Calculated dimensioning as the basis for integrated, sustainable asphalt pavements

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In terms of sustainability, asphalt pavements are superior to concrete pavements in many aspects. The reasons for this are the complete reusability of asphalt as a construction material and the very high energy input required for cement production, which is necessary for concrete. The degree of reuse and, to an even greater extent, the durability of asphalt roads are important factors in reducing the CO_2 footprint of asphalt road construction (ZANDER, 2024)*. With this in mind, it is definitely worth paying particular attention to these aspects when planning future measures for new construction, maintenance or renewal. With the RDO Asphalt 09/24* (FGSV, 2024b) *a tool is available in the catalog of FGSV regulations that is suitable for optimizing asphalt and superstructure concepts in advance of a construction project with the aim for maximum durability by a minimum consumption of resources. In addition to road construction, RDO Asphalt 09/24 can also be used to optimize pavements for port, logistics and industrial areas, allowing them to be tailored precisely to the intended use. This prevents the currently still frequent over dimensioning of asphalt pavements and reduces the consumption of resources. RDO Asphalt 09/24 is therefore suitable for significantly reducing CO_2 emissions over the lifetime of an asphalt pavement and can therefore make an immense contribution to the sustainability of asphalt paving. The experience gained from 15 years of application since the introduction of RDO Asphalt 09 provides a comprehensive basis for this, so there are no obstacles against a broad application of the calculated dimensioning.*

1 Introduction

Asphalt pavements are predominantly dimensioned in accordance with RStO 12/24 (FGSV, 2024bb) which are empirical based and provide various recommendations for the thicknesses of the individual asphalt layers for defined load classes and concepts for the structure of the unbound layers. This enables a relatively simple and quick estimation of the required layer thicknesses. As long as the traffic loads are not significantly higher than assumed in the planning, the layer thicknesses according to RStO 12/24 are capable to build asphalt pavements that are durable for at least 30 years.

Due to the increasing heavy traffic on federal highways, however, a dimensioning-relevant load of B = 100 million equivalent 10 t-axle crossings is often exceeded, which represents the upper limit of load class Bk100 according to RStO 12/24. As a result, the underlying empirical background is also abandoned. Pavements with a dimensioning-relevant load of more than 100 million equivalent 10 t-axle crossings should therefore be dimensioned by calculation in accordance with RDO Asphalt 09/24. However, this method has so far only been applied on a few exceptional cases, as many planners and engineering offices are not familiar with the application of calculated dimensioning. Nevertheless, the concepts according to RStO 12/24 often work, as these contain a large retention dimension and modern asphalt mix concepts have better fatigue behavior than the asphalts on which they are based. However, there is no verifiable basis for this and existing optimization potential may not be used.

A further demand for the application of RDO Asphalt 09/24 arises for the design of asphalt pavements for port, logistics and industrial areas. There is currently a vacuum in the technical regulations here, as only the M VAB, Part 3 (FGSV, 2018aa) has defined uniform regulations for concrete surfaces. As a result, asphalt pavements for these applications are also dimensioned in accordance with RStO 12/24 and are therefore often significantly too thick.
The calculated dimensioning has been consistently applied by the first author in particular for 15 years, since the publication of RDO Asphalt 09, which was replaced by RDO Asphalt 09/24 in 2024, for a wide variety of projects in the field of federal highways, federal roads as well as port, logistics and industrial area pavements. Thanks to the many years of using RDO Asphalt, a very extensive database with stiffness and fatigue parameters has now been built up, which contains a wide variety of asphalt compositions from many regions of Germany, including the most modern concepts currently available. As early as 2017, Schäfer & Rosauer were able to present extensive findings that had been collected in the previous period, using the example of the BAB 14 between the AS Löbejün and Altmödewitz (SCHÄFER & ROSAUER, 2017). The correlations between the composition of the asphalt mix and the results of the calculated dimensioning were also shown. Since then, further extensive practical experience has been gathered. The success of the method is demonstrated by the fact that premature fatigue cracking has not yet been detected on any of the surfaces dimensioned by the authors. By defining appropriate requirements for the asphalt mix and implementing them in practice, it is possible to ensure that suitable asphalts of the required quality are laid in order to verify the results of the calculated dimensioning with the stiffness and fatigue properties determined on drill cores from the finished layer.

In the following sections, the principle of calculated dimensioning will be presented in a condensed form. The procedure is then presented using two examples to illustrate the process in an understandable way.

2 Basic principle of calculated dimensioning

The calculated dimensioning of a traffic area pavement is based on the hypothesis according to Miner (1945) that partial damage to the asphalt pavement occurs with each load change, which accumulates until material fatigue, in other words failure, occurs. It is also assumed that this partial damage occurs on the bottom of the asphalt base layer, as tensile stresses occur precisely there due to the deformation at the axle transition. The stress curve is analogous to a loaded bending beam (Fig. 1). (MINER, 1945)

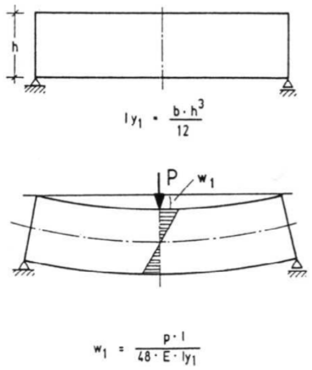


Figure 1: Stress curve of a bending beam with full bonding of the layers (Weber, 1991)

This individual partial damage to the asphalt base layer adds up over the period of use until an initial fatigue crack forms. In addition to the traffic loads that occur, this point in time also depends on the temperature distributions that occur in the asphalt pavement. According to RDO Asphalt 09/24, a total of 4,056 different stress states can occur in an asphalt pavement based on the axle load distributions and the characteristic temperature profiles. The result of the calculation is a fatigue status that indicates the percentage of partial damage occurring during the period of use in relation to the total sum of partial damage that would lead to failure. In addition to the fatigue status of the asphalt pavement, the proportion of the maximum compressive stress criterion for the underlying layers is also determined. If this percentage is 100%, plastic deformation would occur in the unbound layers, which could lead to damage in the asphalt pavement.

3 Procedure for calculated dimensioning

When creating a suitable pavement concept for the respective application, a layer structure in accordance with RStO 12/24, Board 1 should be used as a starting point. This is already an important step on the way to sustainable road surfacing. Taking into account the regional availability of building materials, it is useful to match the unbound layers accordingly in order to be able to use the existing layers at best and to keep the supply of other building materials to a minimum. In northern Germany, for example, it is advantageous to choose a construction method that uses frost-resistant layers of dense graded sands. In southern Germany, on the other hand, the transportation routes from quarries are usually short, meaning that frost protection or gravel base layers made from crushed material mixtures can also be used here.

The selected structure of the unbound layers then results in the corresponding layer thicknesses for the asphalt layers according to the respective standard structures in accordance with RStO 12/24, Board 1. These should then be transferred to the software for calculating the dimensions in order to make further optimizations.

3.1 Dimensioning-relevant load

The determination of the dimensioning-relevant load of roads for the calculation based dimensioning is usually carried out according to AP EDS-1, Ausgabe 2022 (FGSV, 2022) and can be calculated using either traffic count data or detailed data from axle load weighing.
In many cases, however, a load class Bk10 or even Bk32 is assumed for port, logistics and industrial areas due to the almost exclusive truck traffic. However, a more differentiated view of the planned operating procedures usually reveals that significantly lower traffic loads are to be expected. In addition, there is predominantly no lane-running traffic on these areas, except for the area directly in front of any loading ramps. This distribution of traffic plays an even greater role in port areas, as cargo handling vehicles are operated here, which can have axle loads of up to 100 tons. When applying the established calculation method, extremely high dimensioning-relevant loads then arise. These lead to large thicknesses of the asphalt pavement. It must be taken into account that the load is distributed over a large area, so that the actual traffic load acting on a point of the asphalt base layer is much lower.

It is therefore essential to take a close look at the intended use and the spatial conditions before carrying out the calculated dimensioning, especially for areas with special use, in order to create an optimized pavement concept. In many cases, considerable amounts of asphalt can be saved without restricting the durability. These findings and experiences will also be included in the “Merkblatt für Planung und Bau von Hafen-, Logistik- und Industrieflächenbefestigungen” (M HLI) *(FGSV, 2024a)*.

3.2 Material characteristics

In general, the RDO Asphalt 09/24, Annex 4 provides the comparative values for the calibration asphalts that are used to determine the adjustment factors. However, these correspond to theoretical characteristic values and do not represent the service behavior of real asphalts. For this reason, material parameters must be used for the mathematical dimensioning, which are determined using the Spaltzug-Schwellversuch in accordance with TP Asphalt-StB, Part 24 (FGSV, 2018b) or the TP Asphalt-StB, Part 26 (FGSV, 2018c) can be determined. For an initial estimate, characteristic values can be used that originate from comparable construction projects, if possible with a regional reference. Care should be taken here not to use the best possible characteristic values, but to select an asphalt mix that represents the average of known asphalts. In this way, a pavement concept dimensioned by calculation can be created in advance of a construction project.

Nevertheless, extended tests should be carried out as part of the preparation of the suitability certificates for the asphalts actually intended for use in order to determine the service behavior. As mentioned above, the stiffness-temperature function and the fatigue function, as well as the cooling behavior, are of particular relevance here. If significant deviations from the assumed material parameters and a fatigue status of over 100 % are found, either the asphalt mix needs to be optimized or the pavement concept needs to be adapted.

3.3 Target values

The layer thicknesses of the asphalt pavement, which are determined in the calculated dimensioning, are absolute values, so that the tolerances of the ZTV Asphalt-StB 07/13 (FGSV, 2013) still apply due to the currently still common construction contract design, but lead to striking deviations in the results of the mathematical dimensioning when fully utilized with regard to the minimum layer thickness. It is therefore imperative to provide for a sufficient reserve when determining the layer thicknesses in order to take into account the construction related fluctuations. It has proven to be expedient to carry out an additional calculation run in which the thickness of the asphalt base course is reduced by 2 cm. In order not to change the thickness of the frost-resistant superstructure, the thickness is equalized in the lowest layer of the unbound layers. In this case, a fatigue status of around 75 % should not be exceeded. Experience shows that this generally ensures that a fatigue status of 100% is not exceeded when the results of the calculated dimensioning are checked later using asphalt parameters from the built layers.

4 Practical examples

To better illustrate the procedure, two examples borrowed from practice are presented below. Both a typical highway and a special application in the field of industrial areas are shown. This is intended to demonstrate how the RDO Asphalt 09/24 can be used for the various applications in order to develop the most suitable superstructure concept. However, the results presented do not represent a generally valid recommendation and are only applicable under the assumptions made and the corresponding material parameters applied. The asphalts used for the calculation were already composed at the time for the respective prevailing stresses as specified in the update of the TL Asphalt-StB (FGSV, 2024cc) as this improved composition of the asphalt mix is suitable for significantly improving performance. The stiffness-temperature functions and the fatigue functions of all asphalts used in the following calculations are shown in Figures 2 and 3. For comparison, the corresponding functions of the calibration asphalts from the RDO Asphalt 09/24 are also included in the diagrams.

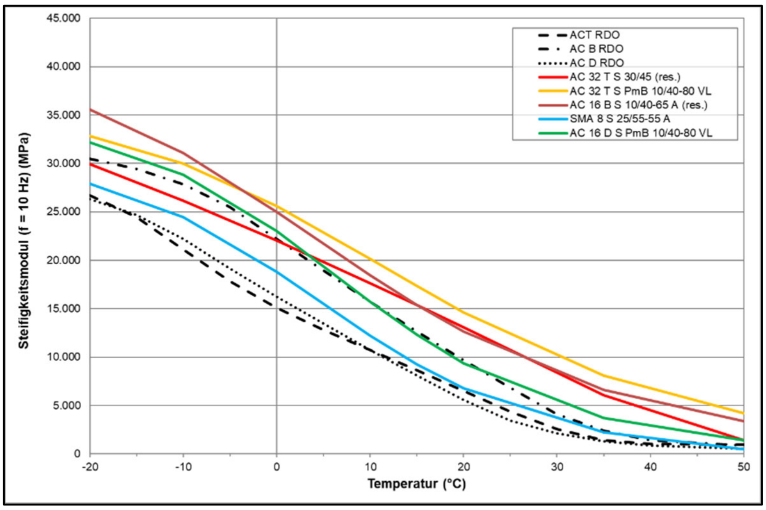


Figure 2: Stiffness-temperature functions of the asphalts used for the calculated dimensioning in the following sections

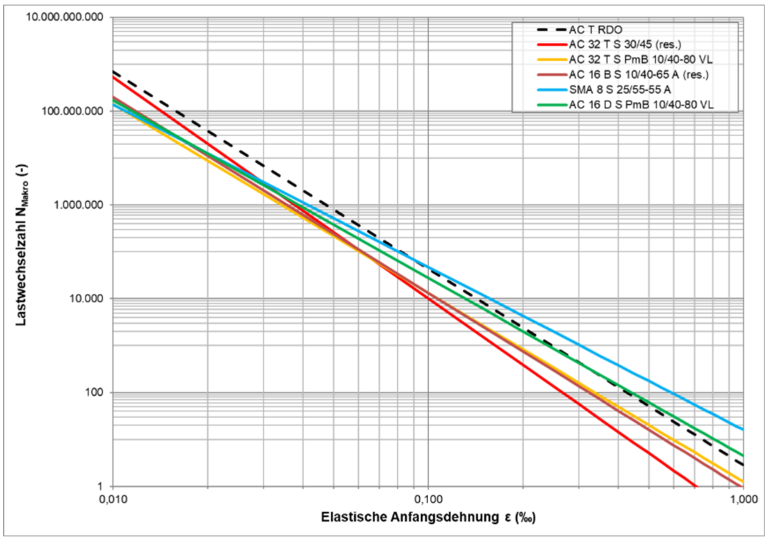


Figure 3: Fatigue functions of the asphalts used for the calculated dimensioning in the following sections

4.1 Example of a federal highway

In the area of the federal highways, a road with a dimensioning-relevant load of B = 150 million equivalent 10-t-axle crossings over a service life of 30 years was assumed for the example calculation. In addition, it was planned to produce the asphalt layers on a gravel base layer and a frost protection layer in accordance with RStO 12/24, Board 1, line 3, so that this represents the reference structure for the dimensioning calculations.

Accordingly, an asphalt pavement with a combination of asphalt wearing and binder course of 12 cm thick, an asphalt base layer 18 cm thick and a gravel base layer 15 cm thick should be provided, on the surface of which a deformation modulus E_{V2} of at least 150 MPa must be achieved. A frost protection layer with a deformation modulus of at least 120 MPa must be placed underneath. This results in a minimum thickness of 30 cm with a deformation modulus of 45 MPa on the subgrade. Based on many years of experience, it can be assumed for this structure that a service life of 30 years can be safely achieved with standard asphalts that have been installed in accordance with the requirements, with a dimensioning-relevant load of up to 100 million equivalent 10-t-axle crossings.

The 150 million equivalent 10-t-axle crossings envisaged for this example are 50 % higher than the upper limit of the Bk100, so that a calculated dimensioning should be carried out here. The parameters used to achieve this dimensioning-relevant load are summarized in Table 1.

Table 1: Applied dimensioning parameters

Dimensioning parameters	
$DTV^{(SV)}$	13,650 vehicles/24h
f_A	4,38
f_1	0,5
f_2	1,0
f_3	1,02
p_Z	0,02
Axle load collective	BAB "Fern"
KiST-Zone	2

As described in Section 3.2, the calibration asphalts are initially available for the calculated dimensioning, which represent the experience background of the RStO. If these material parameters are now used for the dimensioning-relevant load of B = 150 equivalent 10-t-axle crossings and the structure described above, a fatigue status of 173.53 % is plausibly achieved in the asphalt base layer, resulting in a service life of only around 19 years. In order to reliably achieve the service life of 30 years, the thickness of the asphalt base course would have to be adjusted by 3 cm to 21 cm.

However, in order to be able to adequately take into account the actual state of development of asphalt technology, material parameters of asphalts from other projects should be used instead of the calibration asphalts, which reflect the expected service behavior. In the calculated dimensioning carried out here, these are an AC 32 T S with a resulting road bitumen 30/45 and 60% reclaimed asphalt, an asphalt binder AC 16 B S with the resulting polymer-modified bitumen 10/40-65 A and 50% reclaimed asphalt and a stone mastic asphalt SMA 8 S with the polymer-modified bitumen 25/55-55 A. Applying the corresponding material characteristics, the structure described above in accordance with RStO 12/24, Board 1, line 3, results in a fatigue status of only 26.72 % for a service life of 30 years and B = 150 million equivalent 10-t-axle crossings, so that a service life of 69 years is achieved here. Accordingly, there is even further optimization potential for saving asphalt.

The optimization here should be carried out according to the principle already described in which it is determined that if the asphalt pavement falls 2 cm below the target thickness, a fatigue status of 75 % is not exceeded. Based on this assumption, it is possible to reduce the thickness of the asphalt base course by 2 cm to 16 cm without restricting the expected service life.

Another option included in the comparison was the compact asphalt wearing and binder course. It is known that the very good compaction properties of compact asphalt make it possible to achieve a very high durability of the layers laid in this way, which is comparable to mastic asphalt layers. In addition, the formation of permanent deformations is significantly less likely due to the reduced thickness of the asphalt wearing course (Schäfer & Rosauer, 2007).

When using compact asphalt, reducing the thickness of the asphalt surface to 10 cm and increasing the thickness of the asphalt base layer in the same way has proven to be effective. This often results in a higher reuse rate, as larger quantities of asphalt granulate can be added to the asphalt base course mix. At the same time, this procedure offers an advantage for subsequent renewal measures, as milling is usually carried out somewhat deeper than necessary and a paving thickness of 12 cm is then also possible. The result of the calculated dimensioning shows that even in this case, the reduced thickness of the asphalt surface can be compensated with the asphalt base course, resulting in a structure of 2 cm asphalt surface course, 8 cm asphalt binder course and 18 cm asphalt base course. For a service life of 30 years, a fatigue status of 38.20 % is achieved.

In Figure 4 the asphalt pavement variants described above are compared again with the corresponding fatigue status.

This clearly shows that the consistent application of RDO Asphalt 09/24 when dimensioning highways can ensure that the standard structure in accordance with RStO 12/24 is at all suitable for absorbing the expected traffic load and, on the other hand, that a frequently existing optimization potential can be exploited.

Particularly with regard to the "eternal road" and the increasingly prevalent concept of sustainability, it can also make sense to consider longer periods of use than the 30 years usually as-

sumed. The application of RDO Asphalt 09/24 is also ideally suited for this purpose. By extending the period of use in the calculation example presented above to 50 years, this results in a dimensioning-relevant load of B = 312.8 million equivalent 10-t-axle crossings. With this traffic load, the fatigue status for the optimized structure in compact design described above is 79.64 %, so that it would also be suitable in principle if the target thicknesses were adhered to. Nevertheless, if the overall thickness is diminished by 2 cm, a fatigue status of around 75 % should not be exceeded. This means that the thickness of the asphalt base layer must be increased by 3 cm to 21 cm. After this adjustment, a fatigue status of 44.80 % is achieved over a service life of 50 years.
This consideration shows that the additional cost for a significant extension of the service life, especially compared to a non-optimized structure, is very low, so that very durable asphalt pavements can be produced with modern asphalt mix concepts. Assuming that overall durability has the greatest influence on the carbon footprint of a road construction project, this extension of the service life should definitely be taken into account.

At the same time, the RDO Asphalt 09/24 is in principle also suitable for carrying out a success check after the asphalt pavement has been laid. It has proven useful to calculate the fatigue status at the thinnest point of the asphalt pavement in the main lane. However, it must be taken into account that the adjustment factors used for the mathematical dimensioning in the run-up to the construction project also take into account the uncertainty of the laboratory mix compared to the large-scale asphalt mix, which is no longer present when determining the stiffness-temperature and fatigue function on the finished layer. For this reason, a correction of the adjustment factor is necessary. A factor of 1.43, by which the adjustment factor is increased, has proven itself in this example for an asphalt pavement on a gravel base course from 3,000 to 4,920. Experience shows that a very good estimation of the actual fatigue behavior is possible with this method.

4.2 Example of industrial paving

As already mentioned in the introduction, individual solutions for the use of asphalt pavements on port, logistics and industrial areas can be designed using calculated dimensioning in accordance with RDO Asphalt 09/24. The special features of the loads on these surfaces can be taken into account very precisely, so that over dimensioning, as has often been the case up to now, can be avoided. For example, the asphalt binder course can usually be omitted for areas with predominantly slow-moving traffic, as only a few shear forces occur at this depth during operation, as these are usually due to braking, acceleration and steering processes.

In practice, it has also been shown that it makes sense to increase the thickness of the asphalt wearing course to 6 cm, especially on surfaces subject to high loads, in order to use an asphalt concrete AC 16 D S that is less sensitive to surface shear stresses and permanent deformations. The use of high-performance bitumen, also in the asphalt base course, has also proven its worth in order to ensure greater elasticity here. This can achieve a further significant reduction in the fatigue status. The aim must always be to offer the operator of the surface, for whom it represents an operating resource, the best combination of cost-effectiveness and durability.

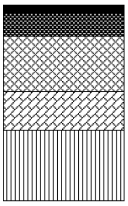
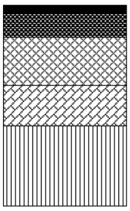
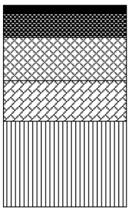
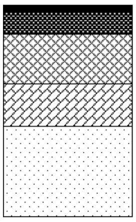
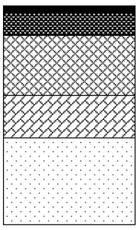
Structure RStO with calibration asphalt  3,0 cm Asphaltdeckschicht, Kalibrierasphalt 9,0 cm Asphaltbinderschicht, Kalibrierasphalt 21,0 cm Asphalttragschicht, Kalibrierasphalt 15,0 cm Schottertragschicht, E_{V2} ≥ 150 MPa 27,0 cm Frostschutzschicht, E_{V2} ≥ 120 MPa **75,0 cm Gesamtdicke** anstehender Boden / Planum, E_{V2} ≥ 45 MPa	**Fatigue status after 30 years:** **B = 150.0 m equivalent 10 t axles.** Asphalt base course: 93.38 % **Criterion max. compressive stress:** Gravel base course: 0.00 % Frost protection layer: 0.00 % Planum: 20.45 %
Structure RStO with optimized asphalts  3,0 cm Asphaltdeckschicht, SMA 8 S, 25/55-55 A 9,0 cm Asphaltbinderschicht, AC 16 B S, 10/40-65 A 18,0 cm Asphalttragschicht, AC 32 T S, 30/45 15,0 cm Schottertragschicht, E_{V2} ≥ 150 MPa 30,0 cm Frostschutzschicht, E_{V2} ≥ 120 MPa **75,0 cm Gesamtdicke** anstehender Boden / Planum, E_{V2} ≥ 45 MPa	**Fatigue status after 30 years:** **B = 150.0 m equivalent 10 t axles.** Asphalt base course: 26.72 % **Criterion max. compressive stress:** Gravel base course: 0.00 % Frost protection layer: 0.00 % Planum: 0.01 %
Optimized structure according to RDO Asphalt  3,0 cm Asphaltdeckschicht, SMA 8 S, 25/55-55 A 9,0 cm Asphaltbinderschicht, AC 16 B S, 10/40-65 A 16,0 cm Asphalttragschicht, AC 32 T S, 30/45 15,0 cm Schottertragschicht, E_{V2} ≥ 150 MPa 32,0 cm Frostschutzschicht, E_{V2} ≥ 120 MPa **75,0 cm Gesamtdicke** anstehender Boden / Planum, E_{V2} ≥ 45 MPa	**Fatigue status after 30 years:** **B = 150.0 m equivalent 10 t axles.** Asphalt base course: 40.20 % **Criterion max. compressive stress:** Gravel base course: 0.00 % Frost protection layer: 0.00 % Planum: 0.04 % **Fatigue status, total asphalt thickness undercut by 2 cm: 67.64 %**
Optimized structure according to RDO Asphalt Compact asphalt  2,0 cm Asphaltdeckschicht, SMA 8 S, 25/55-55 A 8,0 cm Asphaltbinderschicht, AC 16 B S, 10/40-65 A 18,0 cm Asphalttragschicht, AC 32 T S, 30/45 15,0 cm Schottertragschicht, E_{V2} ≥ 150 MPa 32,0 cm Frostschutzschicht, E_{V2} ≥ 120 MPa **76,0 cm Gesamtdicke** anstehender Boden / Planum, E_{V2} ≥ 45 MPa	**Fatigue status after 30 years:** **B = 150.0 m equivalent 10 t axles.** Asphalt base course: 38.20 % **Criterion max. compressive stress:** Gravel base course: 0.00 % Frost protection layer: 0.00 % Planum: 0.03 % **Fatigue status, total asphalt thickness undercut by 2 cm: 63.81 %**
Optimized structure according to RDO Asphalt Compact asphalt "Eternity road"  2,0 cm Asphaltdeckschicht, SMA 8 S, 25/55-55 A 8,0 cm Asphaltbinderschicht, AC 16 B S, 10/40-65 A 21,0 cm Asphalttragschicht, AC 32 T S, 30/45 15,0 cm Schottertragschicht, E_{V2} ≥ 150 MPa 30,0 cm Frostschutzschicht, E_{V2} ≥ 120 MPa **76,0 cm Gesamtdicke** anstehender Boden / Planum, E_{V2} ≥ 45 MPa	**Fatigue status after 50 years:** **B = 312.8 million equivalent 10 t axles.** Asphalt base course: 44.80 **Criterion max. compressive stress:** Gravel base course: 0.00 % Frost protection layer: 0.00 % Planum: 0.00 % **Fatigue status, total asphalt thickness undercut by 2 cm: 64.62 %**

Figure 4: Compilation of the different superstructure concepts for a federal highway

Over the last 15 years, a wide range of port-, logistics and industrial area pavements have also been dimensioned on a calculation base, primarily by the first author. The projects include multipurpose terminals, container terminals, such as the Container Terminal Wilhelmshaven or inland container terminals, heavy load routes and logistics yards. In the following example, one of these construction projects with particularly high traffic loads was selected to show the range of applications for which the asphalt construction method is suitable with the right planning and implementation of the construction measures.

The site is located in northern Germany on the Lower Weser and is used for the production and transportation of monopiles. These are foundation elements for offshore windmills. In principle, these are large steel pipes that taper at one end and are driven into the seabed with the thicker end. The current generation of monopiles weigh up to 2,500 tons, are up to 120 m long and around 10 m in diameter. Due to their great length and weight, the monopiles are usually transported on self-propelled modular transporters (SPMT) with axle loads of currently up to around 35 tons and in future up to 48 tons with a maximum appropriate outreach. Figure 5 shows an example of the transportation of a monopile with a weight of 2,300 ton 24 x 3 axle lines.

Figure 5: Transport of a monopile on SPMT

Figure 6: Transport of a monopile by SPMT over a dike crossing

As already shown in Figure 5 the special feature of these transports in this particular case is that the dyke between the factory premises and the associated external warehouse has to be crossed by means of a ramp with a gradient of around 4.5 %. This is illustrated in Figure 6. This results in considerable loads acting on the asphalt pavement. A pavement concept was also developed for this application on the basis of the calculated dimensioning.

At the time, the expected annual production output of the plant was used as the basis for determining the dimensioning-relevant load, resulting in a B number of 32 million equivalent 10-t-axle crossings for a utilization period of 30 years. As the very slow travel speed of the SPMT results in almost static loads, it was also necessary to ensure that these loads were sufficiently distributed in the subsoil of dense graded sand, so that a thickness of 50 cm was selected for the gravel base layer and in addition, high demands were placed on the crushed material 0/32 of natural stone for gravel base courses in order to ensure a large load transfer angle and high durability. The asphalt pavement consists of a 6 cm thick asphalt surface course made of an asphalt concrete AC 16 D S with PmB 10/25 VL and a 14 cm thick asphalt base course made of asphalt base course mix AC 32 T S with the resulting bitumen 30/45 and thus has a total thickness of only 20 cm (Figure 7), compared to a comparable structure according to RStO 12/24, Board 1, line 3 with a total thickness of 26 cm. With the assumptions made at the time, this resulted in a fatigue status of the asphalt base course of 57.2 %.

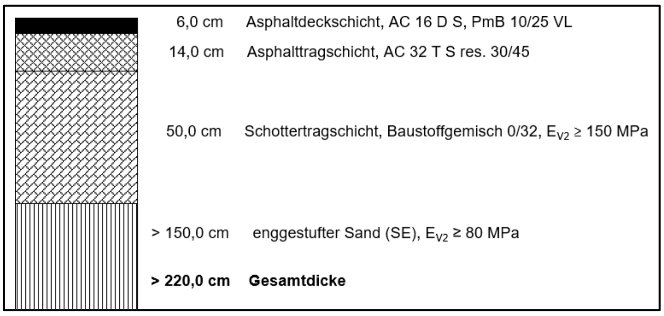


Figure 7: Layerstructure of the pavement for the dike crossing

The dyke crossing created in this way has been in use since 2015, initially with monopiles weighing up to around 1,000 tons. Since February 2022, transports with a total weight of up to 2,500 tons have been carried out. Previous use has not resulted in any damage to the asphalt pavement caused by these extremely heavy and demanding transports. No cracks or deformations have occurred, so that it can be assumed that the calculated asphalt pavement is up to the demands.

Due to new findings, an AC 16 D S with the viscosity-modified polymer-modified bitumen PmB 10/40-80 VL is now being used, in contrast to the asphalt concrete AC 16 D S with PmB 10/25 VL that was used as the input parameter for the calculation. This bitumen offers a higher polymer modification and is therefore even more resistant to permanent deformation and offers better low-temperature flexibility, which is particularly advantageous for large asphalt surfaces due to temperature-induced material expansion and shrinkage. The very good properties of this bitumen were confirmed in studies that led to extensive investigations into the cause and possible measures to prevent this damage due to rutting that occurred nationwide after the summer of 2019 (Schäfer, 2022).

4.3 Conclusions

The two examples presented show the range of applications that can be covered with RDO Asphalt 09/24. This ranges from standard applications in the field of road construction to highly specialized and individually tailored pavement concepts for use on highly stressed surfaces.

In both cases, it was possible to achieve significant savings in asphalt mix and thus in raw materials compared to a structure according to RStO 12/24, which is not applicable for port, logistics and industrial areas anyway. By assuming material parameters that were determined from laboratory tests on real asphalts, the properties of asphalt mixes with high rates of reclaimed asphalt can also be reproduced, so that a negative influence on the durability of the asphalt pavement can be ruled out.

Due to the calculation method on which the RDO Asphalt 09/24 is based, asphalt pavements can in principle be dimensioned for any length of use. However, it should be taken into account that, in addition to fatigue cracking, the bitumen will also age and damage may also occur due to the ingress of surface water if structural maintenance is neglected. Nevertheless, calculated dimensioning is an important building block on the way to the "eternal road", with which the optimum solution can be developed for the specific application and material.

In conclusion, it can therefore be said that, based on the wealth of experience now available, the time has definitely come to apply this innovative and sustainable approach to all suitable projects.

5 Summary

With the RDO Asphalt 09/24, a tool is available for the dimensioning of asphalt road pavements that can be applied in a user-friendly manner using software solutions that are now available. Compared to a superstructure according to RStO 12/24, the consideration of actual traffic loads in conjunction with characteristic temperature profiles determines calculable load conditions that are suitable for fatigue verification. The resistance to fatigue cracking on the bottom of the asphalt base layer can be determined very precisely by the simultaneous verification with material-specific characteristic values that are applied to the asphalt mix that is to be used in the traffic surface pavement. Thanks to this precise calculation method, it is sometimes possible to optimize the pavement concepts to a considerable extent, which at the same time leads to asphalt savings in the centimeter range. The consistent application of calculated dimensioning in accordance with RDO Asphalt 09/24 in the planning of federal highways and asphalt pavements for specially used areas can save a great deal of resources. At the same time, clearly detailed information on the expected service life of the asphalt pavement can be provided.

Two practical examples were used to demonstrate the need for optimization that arises from calculated dimensioning.

On the one hand, the thickness of an asphalt pavement for a federal highway with a dimensioning-relevant load of B = 150 million equivalent 10 t axle transitions, which is above the experience background of RStO 12/24, was reduced by one centimeter by using asphalts with very good performance properties. At the same time, a service life of 50 years can be achieved with an additional thickness of 3 cm compared to the standard 30 years. In addition, due to the greater durability, the possibility of installing an asphalt surface and asphalt binder course as a compact asphalt pavement was also taken into consideration.

On the other hand, it was shown that an asphalt pavement with a thickness of only 20 cm is suitable for absorbing extreme loads resulting from the transportation of monopiles over a slope with a longitudinal gradient of 4.5% using SPMT, even on highly stressed areas.

These two examples represent only a small part of the wide range of applications of computational dimensioning, but already offer a very clear insight into the possibilities that result from this. Particularly with regard to sustainability, the possibility of using material parameters of asphalts with high reuse rates and ensuring long periods of use can make a major contribution to asphalt construction.

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