Case studies & non-highway applications; Success and failure from real practice

Re-evaluation of tracks built with a system of combined polymer and natural asphalt modification

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Abstract

Natural asphalt additives are used for a variety of purposes like enhancing bitumen properties or giving additional rutting resistance to asphalt pavements. High quality products consist mainly of asphaltenes and no significant filler amounts, which makes them usable as a bitumen additive. It is also used in pulverized form as an asphalt additive by dosing it directly to the hot mix at production stage. In Germany, some sections with extreme traffic amounts in terms of weight (like bus stops) have been built in different layouts and with different pavement types. The oldest section dates from 2009. The scope of the paper is presenting the results of a visual inspection of these areas after a service life of five to nine years.

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1. INTRODUCTION

An essential aspect of road safety is the conservation of evenness in the transverse direction. If the resistance against permanent deformation of the asphalt materials used is not adopted to the climatic and traffic conditions, unevenness in the transverse direction ("rutting") may result caused from negative volume changes and/or plastic deformations within the asphalt layers.

The often-seen crack sensitivity of asphalts with high viscos binders can be partially compensated for by adapted asphalt mix designs (e.g., with higher binder volumes). In Germany, adapted asphalt concepts from various providers for high traffic loadings have been available on the market for many years. Frequently, these concepts are based on a specific binder modification of all bound layers, whereby the modification variants used are quite different. Common modes of modification for increasing rutting resistance are polymer, wax and rubber modifications. Deviating from this, a combined pavement system for high loads was developed in Germany by the company EUROVIA, which is based on a combination of modifying binders with polymers and natural asphalts.

On the international market, there is a variety of natural occurring bituminous asphalts or asphaltite bitumens from different sources available [1]. One of the main characteristics to differentiate between the products is the amount of carbon disulfide soluble matter which can typically vary within less than 40 % and more than 99 % [2, 3]. On an industrial scale, a meaningful binder modification can only be done if the inorganic, solid amount is small like in Uintaite (Gilsonite).

2. TECHNICAL CONCEPT

2.1. Binder modification

In the literature, bitumen is often defined as solid or liquid hydrocarbons soluble in organic solvents [4]. The proportion of the element carbon in bitumen derived by refining crude oil typically amounts to more than 80 %, with up to four hydrogen molecules being able to accumulate. Depending on the source of the crude oil it may contain differing mass proportions of oxygen, nitrogen and sulfur [5]. Also traces of metals such as vanadium, nickel, iron, magnesium and calcium can be found [12]. The use of natural asphalts with low amounts of mineral matter to specifically modify binders is a compatible way of adapting bitumen viscosity. One of the widely known sources for natural asphalt with low amounts of inorganic matter is based in the Uinta basin of northeastern and north-central Utah, USA. It is called “Uintaite” or more common “Gilsonite” and was found in the 1860s [6, 7]. It is believed that the hydrocarbons of Gilsonite have emerged from oil-rich shales, which can also be found in the near riverbed of the Green River. Presumably, fissures in the rock were filled with heavy, viscous crude oil that had lost its volatiles through geological processes and solidified. The decomposition into fractions took place in principle by filtration within the rock layers under high pressure [8, 9]. In today’s form, Gilsonite mainly consists of solid hydrocarbons of high purity, which are produced by using advanced mining techniques. Main constituents of this natural asphalt powder are asphaltenes and nitrogen with rather small amounts of sulfur [10].

Table 1 shows the comparison of a chemical elemental analysis of Gilsonite natural asphalt with a typical penetration grade bitumen produced by subsequent atmospheric and vacuum distillation. It reflects the typical high nitrogen amount compared to bitumen with at the same time reduced sulfur content. The characteristic smell of Gilsonite modified material might also be traced back to the fact that it contains less sulfur than most other natural asphalts. This fact fortunately also prevents the danger of hydrogen sulfide (H_2S) formation when adding it to bitumen on an industrial scale, which otherwise could raise HSE concerns.

Table 1: Comparison of elemental chemical compositions of Bitumen and Gilsonite [5, 11]

Chemical Element	Typical composition of bitumen	Gilsonite Resin
Carbon, Wt %	82 – 88	83,95
Hydrogen, Wt %	8 – 11	10,03
Nitrogen, Wt %	0 – 1	3,26
Sulfur, Wt %	0 – 6	0,27
Oxygen, Wt %	0 – 1,5	1,37

The principal chemical likeness of Gilsonite and refined bitumen allows for industrial blending of the two materials with high technical process reliability and small effort. The restricted mobility of the long asphaltene molecule chains can be balanced by inducing sufficient heat energy. Gilsonite dispersed in bitumen is permanent storage stable. The obtained bitumen characteristics are homogeneous and uniform.

Table 2: Comparison of SARA separations of TLA and Gilsonite [12]

	TLA	Gilsonite
Saturates	4,1	1,6
Aromatics	22,9	0
Resins	37,4	18,7
Asphaltenes	35,6	79,7
Colloidal instability index	0,65	4,34
Stability	Stable	Very unstable

The addition of Gilsonite to refined bitumen mainly takes effect on the colloidal system by lifting the amount of asphaltenes. The degree is of course depending on the dosage, where Gilsonite additions of 5 to 10 % by the bitumen mass are typical. Consequently, the resulting amounts of saturates and aromatics are slightly decreased. At production stage, the effect of this change in the colloidal system is comparable to a deeper distillation regime, although here no maltenes are volatilized but instead asphaltenes are added, which could be denoted by the term "colloidal thickening". It cannot be compared to blowing processes as no significant oxidation takes place. The penetration index typically does not change significantly with increasing amounts of Gilsonite, which would be a typical sign for oxidation processes.

2.2. Asphalt and pavement conception

Modifying bitumen with Gilsonite leads to an increased viscosity of the binder. This stiffness increase of the binder is generally transferred to the asphalt mix, but is at the same time influenced by other compositional characteristics like binder or void content of the mix. Typically, asphalt mixes with Gilsonite modified binders exhibit a significant stiffness increase over the entire temperature range compared to the same mix type with a polymer modified binder. Figure 1 shows a typical shift of the stiffness-temperature-function according to German technical regulation AL Sp-Asphalt [15] at a frequency of 10 Hz for a binder course AC 16 according to EN 13108-1 [16]. Using a logarithmic scale, it can be seen that a Gilsonite modification generally lifts the stiffness level over the whole temperature range of the test, whereas the main effects take place at temperatures above 20 °C. Obviously the long asphaltene molecule chains build up a network in the matrix, which leads to significant stiffness increases at higher temperatures. At lower temperatures, also significant stiffness shifts are visible which favor the development of cryogenic stresses, which has to be taken care of in further steps of the material design.

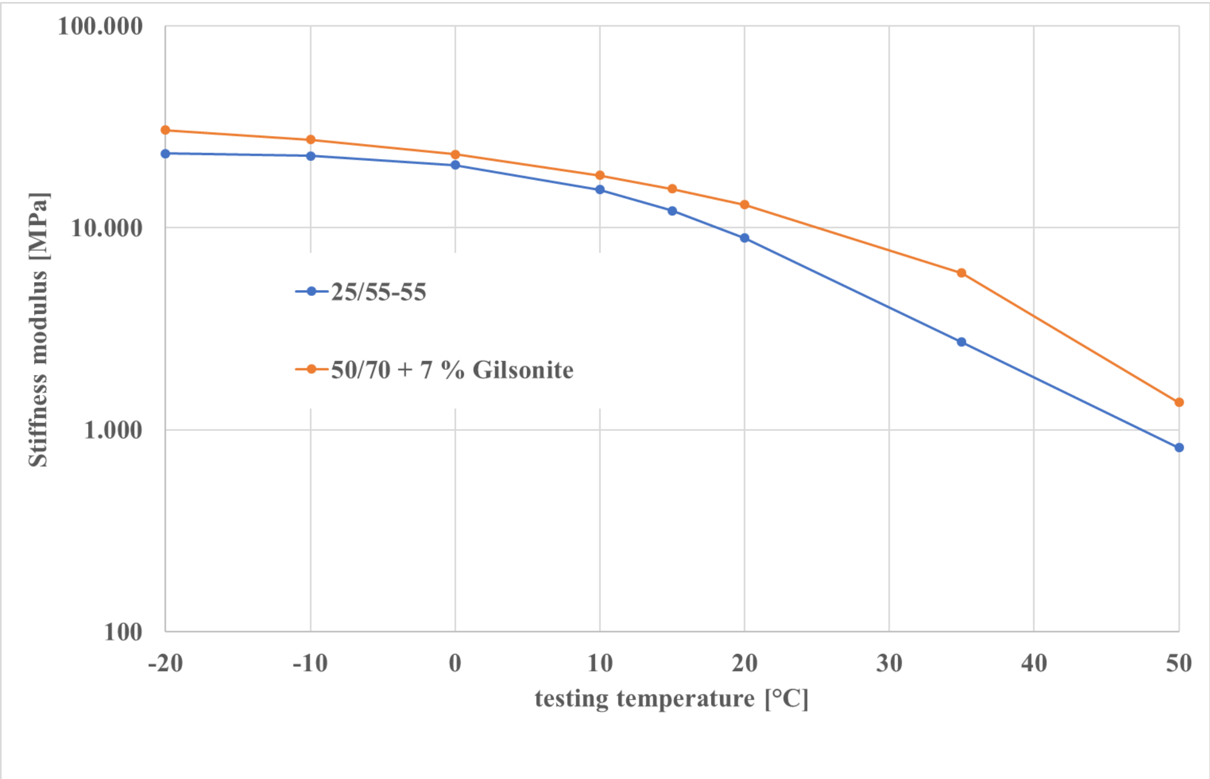

Figure 1: Stiffness-temperature-relationship for an AC 16 at 10 Hz

The basic design of the pavement system is based on stresses within the construction under high axle loads. The base and binder course are optimized for high stiffness. Due to their position in the structure, these layers are subject to significantly lower temperature changes as a result of climatic conditions than the surface layer, which in principle allows restrictions in the low-temperature behavior compared to wearing courses. A reduction of the total layer thickness of the asphalt system is not a fundamental objective, since the system should not only be used for new constructions but also for renewal of partial layers of the pavement. From a design point of view, substantial improvements in the fatigue behavior of the overall system are possible, in particular, through an increase of the total layer thickness or an improvement of the fatigue behavior of the lowest bound layer, which would not be feasible in the case of renewal [18]. In this respect, the base course is not optimized for increased fatigue resistance, but above all it should not suffer any plastic deformation. Therefore, these base layer types are modified with Gilsonite. The binder layers are also fundamentally optimized for stability. In addition to the vertical load transfer, in this pavement depth mainly shear stresses occur that contribute to the typical rut depth phenomena. Again, therefore, a Gilsonite modification is used here. In direct contrast to that, the surface layer has another task. It must represent the properties important for the user and, above all, ensure that water penetration into the underlying layers by cracks or open seam structures is permanently prevented. It also should be paved thinly to prevent plastic deformations to rise to considerable amounts. In this respect, no Gilsonite modification takes place in this layer. Here, a higher polymer-modified binder is used [21,22]. The total layer thickness of the system results from the use of conventional design methods. Significant changes compared to conventional asphalts are not expected.

3. BEHAVIOR OF REAL TRACKS IN USE

To evaluate the behavior of pavements built with the described combined pavement concept, three pavements of significant age and with different traffic types were chosen. All tracks have significant usage times between five and nine years and are subject to extraordinary loading conditions. The different pavements are used by cars and trucks, busses and container handling vehicles called reach stackers, respectively. All tracks were re-evaluated in July 2019 by a visual inspection and an evenness measurement according to TP Eben [19]. The tracks are listed in Table 3.

Table 3: Re-evaluated tracks

No.	Location	Type	Main traffic	Built
1	Bottrop, Germany	Highway A42 Exit Bottrop Süd	mixed middle-distance traffic	2014
2	Bottrop, Germany	Bus lane at central train station	busses	2012
3	Mülheim, Germany	Steelpipe production facility	reach stacker	2009

3.1. Highway exit A42, Bottrop Süd

This track connects the highway exit Bottrop Süd of Autobahn A42 in western direction with the local road network. It consists of an approximately 150 m long four lanes wide road, where one lane follows the positive slope in direction onto the highway, two lanes go downhill and end at traffic lights at the junction with the local road. One lane is used as an emergency lane and is only used in case of breakdowns. It bridges the elevation differences between the highway system and the local road system, which results in a significant longitudinal slope of more than 4 %, which – on the way up to the highway – leads to increased loading conditions, as trucks must accelerate from almost zero velocity to sufficient speed to safely get into the flowing traffic and in the same moment to overcome the height difference (cf. Figure 2).

This road section was renewed in 2014 by exchanging the binder and surface layer. The renovation comprised of 9 cm of Gilsonite modified binder layer and 3 to 3,5 cm highly polymer modified surface layer (cf. Table 4). The visual inspection in July 2019 showed the typical slightly coarse surface structure with a small number of stones being cracked by the combined influence of traffic and weather. The surface looks smooth with no signs of raveling. No cracks or open seams between the paving lanes were found over the whole renewed pavement area.

Figure 2: Highway exit A42, Bottrop Süd

Table 4: applied asphalt concepts, highway exit A42, Bottrop Süd

designation of layer	AC 16	AC 8
function	binder course	wearing course
Reference	EN 13108-1	EN 13108-1
asphalt composition		
aggregate types	limestone powder, limestone	limestone powder, greywacke
fresh binder sort	50/70, Gilsonite	40/100-65 (SFB 5-50)
Recycled asphalt pavement, Wt%	30	0
asphalt gradation		
filler (< 0,063 mm), Wt%	6,5	9,2
fine aggregates (0,063 mm < X < 2 mm), Wt%	20,0	22,4
coarse aggregates (> 2 mm), Wt%	73,5	68,4
binder properties		
fresh binder, Wt%	2,9	6,5
Gilsonite, Wt%	0,4	0,0
binder from RAP, Wt%	1,1	0,0
total binder content, Wt%	4,4	6,5
res. softening point, °C	62,4	90,0
elastic recovery, %	n.d.	90,0
volumetric properties		
Void content Marshall specimen, Vol%	4,8	2,8
VFA, %	69,1	84,3

The evenness measurements were made in the downhill lane connecting the off-highway traffic with the local road. Due to the usually high residual speed during deployment, the unobstructed view of a straight course and the negative gradient, the trucks driving there have comparatively high speeds, which they often have to reduce to zero at the intersection for reasons of traffic and driving dynamics. The pavement sections directly in front of the stop line are predestined for the formation of plastic deformations in the longitudinal and transverse direction due to high braking forces. The measurements were started at the beginning of the pavement variant in the upper area and stationed continuously downhill. The measuring point distance was 15 to 20 m. Deformations in the transverse direction under a 4 m long straightedge were determined quantitatively by means of a measuring wedge. Measurable deformations could only be determined in the middle section. The maximum deformation was 4 mm there. No deformation in the transverse direction could be detected in the immediate crossing area. For detailed results consult Fig. 1. Longitudinal deformations could visually not be identified at any point.

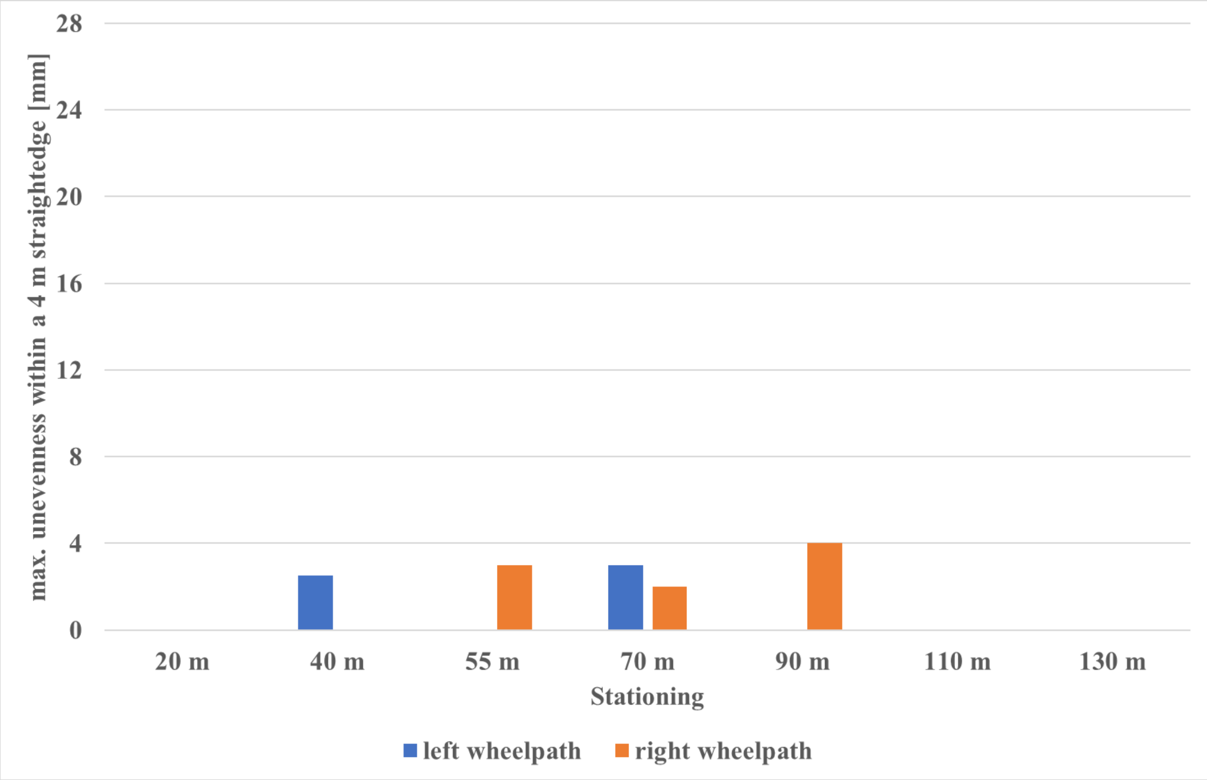

Fig. 1: Result of the evenness measurements, highway exit A42, Bottrop Süd

3.2. Bus stop "Bottrop train station"

The main train station in Bottrop, Germany, also serves as a local hub for public transport (cf. Figure 3). There are three bus stops operated, from which one is built with an asphalt pavement. The other two were constructed using paving blocks. The bus stop with the asphalt pavement was renewed in 2012 by replacing the binder and surface layers according to Table 5.

The deformations measured at the bus stop in the transverse direction are decisive with a maximum value of 28 mm. Interestingly, significant deformations only occur in the left wheel path. The right side remains inconspicuous with maximum deformations of 3 mm. An exact cause for this could not be determined locally. It is possibly influenced by the cross-slope distribution. The detailed results can be found in Figure 4. The pavement does not show any signs of cracking or raveling. As the main rutting appears on the opposite side of the people waiting at the bus station, the serviceability is not limited by it.

Figure 3: bus stop „Bottrop train station“

Table 5: applied asphalt concepts, bus stop “Bottrop train station”

designation of layer	AC 22 S	AC 8 S
function	binder course	wearing course
Reference	EN 13108-1	EN 13108-1
asphalt composition		
aggregate types	limestone powder, limestone	limestone powder, greywacke
fresh binder sort	50/70, Gilsonite	40/100-65 (SFB 5-50)
Recycled asphalt pavement, Wt%	30	0
asphalt gradation		
filler (< 0,063 mm), Wt%	5,9	7,2
fine aggregates (0,063 mm < X < 2 mm), Wt%	22,0	24,8
coarse aggregates (> 2 mm), Wt%	72,1	68,0
binder properties		
fresh binder, Wt%	2,4	6,4
Gilsonite, Wt%	0,4	0,0
binder from RAP, Wt%	1,4	0,0
total binder content, Wt%	4,2	6,4
res. softening point, °C	78,5	90,0
elastic recovery, %	n.d.	90,0
volumetric properties		
Void content Marshall specimen, Vol%	4,7	3,9
VFA, %	68,1	79,2

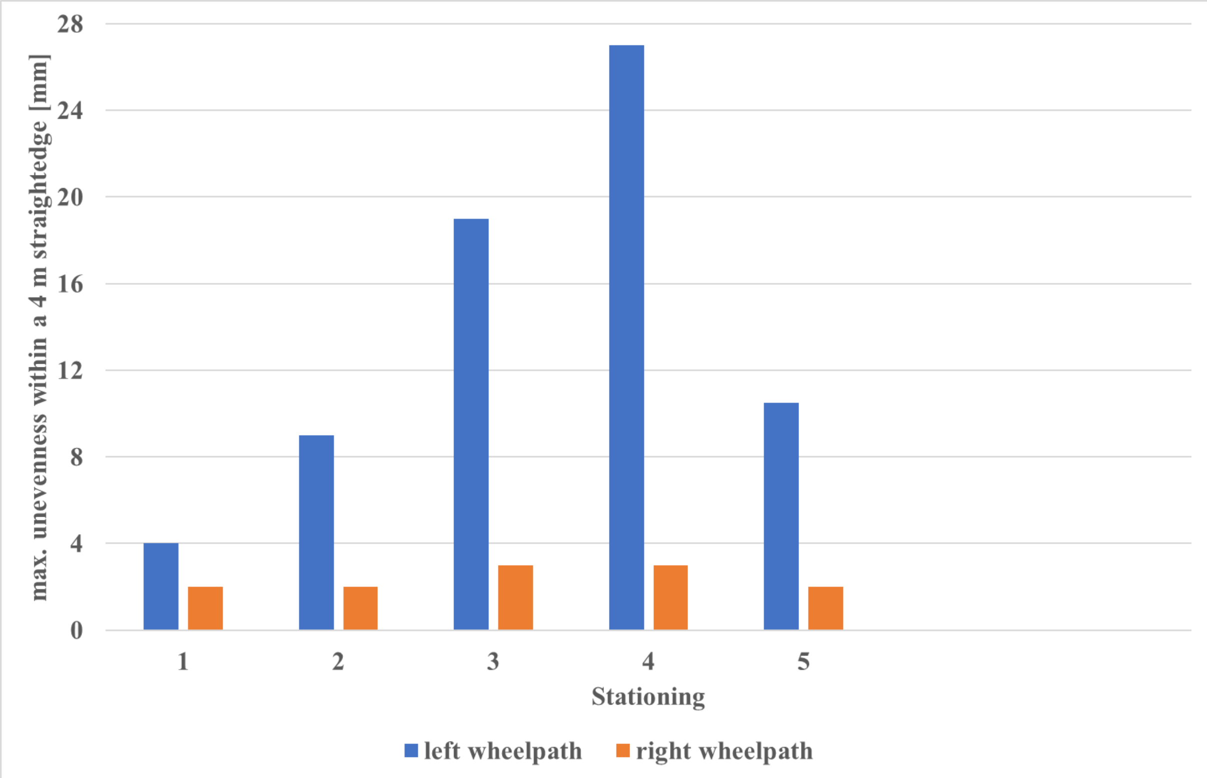

Figure 4: Results of the evenness measurements, Bus stop "Bottrop train station"

Unfortunately, there was no reference track being built adjacent to the bus lane. But another bus lane in the same city, which was built with a conventional concept based on a hard binder was visually checked. It is the central bus stop "Bottrop ZOB" (cf. Figure 5). The ruts being observed there were subjectively significant higher than on the evaluated track.

Figure 5: Rutting at bus stop „ZOB Bottrop" with conventional system

3.3. Steelpipe production facility Mülheim

The premises hosts – next to other production facilities – a steel pipe coating plant. The pipes coming out of the production stage have diameters of up to 1,20 m. The weight of a single pipe ranges from 11 to 16 t. A conveyor belt delivers the new produced pipes to the outside transfer point, where they are picked up by reach stackers. The vehicles used for this purpose have a dead weight of approximately 70 t with unladen axle loads of 36 t in the front and 32 t in the back, respectively. With high loads, the axle load on the front axle can theoretically go up to 99 t even without dynamic peaks. The loading frame can lift up two pipes at the same time, but it often only carries a single pipe. The maximum production is up to 400 pipes in 24 hours. After lifting the pipe at the transfer point, the reach stacker drives backwards in a 90° turn, brakes and accelerates forward. Because of the limited area, driving speeds are usually very slow and do not exceed 20 km/h. The pipes are then stored in the same pavement area by stacks with up to 5 elements high. The only ground support is wooden support beams with a width of 20 cm, from which two are placed next to each other (cf. Figure 6). The total support area under the wooden beams is 2 x 0,40 cm²/m for a single pipe of up to 16 t weight. Taking into account the maximum staple height, this leads to a maximum pressure of 0,82 MN/m², which is constantly acting on the asphalt surface for long durations. All pipes are picked up from the storage place by a reach stacker for a second time when they are leaving the production area for the client by train transport.

Figure 6: wooden support beams for pipe stacks

The asphalt characteristics show a specialty compared to the other two tracks as here in the surface layer a steel slag was used for all aggregate size fractions greater than 2 mm. The bulk density of the slag was 3,554 g/cm³ for the fraction 2/5 and 3,445g/m³ for the fraction 5/8, respectively. This leads to a binder content of 5,9 Wt%.
The evenness measurements have for the most part indicated no measurable deformations. Only at locally visible support points of wooden beams it was possible to detect isolated deformations with individual values of 4 and 9 mm. On some production days cranes with outriggers are also used for handling pipes. The imprints of these paws have partly left visually visible marks in the asphalt surface course. Due to their small area size, the deformations do not allow for direct measurements, but they are small with well below 10 mm. Overall, more straightforward, untreated crack structures in the covering layer can be seen on the surface. However, they do not show a uniform pattern, so that without further investigation information about the origin of the cracks cannot be provided. It is at least theoretically possible that here a limited behavior at low temperatures in the binder or base layer has led to

reflection cracks. On the other hand, the observed crack patterns make the occurrence of reflection cracks appear unlikely as they would typically be straight lined, which is not the case here. In this respect, other causes on the paving or material side are more likely.

Table 6: applied asphalt concepts, steelpipe production facility Mülheim

designation of layer	AC 32	AC 22 S	AC 8 S
function	base course	binder course	wearing course
Reference	EN 13108-1	EN 13108-1	EN 13108-1
asphalt composition			
aggregate types	limestone powder, limestone	limestone powder, limestone	limestone powder, greywacke, steel slag
fresh binder sort	50/70, Gilsonite	50/70, Gilsonite	40/100-65 (SFB 5-50)
Recycled asphalt pavement, Wt%	30	30	0
asphalt gradation			
filler (< 0,063 mm), Wt%	6,2	5,9	7,2
fine aggregates (0,063 mm < X < 2 mm), Wt%	21,5	22,0	26,7
coarse aggregates (> 2 mm), Wt%	72,3	72,1	66,1
binder properties			
fresh binder, Wt%	2,2	2,4	5,9
Gilsonite, Wt%	0,3	0,4	0,0
binder from RAP, Wt%	1,4	1,4	0,0
total binder content, Wt%	3,9	4,2	5,9
res. softening point, °C	n.d.	78,5	90,0
elastic recovery, %	n.d.	n.d.	90,0
volumetric properties			
Void content Marshall specimen, Vol%	5,4	4,7	3,7
VFA, %	63,4	68,1	80,9

4. SUMMARY

Due to its chemical similarities, the natural bitumen Gilsonite can be used to either modify bitumen or asphalt. It mainly increases the stiffness of the binder and the asphalt, respectively. Possible limitations in the low-temperature domain of the bitumen can successfully be addressed by the asphalt composition and a limitation to binder and base courses. In combination with a surface course with polymer modification, a whole pavement system for high loads was developed and successfully used on a variety of roads with high loads. Three tracks built with this system were re-evaluated after five to nine years in use. All tracks were exposed to extraordinary traffic conditions. In the case of the bus stop a significant rut depth could be measured in one wheel path with a maximum amount of 27 mm. The other tracks showed no significant rutting. One track suffered from occasional cracking in the surface layer, for which the reasons could not be identified within the scope of this paper. No track was limited in his usage due to any pavement distress. Overall, the system consisting of a highly polymer modified surface laver and a Gilsonite modified binder and – if present – base layer showed superior behavior over standard pavement systems for high traffic loads. Especially the reduction in permanent deformation of the pavement system is remarkable. It was proven valuable for high loads or areas sensitive for permanent deformation.

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REFERENCES

[1] Abraham, H., Asphalts and Allied Substances. Van Nostrand, New York, 1945

[2] Website www.americangilsonite.com, American Gilsonite Company, Houston, TX. Last downloaded August 12th 2019

[3] Richardson, C., A Unique geophysical phenomenon, Trinidad asphalt, interesting from the point of view of dispersoid chemistry (1915). The journal of physical chemistry 19(3), 2002, DOI 10.1021/j150156a005

[4] Killops, S., Killops, V., Introduction to organic geochemistry. Blackwell Publishing, Boston, MA, 2005

[5] Read, J., Whiteoak, D., The Shell Handbook, Fifth edition, Thomas Telford Publishing, London, 2003

[6] Bell, K., Hunt, J., Native bitumens associated with oil shales. In: Breger, I. (Ed.), Organic Geochemistry. Elsevier, Amsterdam, 1963

[7] Helms, J., Kong, X., Salmon, E., Hatcher, P., Schmidt-Rohr, K., Mao, J.: Structural characterisation of gilsonite bitumen by adveanced nuclear magnetic resonance spectroscopy and ultrahigh resolution mass spectrometry revealing pyrrolic and aromatic rings substituted with aliphatic chains. Organic Chemistry 44, pages 21-36, 2012

[8] Keighin, C., Hibpshman, M., Preliminary mineral resource study of the Uintah and Ouray reservation, Utah, Technical Report No. 4, Bureau of Indian affairs, Utah, 1975

[9] Kretchman, H., The story of Gilsonite. Salt Lake City, Utah, American Gilsonite Company, 1957

[10] Gillson J., Industrial Minerals and Rocks: Nonmetallics Other Than Fuels, The American Institute of Mining, Metallurgical, and Petroleum Engineers, New York, USA, 1960

[11] Amercian Gilsonite Company: Technical Information, Chemical Composition of Gilsonite Resin, revised 2010

[12] Nciri N., Song S., Kim N., Cho N.,Chemical Characterization of Gilsonite Bitumen. J Pet Environ Biotechnol 5: 193. 2014, DOI 10.4172/2157-7463.1000193

[13] European Standard EN 12607-1, Bitumen and bituminous binders - Determination of the resistance to hardening under influence of heat and air - Part 1: RTFOT method; German version EN 12607-1:2014

[14] European Standard EN 14769, Bitumen and bituminous binders - Accelerated long-term ageing conditioning by a Pressure Ageing Vessel (PAV); German version EN 14769:2012

[15] Forschungsgesellschaft für Straßen- und Verkehrswesen: Arbeitsanleitung zur Bestimmung des Steifigkeits- und Ermüdungsverhaltens von Asphalten mit dem Spaltzug-Schwellversuch als Eingangsgröße in die Dimensionierung AL Sp-Asphalt 09, edition 2009, FGSV-Verlag, Köln, 2009

[16] European Standard EN 13108-1, Bituminous mixtures - Material specifications - Part 1: Asphalt Concrete; German version EN 13108-1:2006

[17] Forschungsgesellschaft für Straßen- und Verkehrswesen: Technische Prüfvorschrift, Verhalten von Asphalten bei tiefen Temperaturen, edition 1994, FGSV-Verlag, Köln, 1994

[18] Ullidtz, P.: Modelling flexible pavement response and performance, Tech Univ. of Denmark Polytekn, 1998

[19] Forschungsgesellschaft für Straßen- und Verkehrswesen: Technische Prüfvorschriften für Ebenheitsmessungen auf Fahrbahnoberflächen in Längs- und Querrichtung, Teil: Berührende Messungen, edition 2017, FGSV-Verlag, Köln, 2018

[20] European Standard EN 12697-46, Bituminous mixtures - Test methods - Part 46: Low temperature cracking and properties by uniaxial tension tests; German and English version prEN 12697-46:2018

[21] EUROVIA GmbH: viafocus 23/2005, Technische Informationen der EUROVIA: Hochstandfeste Asphalte im Einsatz. Website www.eurovia.de, EUROVIA GmbH, Germany, 2005. Last downloaded August, 12th 2019

[22] EUROVIA GmbH: viafocus 24/2006, Technische Informationen der EUROVIA:MICROVIA und RENFOVIA, Rote Asphalte für hohe Beanspruchungen. Website www.eurovia.de, EUROVIA GmbH, Germany, 2006. Last downloaded August, 12th 2019

Annex

ANNEX

1.1. Binder modification (continued)

A recent publication provides a more detailed insight into the components of typical petroleum-based products in relation to Gilsonite, Shale residue and Coal Tar Pitch by utilizing a new separation method (SAR-AD) [23]. The results are given as Figure 7 and can help in comparing the different materials and their potential use in optimizing the colloidal structure of a binder. Table 7 shows typical Gilsonite products from Asia and America, which do have significant differences. This underlines the importance of choosing the right provenience of the product to use.

This addition is intended to provide more detailed information and has no further impact on the conclusions of the paper.

Table 7: Comparison of SARA separations of different Gilsonite products

	Gilsonite, Asia [12]	Gilsonite, USA [25]
Saturates	1,6	3,4
Aromatics	0	13,6
Resins	18,7	38,2
Asphaltenes	79,7	44,8
Colloidal instability index	4,34	0,93
Stability [24]	very unstable	slightly unstable

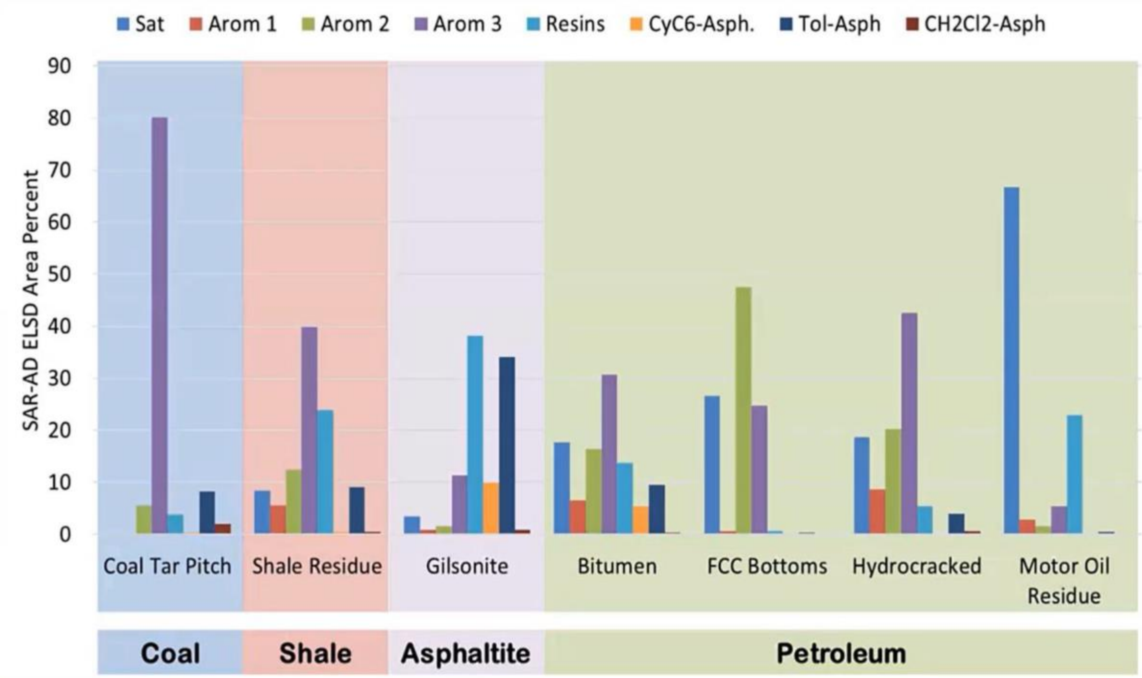

Figure 7: Profiles for some naturally occurring materials and refined materials (FCC is fluidized catalytic cracking) [23]

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ADDITIONAL REFERENCES

[23] Adams, J., Rovani, J., Boysen, R., Elwardany, M., Planche, J.-P.: Innovations and developments in bitumen composition analysis. Proceedings of the 7th Eurasphalt & Eurobitume Congress v1.0, first published 1st July 2020, ISBN: 9789080288461

[24] Ashoori, S., Sharifi, M., Masoumi, M., Salehi, M. M.: The relationship between SARA fractions and crude oil stability. Egypt. J. Pet. 2017, 26, 209–213. 10.1016/j.ejpe.2016.04.002.

[25] American Gilsonite Company: SARA Fractionation of Gilsonite. A sample of Gilsonite was analyzed for SARA fractions at the Western Research Institute, Laramie/Wyoming, USA. Information Bulletin. Message to the author, 24.02.2021. Unpublished.