	Laying costs [€]	Total [€]	Ratio [%]
SMA	29.000	35	162,000	78.000	240,000	100
MA	29.000	35	190,000	185.000	375,000	156

Table: Mix and laying costs SMA - MA

The life cycle costs are determined for a 30 year period. In this way it is possible to list and compare both the costs and well as any savings of the two methods of construction. The securing of traffic, breaking up work and the mix and laying costs, among other things, are taken as parameters of comparison

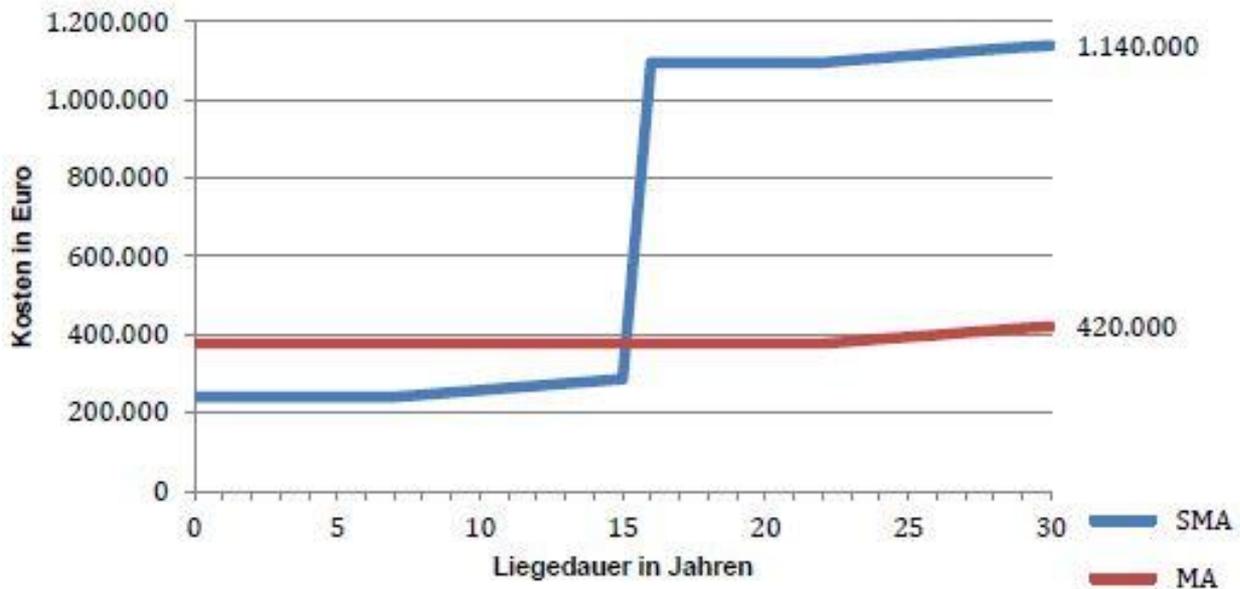
<i>During the period considered</i>	<b>Work</b>	<b>Comprising</b>	<b>SMA</b>	<b>MA</b>
<b>7<sup>th</sup> – 15<sup>th</sup> year after opening to traffic</b>	Maintenance	Among other things: Securing traffic Breaking-up work Mix costs Laying costs Sealing compound	45,000 €	-
<b>15<sup>th</sup> – 16<sup>th</sup> year after opening to traffic</b>	Repair	Among other things: Securing traffic Milling work Mix costs Laying costs Road marking work	810,000 €	-
<b>22<sup>nd</sup> – 30<sup>th</sup> year after opening to traffic</b>	Maintenance	Among other things: Securing traffic Breaking-up work Mix costs Laying costs Sealing compound	45,000 €	45,000 €
<b>Total costs for upkeep over a period of 30 years</b>			<b>900,000 €</b>	<b>45,000 €</b>
<b>Ratio</b>			<b>100%</b>	<b>5%</b>

Table: Maintenance / repair costs over 30 years

<b>Variant</b>	<b>Mix/Laying costs [€]</b>	<b>Maintenance/repair costs [€]</b>	<b>Total [€]</b>	<b>Ratio [%]</b>
<b>SMA</b>	240,000	900,000	1,140,000	100
<b>MA</b>	375,000	45,000	420,000	<b>37</b>
<b>Total savings when using mastic asphalt</b>			<b>720,000</b>	<b>63</b>

Table: Comparison of life cycle costs SMA - MA

## Life cycle costs



*Diagram: Comparison of life cycle costs SMA – MA  
(Costs in Euro / Service life in years)*

The graph shows the overall cost development as a function of the useful life. The higher mix and laying costs for mastic asphalt are predominantly due to the required additional work for the edge strips and the larger workforce needed for laying mastic asphalt. It can be clearly seen that the higher production costs for a wearing course made of mastic asphalt, compared to a wearing course of stone mastic asphalt, equal out after 15 to 16 years, which corresponds to half of the life-cycle-cost analysis period and is due to repair costs incurred for the SMA wearing course. Cost intensive factors for repair work are increasingly extensive traffic securing measures, milling work and road marking work for the stone mastic asphalt wearing course. The break-up process and relaying of the wearing course and binder course make up the largest share of the repair costs. Due to the voids content in SMA dirt and rainwater penetrate right down to the binder course and cause signs of wear. For this reason, repair work after 15 to 16 years is often required in both layers. Mastic asphalt, on the other hand, is produced without voids and forms a dense cover under which the binder layer is almost totally protected against rainwater, the aging process is longer and the mastic asphalt remains suitable for use throughout the entire life cycle. When considering different construction methods it becomes evident that maintenance work carried out during the service life is not primarily responsible for the cost difference. This maintenance work concerns small-scale repair jobs such as joint sealing and patching-up work. It is far more the aforementioned repair work that represents the crucial cost factor in the life cycle cost assessment. For the selected standard cross section RQ36 the life cycle costs for an SMA wearing course over a 30-year period amount to approx. € 1,140,000. On the other hand, according to experience, mastic asphalt wearing courses merely require maintenance measures throughout the selected period of use. The life cycle costs for a period of 30 years are approx. € 420,000.- for mastic asphalt.

## 4. Conclusion

Mastic asphalt road surfacing is one of the oldest materials used for wearing courses on federal trunk roads today. Due to its consistent further development there have been major changes over recent years. The mixing and laying temperature has, for example, been reduced and low-noise mastic asphalt wearing courses now also meet the demand for reduced traffic noise. The optimised noise performance of mastic asphalt reaches the same low-noise level as stone mastic asphalt courses. At the same time, mastic asphalt wearing courses offer a higher skid resistance and a longer service life than other wearing courses. Unlike other asphalt paving methods mastic asphalt does not require compaction after laying. It has a high proportion of filler and high binder content. It is void-free, waterproof and therefore highly resistant to all types of weather. Mastic asphalt is extremely hard wearing with a high resistance to deformation, making it particularly long-lasting and durable. The durability of mastic asphalt road surfaces is evidenced by their long life on federal highways under heavy loads. Examples of this long service life are to be found all over Germany. Mastic asphalt road sections with high volumes of heavy traffic and service lives of over 20 years – sometimes over 40 years – have been inspected and recorded and documents that date back to the time of construction have been searched. These road sections are located in Bavaria, Berlin, Hesse, North Rhine-Westphalia and Thuringia.

Due to their durability, mastic asphalt pavements can be preserved over a period of 30 years through maintenance measures, and so save a repair interval compared to stone mastic asphalt. Although costs for a mastic asphalt wearing course are around 1.5 times higher than those for a stone mastic asphalt wearing course, this ratio is reversed during the useful life: at the end of the considered life cycle of 30 years, a mastic asphalt wearing course is 60% more cost-efficient than a stone mastic asphalt wearing course. This scenario underscores the sustainable economic benefits of a mastic asphalt pavement and shows that by calculating the life cycle costs in advance, reservations regarding the choice of a mastic asphalt wearing course can be disproved, despite higher production costs, thus paving the way for a sustainable solution.

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