

The stress resilient membrane (SRM-bit) for concrete, paved and asphalt surfaces

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Paper prepared for the session PV- Designing, Building and Managing a Sustainable Pavement Network
2025 Transportation Association of Canada (TAC) Conference & Exhibition
Québec City, Québec

Abstract

The functionality of infrastructure and roads has an impact on road safety, the economy and people's quality of life. The poor condition of roads in some places is due to a number of factors, including the high volume of traffic, ageing, lack of investment and extreme weather conditions in some places. However, particularly in the context of maintenance and/or repair, wrong decisions are often made in the chosen procedure. For example, due to economic considerations or political decisions, existing road structures are increasingly being rehabilitated or overbuilt with a new asphalt surface course in the course of replacing the top asphalt layer, regardless of the existing condition. However, new asphalt layers that are built over (old) cracked asphalt, concrete or paved surfaces often suffer from reflection cracks after a relatively short period of use, which are caused by the horizontal movements and thermal expansion of the underlying concrete or paved base. This effect is exacerbated by the existing traffic load. The resulting cracks in the asphalt surface layer then allow moisture/water to enter the structure and inevitably lead to an acceleration of crack propagation up to complete system failure. As a result, this process leads to traffic restrictions for road users and to premature and costly renewal measures.

One possible solution is the complete elastic decoupling of two otherwise incompatible layers (e.g. asphalt on concrete/paving etc.). A special stress-relieving and stress-resistant membrane (SRM-bit) based on a bituminous waterproofing mastic with a highly branched polymer matrix was developed for

this purpose. This acts as a highly elastic, crack-bridging and water pressure-tight membrane over the entire service temperature range.

The special properties of the SRM-bit across the entire service temperature range were demonstrated in laboratory tests using physical and rheological analyses and dynamic and static tests on composite systems. The enormous elastic potential, the extreme adhesion and cohesion forces and self-healing effects were demonstrated. In addition, these results have already been validated in several construction projects.

Sustainable construction methods that are both resource-saving and economical are required to maintain the infrastructure. A newly developed stress-resistant membrane for asphalt, concrete and paved roads can be used for this purpose, which guarantees very good performance properties at low and high temperatures. Laboratory and practical results will be shown.

Introduction

The functionality of the road infrastructure has a significant impact on road safety, economic development and the quality of life of the population. The bad condition of some roads is due to various factors, including high traffic volumes, ageing infrastructure, insufficient investment and extreme weather conditions. In the context of maintenance and rehabilitation measures, suboptimal decisions are often made regarding the methods used. For economic or political reasons, the top layer of asphalt is often renewed or built over without considering the condition of the underlying structure.

New asphalt layers that are applied to cracked asphalt, concrete or paved surfaces often show reflection cracks after a short time. These are caused by horizontal movements and thermal expansion of the underlying layers. This effect is intensified by the traffic load. The resulting cracks in the asphalt surface layer allow moisture to penetrate, which accelerates crack propagation and can ultimately lead to complete failure of the road structure. This results in traffic restrictions for users and the need for early, costly renewal measures.

The quality of the road infrastructure has a significant impact on people's quality of life. A well-developed road infrastructure gives people easy access to jobs, educational institutions, medical care and leisure facilities. This is particularly important in rural areas, where good connections can reduce migration to urban areas. Well-maintained roads increase road safety by reducing the risk of accidents and vehicle damage. Potholes and uneven roads can be dangerous and lead to accidents that cause both physical and financial strain

Modern road infrastructure can help reduce pollution by encouraging public transport and cycling. Less private transport means lower CO₂ emissions and better air quality, which has a positive impact on public health.

Previous approaches and solutions

In the past, cracked roads made of concrete, asphalt or paving were covered with so-called SAMI layers (Stress Absorbing Membrane Interlayer) before being overlaid with asphalt. However, long-term studies¹ have shown that standard bitumen and simple polymer-modified bitumen are not suitable for this application due to their properties. One of the decisive factors identified in the study was that elasticity at low temperatures is crucial for the absorption of reflection cracks.

Based on these findings, the **Stress-Resilient Membrane based on Bitumen** (short: **SRM-bit**) developed. The following necessary properties for a stress-resilient membrane can be derived from the results of the study:

- **Highly Elastic:**
The membrane must exhibit high elasticity to adapt to the movements and loads of the road surface and effectively absorb stresses.
- **Crack-Bridging:**
One of the most important functions of the SRM-bit is its ability to bridge cracks in the underlying layer, preventing the formation of new cracks in the asphalt top layer.
- **Sealing | Waterproof:**
The membrane must have excellent sealing capabilities to prevent water ingress, thereby extending the lifespan of the road surface.
- **Frost-Resistant:**
To withstand extreme weather conditions, the SRM-bit must be frost-resistant and maintain its properties even at low temperatures.
- **Aging-Resistant:**
The membrane must exhibit high aging resistance to maintain its functionality and performance over many years.

The SRM-bit is primarily used for overlaying cracked asphalt and concrete surfaces as well as paving surfaces with asphalt. This innovative solution provides an effective method for the rehabilitation and renewal of damaged road surfaces by bridging the underlying cracks and irregularities, creating a stable and durable top layer.

SRM-bit: Laboratory results

The following table (Figure 1) shows the main results of the bitumen tests carried out on the SRM-bit.

Figure 1. Main results of the bitumen tests carried out on the SRM-bit

Technical parameter Unit	Unit	Results of the studies
Density	g/cm ³	1,038
Softening point Ring and ball	°C	92,8
Elastic recovery at 25 °C	%	93,2
Nadelpenetration	0.1mm	52
Flash point	°C	≥ 250
Bendability at low temperatures	°C	≤ -30
Deformation behavior in the dynamic shear rheometer (DSR):		
Complex shear module G* @60 °C	Pa	16.873
Phase angle ϕ @60 °C	°	46,8
MSCRT R3,2kPa @60 °C	%	91,9
MSCRT Jnr @60 °C	k ^{Pa-1}	0,0265
TBTSV	°C	68,5
δ BTsv	°	44,8

The softening point, measured using the Ring and Ball method, is 92.8°C. This value represents the temperature at which the material begins to soften. The material shows an elastic recovery of 93.2% at 25°C, demonstrating its ability to return to its original shape after deformation. The needle penetration value is 52 (0.1 mm units), which measures the hardness or consistency of the material. The flash point is ≥ 250°C, indicating the temperature at which the material emits vapors that can ignite.

The material remains bendable at temperatures as low as ≤ -30°C, showcasing its flexibility in cold conditions.

The deformation behavior of bitumen and bituminous binders in the higher service temperature range is assessed by testing in the dynamic shear rheometer (DSR). The complex shear modulus (G^*) and the phase angle (δ) are determined as significant parameters in the temperature sweep. The complex shear modulus represents the quotient of the maximum stress and the maximum deformation under a harmonic and sinusoidal load in oscillation, while the phase angle describes the phase difference between the applied stress and the deformation. Both characteristic values are determined at gradually increasing temperatures, whereby the temperature range is 30 °C to 90 °C. In the present application, the temperature range for the SRM-bit was extended to -10 °C to 150 °C in order to also investigate the low-temperature behavior of the membrane. The test is carried out in the linear viscoelastic deformation range of the bitumen or bituminous binder to be tested, so that an additional percentage deformation of the bitumen sample (γ) is specified as the maximum deflection of the measuring system for each temperature stage. Figure 2 below lists the selected test parameters in the DSR.

Figure 2. Test parameters for T-sweep using DSR

Measuring system	Plate/Plate
Test type	force-controlled/oscillating
Test temperature range	-10 bis 150 °C (extended)
Temperature levels	10 °C
Holding time Temperature level	15 min.
Test frequency	1,59 Hz
Sample diameter	25 mm
Gap width	1 mm

The complex shear modulus is 16873 Pa, reflecting the material's stiffness and the phase angle is 46.8°, indicating the viscoelastic behavior of the material.

The MSCRT test is used to determine the recovery and flexibility of bitumen and bituminous binders. For this purpose, a creep test is performed in the dynamic shear rheometer (DSR) in accordance with the AL DSR test (MSCRT) (2016 edition). Here, a test sample is subjected to a defined cyclic shear stress with subsequent recovery phases. The resulting creep process can be used to determine the relative viscoelastic strain (recovery R) as a proportion of a maximum strain and the permanent strain (compliance Jnr) in relation to the applied shear stress.

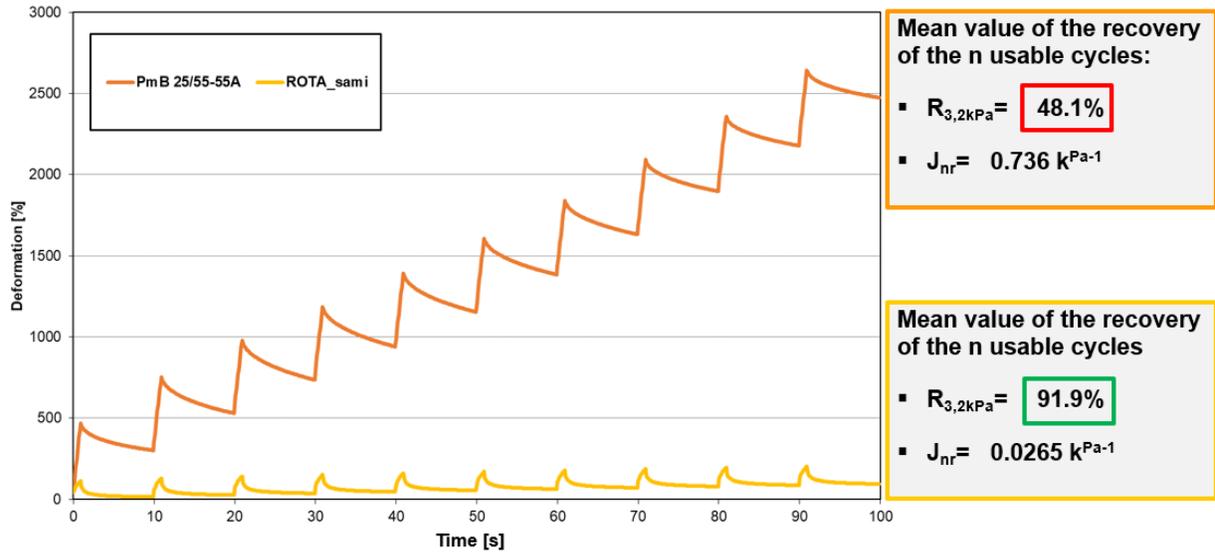
The test Multiple Stress Creep Recovery Test² (MSCRT) is carried out at a constant test temperature of 60 °C and a shear stress of 3.2 kPa. The test comprises a total of ten consecutive cycles, whereby the shear stress is applied for one second and the subsequent recovery phase lasts nine seconds. As a test result, a creep recovery curve can be formed from the ten consecutive cycles. Both the recovery and the resilience are determined as arithmetic mean values from the ten load cycles and specified as a supplementary test result.

The recovery percentage MSCRT is 91.9%, showing the material's ability to recover after being subjected to stress. The non-recoverable creep compliance is 0.0265 kPa⁻¹, indicating the material's deformation under sustained load.

The TBTSV is 68.5°C, representing the temperature at which the material transitions to a brittle state. The phase angle at TBTSV is 44.8°, further describing the material's viscoelastic properties at the brittle transition temperature.

The direct comparison of the SRM-bit (ROTA_sami) with a standard polymer-modified bitumen (PmB 25/55-55 = 50/70 with 3 % SBS) in Figure 3 shows at the MSCRT (60°C) a 43.8 % higher elastic recovery and a 2450 % lower deformation under the same load.

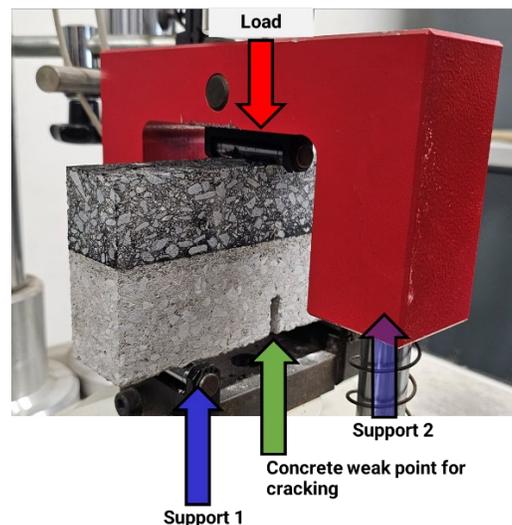
Figure 3. Comparison MSCRT at 60 °C



SRM-bit has over 90 % elastic recovery and hardly any permanent deformation and a extremely high (damage-free) force absorption/ hardly any deformation compared to conventional bitumen solutions.

In the next study, the cracking behavior of the SRM-bit compared to a conventional bitumen variant with polymers was tested under static and dynamic loading in a 3-point bending test (Figure 4). For this purpose, sand mop elements, e.g. consisting of concrete, SRM-bit and an asphalt layer, were produced in the laboratory. The SRM-bit, PmB layer and, without adhesive, the bridging of reflection cracks were tested. In order to obtain a defined crack in the concrete, a 2 cm cut was made in the middle of the concrete layer on the underside. The dynamic load was applied in accordance with the pressure threshold test for asphalt³.

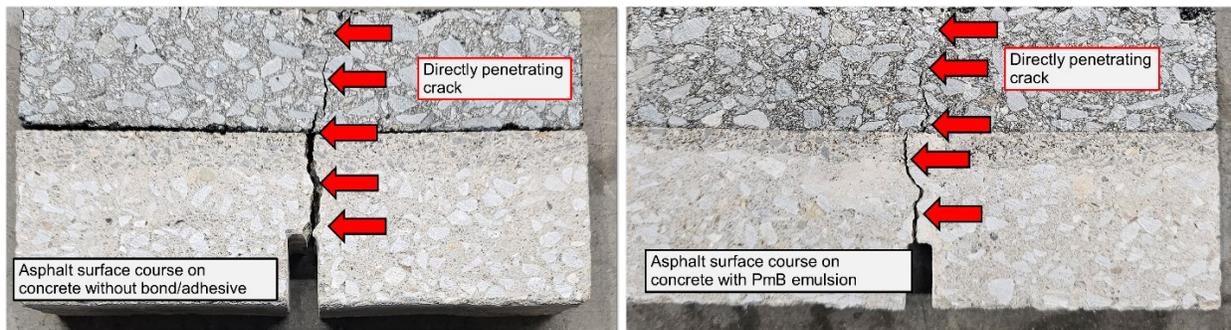
Figure 4. 3-point bending test



Source: PTM

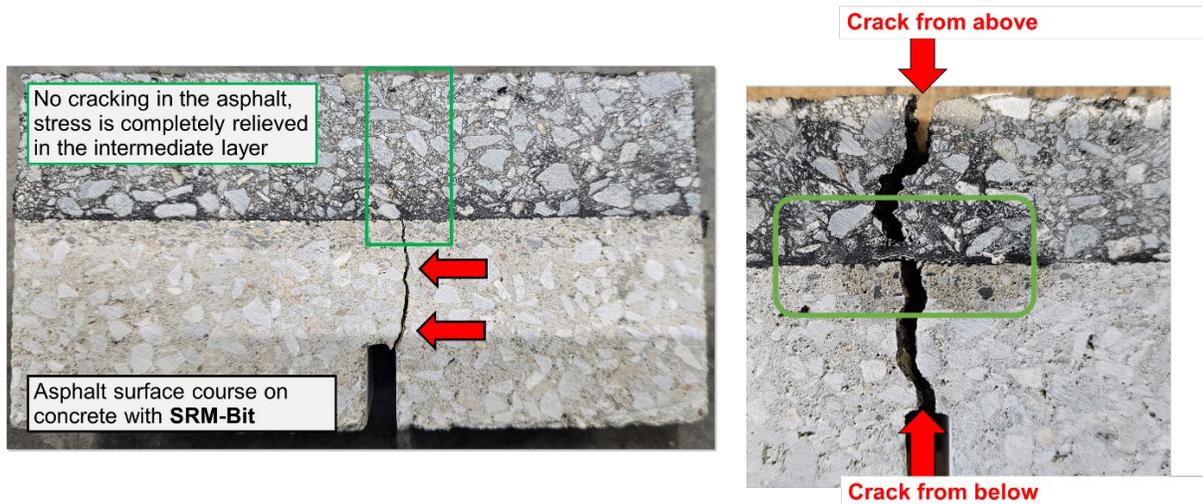
The tests clearly showed that the tested variants without bitumen layer and with PmB bitumen layer offer no protection against cracks from the base. Reflection cracks from the concrete layer penetrated directly into and through the asphalt (Figure 5). The SRM-bit, on the other hand, was able to completely inhibit crack propagation. After increasing the load/tension until the structure was destroyed, i.e. the concrete cracked from below (tensile force) and the asphalt from above (compressive force), the layer of SRM-bit remained intact and waterproof (Figure 6).

Figure 5. Results: 3-point bending test (without bond / with PmB)



Source: PTM

Figure 6. Results: 3-point bending test (with SRM-bit)



Source: PTM

Test tracks

Due to the positive laboratory results on bitumen and asphalt/concrete, several test tracks were realized in Germany. The first one was a Cycle Path in west Germany, L7 from Bienen to Praest. As part of the construction work, 4 cm of the asphalt of the existing cycle path was milled out. The base consisted of cracked asphalt and broken concrete. SRM-bit was applied to the sub-base at a temperature of 170 °C over a total area of 5600 m². The SRM-bit was then sprinkled with 5/8 aggregate (to ensure the passability of the paving vehicles).

Figure 7 shows the cracked base, the application of the SRM-bit and the layer of SRM-bit produced after completion.

Figure 7. Results: 3-point bending test (without bond / with PmB)



Source: PTM

The results of the bitumen analyses of the SRM-bit (industrially produced) were completely within the range of the results from Figure 1. In addition, drill cores were taken from the construction and tested. At this point, the adhesive tensile strength⁴ between the newly applied asphalt surface course and the SRM-bit or the old pavement was of particular importance.

Figure 8. Results: Adhesive tensile strength



Source: PTM

In each case, demolition took place in the asphalt layer below the SRM-bit. This means that the bonding/adhesion between the asphalt surface layer and the asphalt layers bonded with the SRM-bit is greater than the cohesion within the asphalt layer (figure 8).

Conclusion and outlook

In the laboratory, the SRM-bit shows clear advantages over all previously tested stress-resilient layers. The SRM-bit offers the possibility of cost-effectively and sustainably overlaying cracked old materials with asphalt. According to initial findings, reflection cracks from the base layer are significantly reduced.

The new layer of SRM-bit could be installed and overlaid with asphalt without any problems on the test sections so far. The test sections will be regularly monitored and assessed over the next few years.

In addition to overlaying cracked asphalt surfaces, concrete surfaces and paved surfaces with asphalt, the properties of the SRM-bit have led to further applications in asphalt road construction.

These include the following:

- Function as elastic sealing of excavations / trenching slits etc. (keyword: “black tank”)
- Elastic decoupling layer for thin layers in cold construction (DSK)
- Sealing layer to increase the service life by absorbing stresses and preventing moisture transport from “exposed” layers, e.g. on Farm tracks, Cycle paths (possibly protective effect against root penetration)

¹ Großhans, D., Tschierscke, A. "Höhensparende Überbauung von Betonstraßen mit Hilfe der SAMI-Bauweise", Straße und Autobahn 59 (2008) Nr. 3, S. 135-146, 16 B, 2 T, 11 Q

² Arbeitsanleitung zur Bestimmung des Verformungsverhaltens von Bitumen und bitumenhaltigen Bindemitteln im Dynamischen Scherrheometer (DSR), Teil 2: Durchführung der MSCR-Prüfung (Multiple Stress Creep and Recovery Test)

³ Technische Prüfvorschriften für Asphalt, TP Asphalt-StB, Teil 25 B1, Einaxialer Druck-Schwellversuch - Bestimmung des Verformungsverhaltens von Walzasphalt bei Wärme, Ausgabe 2022, Forschungsgesellschaft für Straßen- und Verkehrswesen (FGSV), Arbeitsgruppe „Asphaltbauweisen“, FGSV 756/25 B1

⁴ Technische Prüfvorschriften für Asphalt, TP Asphalt-StB, Teil 48 B, Haftzugfestigkeitsprüfung (TAT), Ausgabe 2023, Forschungsgesellschaft für Straßen- und Verkehrswesen (FGSV), Arbeitsgruppe „Asphaltbauweisen“, FGSV 756/48 B