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# PAVING LOW-TEMPERATURE ASPHALT ON THE B 169 HIGHWAY NEAR HEYDA

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## Abstract

Research into lowering the temperature during the production and installation of hot asphalt has been going on for a long time. In addition to developing appropriate recipes, it is important to gain experience, particularly in asphalt paving technology, since in addition to the behavior of the different asphalt mixtures during their compaction, external factors such as the location of the project and weather conditions also play an important role. The testing of the low-temperature asphalt on the federal highway B 169 was carried out successfully. Due to the high pre-compaction by the paver screed, the required compaction values were achieved on the binder course with 4 rolling passes and on the surface course with 3 rolling passes. The viscosity-changing additives and the selected rolling technology had a positive influence on the results. However, precise measurement results for compaction could not be achieved using the PQI probe.

## Keywords

Low-temperature asphalt; Behavior of asphalt mixtures; Asphalt-related emissions; PQI probe.

## Introduction

Temperature reduction during hot mix asphalt production and paving has long been a subject of research, which led to the development of the corresponding information sheet (FGSV, 2021) and recommendations for implementation (DAV, 2021). Tests have been carried out with the main objectives of saving energy and reducing $CO_2$ emissions.

In addition, the Committee on Hazardous Substances of the Federal Institute for Occupational Safety and Health adopted a significantly lower occupational exposure threshold value for bitumen vapors and aerosols from bitumen in 2019. The 1.5 mg/m³ air threshold value will have to be met by January 1, 2025, which will require changes in the composition of asphalt mixes and other protective measures on paving equipment.

Apart from research into the asphalt formulations themselves, it is important to gain experience, especially in asphalt paving technology, where external factors such as project location and weather conditions, as well as the behavior of different asphalt mixtures during compaction, play an important role.

For these reasons, the German Federal Ministry of Transport and Digital Infrastructure issued Circular 09/2021 (BMDV, 2021) on the implementation of test tracks for construction projects on federal highways using low-temperature roller-compacted asphalt in order to gain as much knowledge as possible.

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The aforementioned Circular specifies the principles for the setup of test tracks. These are used to test the material under paving conditions, taking into account external factors.

Chemnitzer Verkehrsbau GmbH was contracted to build a test track on the B 169 highway between Heyda and Stockhausen.

As part of this project, a diploma thesis entitled "Non-Destructive Compaction Control for Quality Assurance in Asphalt Road Construction Using a PQI Probe" was conducted for the asphalt paving process.

# 1 Definitions

## 1.1 Low-Temperature Asphalt

In addition to the relevant regulations for the delivery of asphalt mixtures (TL Asphalt – StB 07/13) and the supplementary technical contract conditions and guidelines for the construction of asphalt pavements (ZTV Asphalt – StB 07/13), there are also the "Guidelines for Warm Mix Asphalt" (M TA) (FGSV, 2021).

The aim is to reduce the production and working temperature of asphalt mixtures by up to 30K using viscosity-modified bitumen or viscosity-modified additives. The benefits that can be achieved, such as energy and $CO_2$ savings and reduced fumes, are offset by the challenges, particularly when it comes to laying the asphalt. As a result, the lower temperature threshold for quality and damage-free compaction of the paved low-temperature asphalt hardly changes, so the effective compaction time is considerably shorter.

## 1.2 Viscosity-Modified and Polymer-Modified Bitumens for Paving Applications

Paving and polymer-modified bitumens are in accordance with TL Bitumen – StB with viscosity-modifying organic additives.

## 1.3 Viscosity-Modifying Additives

Organic or mineral substances are added to bitumen to modify properties at production and processing temperatures.

# 2 Trial Paving of Low-Temperature Asphalt on the B 169 Federal Highway

## 2.1 Test Field Program

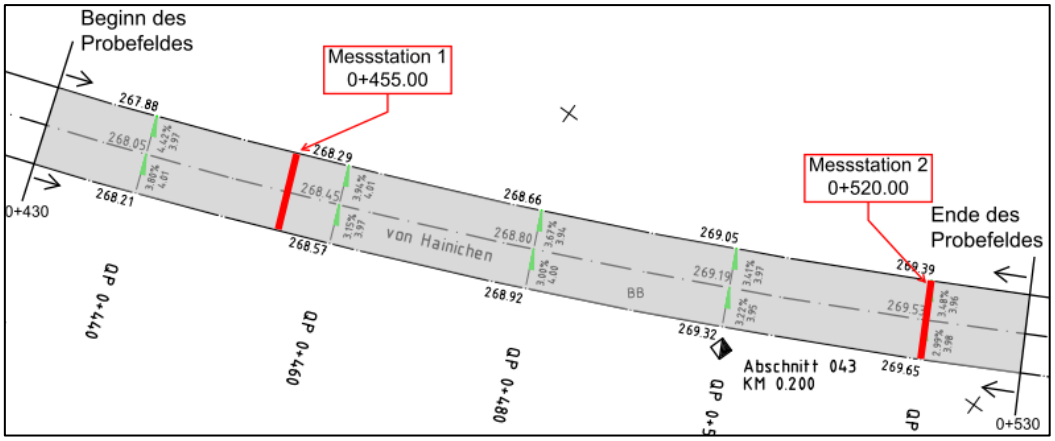
Due to the lack of knowledge about the compaction behavior of temperature-reduced asphalts under construction site conditions, the following priorities were defined for the investigation of both the binder course and the wearing course:

1. investigation of temperature-dependent compaction behavior of low-temperature asphalt by documenting temperature and compaction history,
2. determination of the compaction time during which the asphalt can be compacted in accordance with quality standards,
3. investigation of the influence of weather conditions, air, and subgrade temperatures on the core temperature of paved asphalt,
4. determination of precompaction by the paver,
5. determination of the type and extent of the use of rollers with the number of rollers, the type of compaction, and the number of rollers passes until the completion of work, and

6. investigation of the homogeneity of compaction over the entire road section.

## 2.2 Measurement Program

Recording of weather conditions, measurement of air and surface temperature in terms of location and number of measuring stations is shown in Figure 1. The stations 0 + 25 m and 0 + 90 m of the test track were defined as measuring stations.

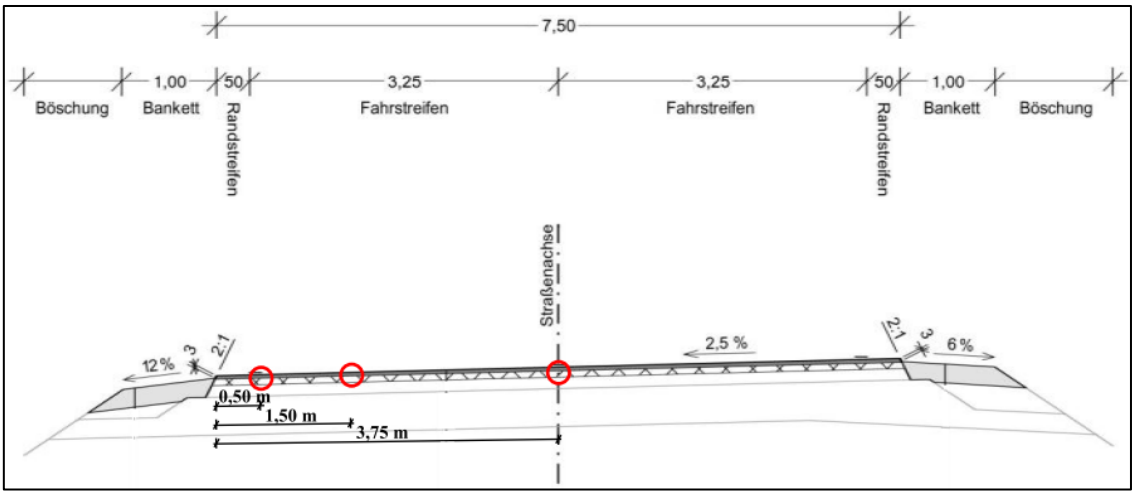



*Source: Own*

***Fig. 1:*** *Location of the measuring stations in the test field*

Three measuring points were marked at each of stations, as shown in Figure 2:

- Edge area is at 0.50 m from road edge.
- Center of wheel path is at 1.50 m from the road edge.
- Center of lane is at 3.75 m distance from lane edge.




*Source: Own*

***Fig. 2:*** *Location of the measuring points at the stations*

## 2.3 Paving Machinery

The equipment listed in Table 1 was used to carry out the asphalt work.

***Tab. 1:*** *Devices used for building asphalt roads*

| Device | Type | Specifications | Use |
|---|---|---|---|
| Feeder | Bomag Feeder BMF 2500 M | Bucket capacity: 15 t<br>Output: 4000 t/h<br>Belt width 1.20 m<br>Mittelanger Gurt 6.50 m | Binder course<br>Wearing course |
| Paver | Dynapac Tracked Paver SD 2550 CS | Hopper capacity: 15 t<br>Theoretical paving capacity: 1100 t/h<br>Max. paving width: 8.80 m<br>Compaction unit: rammer & vibration<br>Screed heating: gas | Binder course<br>Wearing course |
| Attachments | Dynapac-V5100TV | Gas-heated Vario screed<br>Compaction unit: rammer & vibration<br>Extension width: 7.50 m | Binder course<br>Wearing course |
| Rollers | Bomag BW 154 AP-4 AM (with grit spreader) | Tandem vibratory roller<br>Tare weight: 7.30 t<br>Drum width: 1.50 m<br>Static line load: 25.00 kg/cm | Wearing course |
| | Bomag BW 174 AP-4 AM (with grit spreader) | Tandem vibratory roller<br>Tare weight: 9.50 t<br>Drum width: 1.68 m<br>Static line load: 29.80 kg/cm | Binder course<br>Wearing course |
| | Bomag BW 174 ACP-5 AM | Combination roller<br>Tare weight: 9.30 t<br>Drum width: 1.68 m<br>Static line load: 29.20 kg/cm | Binder course |
| | Bomag BW100 AD-5 | Tandem vibratory roller<br>Tare weight: 2.50 t<br>Drum width: 1.00 m<br>Static line load: 13.00 kg/cm | Transitions from old to new edges |

*Source: Own*

## 2.4 Asphalt Mixture for the Test Track

The mixture contained

- temperature-reduced asphalt binder SMA 16 BS, binder PmB 25/45 VL, additive Viatop Premium, and
- temperature-reduced stone mastic asphalt SMA 11 S, binder PmB 25/45 VL, additive Viatop Premium.

The initial tests for both types were confirmed by the contracting authority.

The mixture was delivered from the mixing plant in Breitenau; the transport distance to the construction site was 37.4 km.

## 2.5 Intended Rolling Technology

The following rolling technology was used:

- first roller pass: tandem rollers with static compaction,
- further roller passes: heavy rollers with dynamic compaction.

The rollers were equipped with the BOMAG measuring system and GPS receiver and are shown in Figure 3.




*Source: Own*

***Fig. 3:*** *Rollers in operation*

The above-mentioned equipment of rollers allows for the networking of the rollers. The number of passes and the resistance of the asphalt material can be recorded.

## 2.6 Test Scope

The following points indicate the kinds of tests performed:

- temperature testing of air and substrate at the paving site, recording of weather conditions,
- visual inspection of the condition of the asphalt mixture,
- continuous testing of asphalt temperature on trucks as they arrive at the construction site, in the feeder, in the paver at the auger, during the rolling process on the surface of the paved asphalt, and recording of the core temperature,
- control of paving thickness,
- continuous roller compaction control and documentation,
- compaction measurements with the PQI probe to be tested as a non-destructive and non-nuclear alternative to the Troxler probe,
- drill core tests after asphalt paving is completed to verify the results of the PQI probe measurements.

### 2.6.1 PQI Probe

The physical principle of the PQI-Probe shown in Figure 4 and its use shown in Figure 5 is based on the different reactions of air and asphalt to the emitted electric field. Calibrating the probe to the initial test of the material provides a target value in the form of the dielectric constant. Deviations are due to the inclusion of air. Once the predetermined dielectric constant is reached, it also means that the required density from the initial test has been achieved.



*Source: Labtek, (2021)*

***Fig. 4:*** *PQI probe*



*Source: Own*

***Fig. 5:*** *PQI probe measurements*

## 2.7 Test Procedure

Measurement of existing ambient conditions has been performed by the paver's mobile weather station: These conditions include air temperature, clouds, precipitation, wind speed, and humidity. Ground temperature was measured with an infrared thermometer. The measured values of those conditions are shown in Table 2.

***Tab. 2:*** *Ambient conditions*

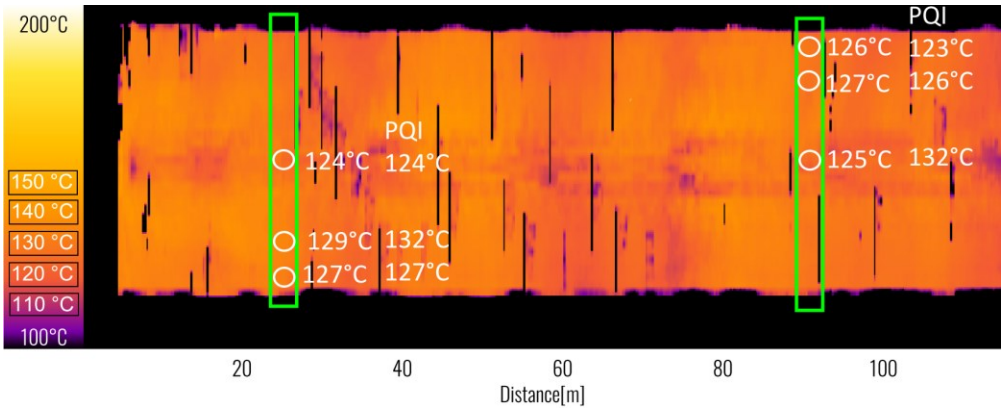
| **Ambient conditions** | **Binder course** | **Wearing course** |
|---|---|---|
| Substrate temperature | 21 °C | 22 °C |
| Air temperature | 18 °C | 18 °C |
| Cloud cover | overcast 8/8 | slightly overcast 4/8 |
| Precipitation | 0 l/m² | 0 l/m² |
| Wind speed | 5 km/h | 3 km/h |
| Humidity | 94% | 91% |

*Source: Own*

The asphalt temperatures were then measured using a penetration thermometer at the "mixing plant", "arrival on-site", and "feeder hopper" stations.

Additional temperature measurements have been taken by infrared thermometers permanently installed on the paver in the hopper and on the spreading auger. The times of all temperature measurements were documented. This enabled a time-dependent curve to be displayed in the subsequent evaluation. The first measurement of compaction and temperature is taken by the PQI sensor as soon as the asphalt is placed on the screed.

It is important that no compaction by the rollers has taken place at this point. The measured compaction value, therefore, corresponds to the precompaction of the screed. This value is measured at the 3 measurement points described in the test program in Figure 2. The comprehensive temperature measurement by an infrared scanner on the freshly paved surface is also free from the influence of the rollers. It can, therefore, be compared with the PQI probe.




*Source: Own*

***Fig. 6:*** *Surface temperatures of the binder course behind the paver*

Spray paint markings were applied to the surface to ensure that compaction measurements were always taken at the same location. This allowed for better comparability. From that point on, compaction, surface temperature, and core temperature (Figure 6) were recorded for each compaction operation by the rollers, taking into account the type of compaction and time. The core temperature was measured with a penetration thermometer at the edge of the asphalt layer in the center of the layer.

When measuring compaction, it was important to ensure that there were no air pockets due to an uneven surface or materials on the sensor plate. It was important to ensure that the sensor plate was constantly cleaned and in full contact with the surface during the measurement process.

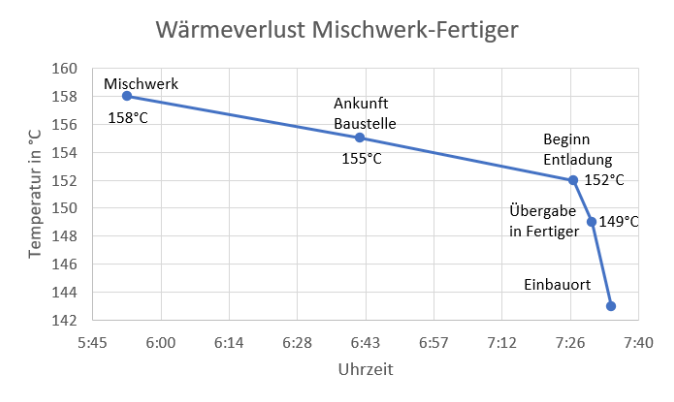
## 3 Results

### 3.1 Mixture Heat Loss

Analysis of the temperature data showed that, contrary to expectations, the heat loss during transport was minimal despite the 37 km distance. The temperature drop of the mixture from the time it left the mixing plant to the time it arrived at the paving site was 2-4 K, depending on the truck. This clearly demonstrates the effectiveness of the tarpaulins on the truck and the use of thermal troughs.

When the mixture was exposed to ambient conditions (temperature, weather, wind) during unloading, a sharp drop in temperature was observed. This was significant throughout the conveying process from the feeder to the paver, as shown in the diagram in Figure 7.

For the binder mixture, an average temperature difference of 6.83 K was measured over the entire transport from the mixing plant to the paver. The transport route accounts for 2.83 K, while the remaining 4 K is due to the time spent conveying the material to the paver.




*Source: Own*

***Fig. 7:*** *Heat loss of the mixture for wearing courses from the mixing plant to the paver*

Proportionally, however, the greatest drop in temperature during the paving operation occurs from the time the mixture leaves the paver. This is due to the rearrangement of the material from a heap to a thin layer with a correspondingly large surface area. This also provides the contact surface for cooler weather conditions. In addition, additional heat is drawn from the rollers and the watering of the drums.

Accordingly, the compaction threshold temperature of 100°C is reached on the surface after 10 minutes for the binder course and after 9 minutes for the wearing course.

This period may be extended depending on the core temperature of the paved layers. The average temperature difference between the surface and the core material is 14.23 K for the binder course and 8.34 K for the wearing course. Because the wearing course is significantly thinner, its temperature drops faster.

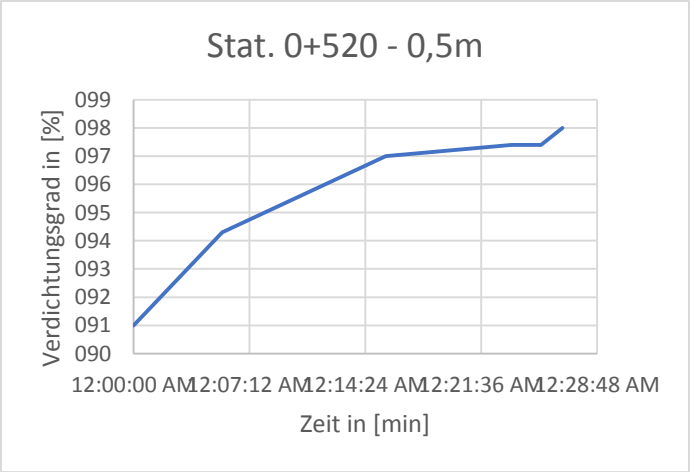
This higher temperature in the center of the layer has a positive effect on the compaction time of 10 minutes for the binder course and 4 minutes for the wearing course.

In this context, it was interesting to observe the temperature evolution over the cross-section. It was assumed that the mixture loses temperature as it travels through the auger and is coolest at the edges of the paved surface. In principle, this assumption was confirmed, but the temperature in the middle of the road was only slightly higher than at the edge.

## 3.2 Compaction Progression

The compaction process begins with pre-compaction by the paver screed. This ranged from 91% to 94% in the measurements. The lowest value was again measured at the edge. This is due to the thermo-viscous behavior of the material and the structure or vertical stiffening of the screed. This is much lower on both sides, which can cause the screed to deflect due to compaction pressure. Nevertheless, the measured values are consistently in the high range, bearing in mind that a hard bitumen mixture is used, which is difficult to compact. This confirms the positive effect of viscosity-changing additives on the material.

This effect is also evident when looking at the compaction progression of the binder course. Taking all measuring stations into account, it took an average of only 4 roller passes to reach the 98% threshold. The first roller passes show significantly higher compaction efficiency than the subsequent passes, as shown in Figure 8. This is due to the exponential compaction effort and the decrease in thermos-viscous properties during the compaction process. The threshold temperature of 100°C in the core of the layer is not reached until the end of compaction. Therefore, under the described boundary conditions, the mixture could be classified as suitable for practical use.

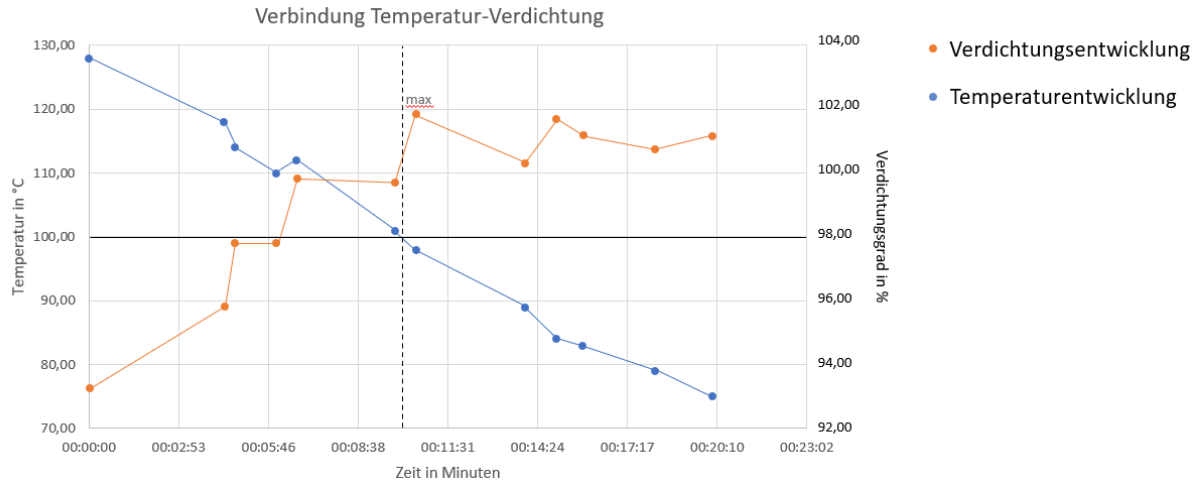



*Source: Own*

***Fig. 8:*** *Compaction progression of the binder course*

The wearing course shows a similar compaction progression, with an average of only three passes necessary to achieve the required minimum compaction. This can be explained by the thinner layer thickness.

On average, no increase in compaction was observed after the sixth roller pass, and subsequent compaction processes resulted in a slight decrease in compaction. Once a temperature of 100°C is reached, compaction does not increase. Further passes may cause damage to the structure. In addition, the direct correlation between temperature and compaction was demonstrated in the wearing course, as shown in Figure 9.




*Source: Own*

***Fig. 9:*** *Progression of compaction in the wearing course as a function of temperature*

As a result, the inclusion of the viscosity-changing additives significantly improved the compaction behavior of the stone mastic asphalt and achieved the desired degree of compaction with less compaction effort.

The suitability of the material under the given conditions can be confirmed by the compaction values obtained.

It was important to test the PQI probe's practical suitability. The measured values were collected and compared to the values of the cores taken. The results differed in both the binder course and the wearing course. In the binder course, the 100.4% compaction measured with the PQI probe contrasted with the 98% measured with the core.

## Conclusion

Low-temperature asphalt has been successfully tested on the B169 highway. A large amount of measured data allowed detailed conclusions to be drawn.

An important consideration is the temperature development of the mixture from production to paving. It was found that the sub-process of transferring the mixture from the truck to the feeder to the paver must be given great importance, as it is here that the temperature drops significantly. Adverse weather conditions can exacerbate this, further reducing the time frame for successful compaction and compromising the quality of the pavement.

Due to the high precompaction of the mixture by the paver, the required compaction values were achieved with four passes on the binder course and three passes on the wearing course. The selected rollers and the viscosity-changing additives in the mixture had a positive influence on these results.

However, in its current form, the PQI probe can only indicate the compaction achieved. Precise measurements require further improvements.

The increased use of low-temperature asphalt is strongly recommended for environmental and economic reasons. However, in addition to suitable asphalt formulas, suitable mechanical modifications to the paving equipment are essential to meet occupational health and safety requirements for significant aerosol reduction during asphalt paving. This aspect was not part of the testing on the B 169 highway.

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## POKLÁDKA NÍZKOTEPLOTNÍHO ASFALTU NA SILNICI B 169 U OBCE HEYDA

Výzkum snižování teploty při výrobě a pokládce horkého asfaltu probíhá již dlouhou dobu. Kromě vývoje vhodných receptur je důležité získávat zkušenosti, zejména v oblasti technologie pokládky asfaltových směsí, protože kromě chování různých asfaltových směsí při jejich hutnění hrají důležitou roli také vnější faktory jako např. umístění projektu a povětrnostní podmínky. Testování nízkoteplotního asfaltu na spolkové dálnici B 169 proběhlo úspěšně. Díky vysokému předhutnění pomocí rozmetadla bylo dosaženo požadovaných hodnot zhutnění na živičné vrstvě při 4 pojezdech a na povrchové vrstvě při 3 pojezdech. Přísady měnící viskozitu a zvolená technologie válcování měly pozitivní vliv na výsledky. Přesných výsledků měření zhutnění však nebylo možné dosáhnout pomocí sondy PQI.

## EINBAU VON NIEDRIGTEMPERATUR-ASPHALT AUF DER BUNDESSTRAßE B169 BEI HEYDA

Seit langem wird an der Absenkung der Temperatur bei der Herstellung und dem Einbau von Heißasphalt geforscht. Neben der Entwicklung geeigneter Rezepturen ist es vor allem in der Asphalteinbautechnik wichtig, Erfahrungen zu sammeln, da neben dem Verhalten der verschiedenen Asphaltmischungen bei der Verdichtung auch äußere Faktoren wie die Lage des Bauvorhabens und die Witterungsverhältnisse eine wichtige Rolle spielen. Die Erprobung des Niedrigtemperatur-Asphalts auf der Bundesstraße B 169 wurde erfolgreich durchgeführt. Aufgrund der hohen Vorverdichtung durch die Einbaubohle wurden die geforderten Verdichtungswerte in der Binderschicht mit 4 Walzübergängen und in der Deckschicht mit 3 Walzübergängen erreicht. Die viskositätsverändernden Zusätze und die gewählte Walztechnik hatten einen positiven Einfluss auf die Ergebnisse. Genaue Messergebnisse für die Verdichtung konnten mit der PQI-Sonde jedoch nicht erzielt werden.

## UKŁADANIE ASFALTU NISKOTEMPERATUROWEGO NA DRODZE B 169 W POBLIŻU MIEJSCOWOŚCI HEYDA

Badania nad obniżaniem temperatury podczas produkcji i układania gorącego asfaltu trwają już od dłuższego czasu. Oprócz opracowania odpowiednich receptur, ważne jest zdobycie doświadczenia, szczególnie w technologii układania asfaltu, ponieważ oprócz zachowania różnych mieszanek asfaltowych podczas ich zagęszczania, ważną rolę odgrywają również czynniki zewnętrzne, takie jak lokalizacja projektu i warunki pogodowe. Testy asfaltu niskotemperaturowego na autostradzie federalnej B 169 zakończyły się sukcesem. Dzięki wysokiemu zagęszczeniu wstępnemu przez stół układarki, wymagane wartości zagęszczenia zostały osiągnięte na warstwie wiążącej przy 4 przejazdach walca i na warstwie wierzchniej przy 3 przejazdach walca. Dodatki zmieniające lepkość i wybrana technologia walcowania miały pozytywny wpływ na wyniki. Nie udało się jednak uzyskać precyzyjnych wyników pomiaru zagęszczenia przy użyciu sondy PQI.