Gilsonite for Asphalt Application

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Release 03/13 issued on September 30, 2013

A. INTRODUCTION ON GILSONITE

1. What is Gilsonite

GILSONITE is a pure hydrocarbon, with a melting point between 160°C and 220°C. The mineral is natural bitumen and geologically petroleum based solid and therefore extremely compatible with petroleum bitumen. When blended, a very intimate molecule of GILSONITE and bitumen is formed, one that takes on some hardness and durability of GILSONITE while still retaining the flexibility of the bitumen.
Gilsonite is mined in underground shafts and resembles shiny, black substance similar in appearance as the mineral Obsidian It is brittle and usually micronized into dark brown powder. It is mainly composed of asphaltenes; thus, Gilsonite Is classified as a Natural Asphalt and also known as Gilsonite or Uintaite. Discovered in the 1860s, it was first marketed as a lacquer, electrical insulator, and waterproofing compound. This unique mineral is used in more than 160 products, primarily in dark-colored printing inks and paints, oil well drilling muds and cements, asphalt modifiers, foundry sand additives, and a wide variety of chemical products.

2. What makes GiLSONITE different from other natural Asphalts

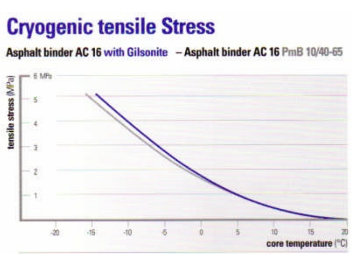
1	high purity and consistent properties
2	high nitrogen content
3	high molecular weight
4	high asphaltene content
5	high solubility in organic solvents

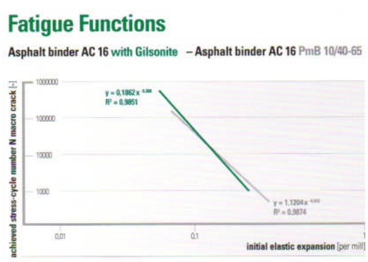
GILSONITE doesn't contribute to low temperature cracking. This is contrary to logic and experience with other bitumen modifiers that also impart hardness, The semi-polymeric nature of GILSONITE and its unique chemical composition are responsible for this unusual behavior.
The high asphaltene content and high molecular weight function mainly as a solution thickener or flow controller, These two factors are the main reason for the improvement in the pavement stability characteristics.
The high nitrogen content of GILSONITE gives the modified bitumen better adhesion to aggregate which improves stripping characteristics, as well as oxidation resistance.
The minimal sulphur content also means that GILSONITE is a low odor product
GILSONITE only needs 1/3 of other natural asphalts to give even better performance. Due to its pureness, only a replacement of 5 — 15 % of the actual bitumen content shows significant improvement in stiffness and re-sistance to deformation as well as ductility and viscosity.

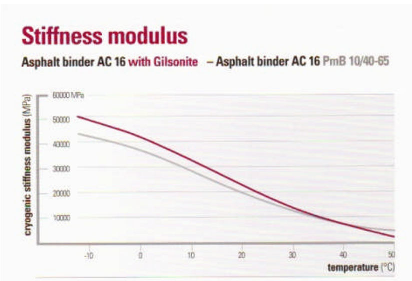
3. Where to use GILSONITE

GILSONITE is a very economic and cost effective way to modify road construction bitumen for high performance roads.
Sophisticated test methods such as Indirect Tension Stress Test, Cryonic Tensile Stress Test and the Splitting and Erectile Tension Test have proved that GILSONITE modified bitumen offers superior properties in:

- fatigue behavior
- stiffness modulus
- cold temperature performance







Special computer software for the dimensioning of traffic surfaces of asphalt was used to calculate and compare the utilization period of Gilsonite and Polymer modified binder courses; result was that the *calculated life time of binder courses on US federal motorways* increased from 18 to 29 years.
GILSONITE modified bitumen will increase the susceptibility to deformation from static or slow moving loads at Toll Plazas, Airport Taxiways, Exit Ramps, Container Terminals, Sharp Curves, Port Facilities, Intersections, Truck Terminals, Bus Stops and Lanes, Bridge Decks, Roundabouts, Park Decks.
GILSONITE modified bitumen will help against moderate rutting caused by high speed, heavy volume traffic at Truck Lanes, Racing Circuits, Highways, Airport Runways
A GILSONITE modification makes the most sense when used in high performance binder courses, but can also be used in a wide variety of asphalt surface courses such as Stone Mastic Asphalt, Asphalt Concrete, Gussasphalt, Hot Rolled Asphalt.
Gilsonite can significantly improve the high temperature properties of asphalt binders.
Gilsonite increases the Ring & Ball Softening Point, the Absolute Viscosity and reduces the Penetration values of both neat and modified asphalt binders.
Consequently, it also increases the high temperature stiffness and reduces the phase angle of the base asphalt
GILSONITE has been used widely in addition to up to 50 % with recycled asphalt.

4. How to use GILSONITE

GILSONITE is a free flowing granular material which will not cake or block during storage.
Because of the nature of this hydrocarbon, GILSONITE is completely soluble in bitumen, forming a very intimate molecule that will NOT separate. It can be used:

- in bitumen pre-blend: a pre-blend of GILSONITE and bitumen in the proper percentage (5-15 %) can be produced in the bitumen tank with temperatures maintained around 170°C. During the GILSONITE solution, agitation and recirculation under heat should be maintained for 12 — 24 hours.
- in pug mill: addition of GILSONITE to a pug mill can be accomplished by the introduction of pre-weighted plastic bags, or in bulk by using an automatic dosage system. The GILSONITE should be added onto the hot aggregate before the bitumen is added. The wet mix circle must be extended by 15 sec. to ensure proper blending.
- in drum plants: GILSONITE may be added to a drum plant, either by the master batch method or with a dry mineral feeder at the correct rate of flow along with the bitumen.

Paving conditions should remain identical to non-modified bitumen, except that mix temperatures should be maintained at a minimum of 160°C to compensate for the addition of the GILSONITE. Lay down and compaction should be normal providing this slightly higher temperature is maintained.
GILSONITE is available in 25 kg meltable plastic bags, 30 kg craft paper bags and 1,000 kg big bags.

5. Purpose of GILSONITE modification of Asphalt Pavement Mixtures

1	Improved resistance to deformation
2	Improved the economic performance of the road
3	Improved resistance to stripping
4	Improved resistance to fatigue
5	Improved durability
6	Compensation for poor mix design
7	Compensation for poor aggregates

6. Gilsonite in Hot Mix Asphalt

According to FHWA (U.S. Federal Highway Administration) research data, up to 80% of pavement flexibility is lost during the first 5 years. When the aging process is halted and the pavement is preserved early on, maintenance is less invasive and much less expensive.
Furthermore, FHWA, FAA (Federal Aviation Administration), NAVFAC (Naval Facilities Engineering Command), MDOT (Michigan Department of Transportation), and AzDOT (Arizona Department Transportation), research shows agencies that used Gilsonite-based treatments reduced pavement replacement costs by up to 60%

compared to using the worst first-practices.
While HMA (Hot Mix Asphalt) pavements perform poorly when they become hard (like cement), when Gilsonite is applied to the surface of asphalt pavement it maintains oils, resiliency, and flexibility by filling micro-voids and keeping asphalt binders soft and pliable. The use of Gilsonite lowers viscosity by over 30%, increases ductility by 30%, and increases Marshall Stability by almost 40% (strength of binder) after just 5 years. Contrary to many engineers' belief, Gilsonite does NOT harden pavement. However, it DOES toughen the surface to better withstand traffic and the aging process. The stability of Gilsonite-fortified pavements makes them more resistant to problems, such as rutting and shoving, and increases the pavement's load carrying ability. In some cases these high-performance mixes will halt, and reverse the effects of aging and degradation from water penetration, oxidation, and UV radiation. In addition, other benefits include increased resistance to water stripping, oxidation and the aging process.

7. Notes on Ashes and Volatiles

GILSONITE is an Organic matter; a hydrocarbon consisting of Carbon and volatile gases like Methane. With very special characteristics defining it as Bituminous matter. These characteristics are very similar to those, which are synthetically produced in the refineries.
This chemistry, which defines this bitumen without its volatile gases, is nothing but something similar to a Coal. Then "the higher the volatile matter Ratio to Carbone the closer it is to synthetic Bitumen".
In the laboratory the test procedure is defined to quantify these matters. We slowly apply heat to GILSONITE to initially reach to its softening points 170-220 degrees C . The heat is applied further at a constant rate in order to reach the temperature of 350 degrees C at which the volatile gases are fully evaporated. At this stage we reach a point referred to as FIXED CARBONE.
The Temperature is still increased beyond 350 degrees C at a constant rate until all Fixed Carbone is disintegrated fully at temperatures above 800 degrees C. The specimen is kept at this temperature for a while and then cooled off. The remaining balance is then analyzed and measured.
The balance is collectively referred to "ASH" which, are basically Ferrous Silicate: FeSi2, Calcium Carbonate: CaCo3 , SO2, MgO, Al2O3 and SIO2

8. Notes on Asphaltene content

Asphaltenes are molecular substances that are found in crude oil, along with resins, aromatic hydrocarbons, and alkanes (i.e., saturated hydrocarbons). The word "asphaltene" was coined by Boussingault in 1837 when he noticed that the distillation residue of some bitumen had asphalt-like properties. Asphaltenes in the form of distillation products from oil refineries are used as "tar-mats" on roads.
Asphaltenes consist primarily of carbon, hydrogen, nitrogen, oxygen, and sulfur, as well as trace amounts of vanadium and nickel. The C:H ratio is approximately 1:1.2, depending on the asphaltene source. Asphaltenes are defined operationally as the n-heptanes (C_7H_{16})-insoluble, toluene ($C_6H_5CH_3$)-soluble component of a carbonaceous material such as crude oil, bitumen or coal. Asphaltenes have been shown to have a distribution of molecular masses in the range of 400 u to 1500 u with a maximum around 750 u.
Unique natural hydrocarbon is high in asphaltenes and nitrogen. It makes it fully compatible with bitumen. It be melted into hot bitumen, added during the hot-mix manufacturing process, or blended into a preservation treatment. In either case, GILSONITE dissolves easily in bitumen and achieves a uniform, easily workable product.

Gilsonite resin is often used by asphalt producers, road paving engineers and paving contractors who are concerned with PG specifications, high-performance and cost-effectiveness. Gilsonite, long known as a bitumen re-enforcer and strengthening agent, also offers a unique combination of high-performance and economy for high-stress paving, and preservation applications. Gilsonite is an approved mineral by the U.S. Food & Drug Administration for use in resinous and polymeric coatings that come into direct contact with food. Gilsonite falls under Section 175.300 (formerly Section 121.2514) of the FDA regulations, Part 3, subpart (iv), which lists Gilsonite as one of several approved natural resins. Besides being non-toxic, Gilsonite products are non-carcinogenic and non-mutagenic.

9. Gilsonite Solubility

A variety of sophisticated analytical tests have been run on Gilsonite to characterize its unique properties. For reference, the test methods include vacuum thermal gravimetric analysis (TGA), nuclear magnetic resonance (NMR), Fourier transform infrared spectrometry (FTIR), vapor pressure osometry (VPO), high performance liquid chromatography (HPLC), rapid capillary gas chromatography (RCAP), and several fractionation techniques. H/C ratios and NMR analysis indicate the presence of a significant aromatic fraction. Most of the aromatics exist in stable, conjugated systems, probably porphyrin-like structures that relate to the geologic source of the product. The remainder of the product consists of long, paraffinic chains. A very unique feature of Gilsonite is its high nitrogen content, which is present mainly as pyrrole, pyridine, and amide functional groups. Phenolic and carbonyl groups are also present. The law oxygen content relative to nitrogen suggests that much of the nitrogen has basic functionality. This probably accounts for Gilsonite special surface wetting properties and resistance to free radical oxidation. The average molecular weight of Gilsonite is about 3000. This is very high relative to other asphalt products and to most synthetic resins. This may relate to Gilsonite "semi-polymeric" behavior when used as a modifying resin in polymeric and elastomeric systems. There is some reactive potential in Gilsonite. Crosslinking and addition type reactions have been observed. Gilsonite is known to react with formaldehyde compounds under certain conditions

Gilsonite is an important component of today's printing inks, paints & industrial coatings. Gilsonite is used as a hard resin and carbon black dispersant in a variety of coatings. Solutions of Gilsonite (sometimes called cutbacks or varnishes) are an excellent starting point for blending Gilsonite with other components of a final product formulation. Some formulators convert dry Gilsonite into liquid solution in their own facilities. Others will request a pre-made solution. Converting dry, granular Gilsonite to a liquid solution also provides the opportunity to remove the small amount of abrasive grit that occurs in natural asphalt. Stabilizing additives can also be added if a poor solvent is used or if high concentrations of Gilsonite are desired.

Solubility: Gilsonite is soluble in aliphatic, aromatic and chlorinated hydrocarbon solvents. It has limited solubility in most ketones, but is soluble in mixed aromatic solvents that contain a ketone component. Gilsonite is not soluble in water, alcohols, or acetone. Solution Preparation: Three basic procedures are used to dissolve Gilsonite. In each case, precautions for flammable materials should be used. Cold-cutting: Gilsonite is generally soluble in aliphatic and aromatic solvents at ambient temperatures. Some agitation should be used. The rate of solution will depend on the type of solvent, the type and severity of mixing, and the grade of Gilsonite. The solution rate can be increased by using a high shear mixer, such as a Cowles disperser. When a ball mill or a paddle mixer is used, lump grade Gilsonite is recommended. When high energy mixing is available, either lump or pulverized grades may be used. Care must be taken to avoid "dry balls" of undissolved solid when using pulverized grades. Hot-cutting: The rate of solution can be increased by heating. Steam coils or hot oil is preferred. Direct-fired heating can be hazardous. Care must be taken to avoid or make up for vaporized solvent.

Facilities for solvent containment are often necessary. The maximum processing temperature will depend on the boiling range of the solvent. Hot fluxing: Gilsonite can be hot fluxed into asphalts and high boiling oils.

Once blended, the combination can then be let down with a solvent to reach the desired viscosity. This hot fluxing with another product can help overcome limitations of solubility. Selecting the correct blend or co-solvent can yield compatibility with a solvent that is normally of limited solubility. Hot Fluxing Procedure: Heat the oil to 200 °F or more. Most of the high boiling, law aromatic ink oils in use today will require a temperature of at least 300-330 °F. With good agitation, add dry Gilsonite at a rate that maintains constant dispersion of the particles until they dissolve. Be alert for foaming that can be caused by traces of moisture in the Gilsonite. Continue to agitate for 15 to 30 minutes beyond the point when the last of the Gilsonite particles is detected. The Gilsonite should now be completely dissolved and the solution ready for discharge. Filtration: The varnish must be filtered to remove the grit that is a natural component of Gilsonite. There are two common filtration methods. Each provides a different degree of cleanliness. Both methods are normally preceded by passing the hot varnish through a course wire screen (approx. 1/4") to remove any large stones. For a normal degree of cleanliness, the prescreened, hot varnish is passed through wire screen baskets of about 200 mesh (74 microns). Cloth bag filters can also be used, at a higher cost, when the company doesn’t have the personnel to clean the wire baskets. Disposal of the bags is also a consideration. Be careful to use bags that can tolerate elevated temperatures if hot cutting is performed.

For extra cleanliness, the prescreened, hot varnish is passed through cartridge filters of about 5 to 25 microns. These filters are also disposable. Viscosity Modification: Some Gilsonite solutions can be quite viscous at ambient temperature. Also, some solutions can steadily increase in viscosity over time. These characteristics are usually observed when using law aromatic oils with poor solvent power or when high percentages of Gilsonite are used. In these cases, small amounts of viscosity modifiers are often added to (1) keep the hot varnish sufficiently fluid for easy filtration and (2) to reduce and stabilize the ambient viscosity so the solution remains fluid until it is used. The following is a partial list of modifiers that are effective at stabilizing the viscosity of Gilsonite solutions.

Soft asphalt flux. This is often substituted for 15 to 20 % of the Gilsonite in the varnish. At this level, it reduces the softening point of the Gilsonite by about 30 °F. It should not be used when maximum hardness and rub resistance is desired, or when fast solvent release is required, or when restrictive health safety regulations are in effect.

Tridecyl alcohol (TDA). More volatile than some modifiers (a flash point of 180°F), but effective. Generally used at 3-10%, based on the Gilsonite content.

Low molecular weight alcohols. Examples are n-propanol and n-butanol. These are effective, but their high volatility usually restricts their use to fast drying systems or products that are stored and used at ambient temperature.

Tall oil fatty acids. These are mainly oleic and linoleic acids with small amounts of rosin acids present. They are used for their high flash point and law volatility. In some cases, stearic or oleic acid, or vegetable oils such as linseed or soya bean oil, can be substituted for tall oil fatty acids with comparable performance.

Surfactants. A wide variety of commercial surfactants are also effective. Care must be taken to avoid any undesirable side effects on the performance of the final product.

GILSONITE SOLUBILITY		
Chemical Group	**Item**	**Solubility**
Aliphatic Hydrocarbons	VM&P Naphtha	S
----	Mineral Spirits	S
----	Solvents with KB	S
Aromatic Hydrocarbons	All	S
Alcohols	All	I
Chlorinated Hydrocarbons	All	S
Esters	Methyl Acetate	I
----	Ethyl Acetate	Slight
----	n-Butyl Acetate	Slight
Glycols	All	I
Glycol Ethers	All	I
Glycol Ether Esters	All	I
Ketones	Acetone	I
----	MEK	I
----	MIBK	I
Other Solvents	Carbon Disulfide	S
----	Carbon Tetrachloride	S

10. Gilsonite Compatibility

Adhesive/ coating system	Compatibility	Adhesive/ coating system	Compatibility
Natural rubber	FAIR	Ethylene/vinyl acetate	GOOD
Cellulose esters	POOR	SBS rubber	EXCELLENT
Phenolic	GOOD	Polychloroprene rubber	EXCELLENT
Resorcinol formaldehyde	FAIR	Nitrile rubber	FAIR
Urea formaldehyde	GOOD	Butyl rubber/polyisobutylene	GOOD
Melamine formaldehyde	GOOD	Silicone	GOOD
Alkyd	GOOD	Polyurethane	FAIR
Epoxy	FAIR	Vinyl ethers	GOOD
Polyurethane	FAIR	Resinates	GOOD
Acrylic	FAIR	Resin modified	EXCELLENT
Unsaturated polyester	FAIR	C9 aromatic	GOOD
Polyaromatic	GOOD	DCPD	EXCELLENT
Acrylic acid diester	POOR	Terpene	EXCELLENT
Polyvinyl acetate	FAIR	Terpene phenolic	GOOD
Polyvinyl alcohol	FAIR	Phenolic modified	GOOD
Polyvinyl chloride	GOOD	maleic-fumaric modified	EXCELLENT
Acrylic	FAIR	Alkyd	GOOD
Polyamide	POOR	Shellac	POOR
Phenoxy	POOR		

11. Typical Gilsonite Laboratory Test

TEST	UNIT	SAM-1	SAM-2	SAM-3	SAM-4	ENRICHED
Ash	wt%	12.4	14.88	4.71	1.87	0
Moisture	wt%	0.12	0.14	0.15	0.18	0.10
Volatile	wt%	68.9	71.6	68.45	72.6	75.0
Fixed Carbon	wt%	18.7	13.52	26.51	25.25	30
Density	g/qcm	1.18	1.21	1.12	1.08	1.10
Softening point	c	190-200	230-245	180-195	200-210	160
Flash point	c	430	440	410	430	430
Sulphur	wt%	1.77	3.74	0.74	0.67	1

Notice: all the information in this document has not a scientific value. The only purpose is to inform with generic data.

B. Historic Applications and Performance of Gilsonite, Modified Asphalt and Hot Mix Asphalt

The history of Gilsonite in hot mix applications is broad and worldwide. Gilsonite successful uses range from high stress areas in the City of Oslo, Norway; toll booth approaches on the New Jersey Turnpike in the United States; and major city streets and highways in Australia, Singapore, Indonesia, Japan, France and Germany to mention only a few.

In many paving situations it is important to achieve and extend the performance-range of the asphalt by increasing the stability without compromising other properties. Gilsonite has been successfully used in difficult to pave areas that combine very high loads with stop-and-go traffic. The following examples illustrate the breadth and variety of successful Gilsonite uses in hot mix asphalt (HMA).

12. Oslo, Norway

The city of Oslo, Norway, has been using Gilsonite since the early 1970's for highly stressed areas and for areas with water stripping problems. This use is unusual in that they start with a hard (40-50 penetration) asphalt, and add Gilsonite to produce an extremely hard pavement. These mixes have been found to often double the expected pavement life while giving dramatic visual evidence of improved stripping resistance. Most encouraging is the fact that, even in the severe climate of Oslo, the use of Gilsonite has not created a low temperature cracking problem.

13. New South Wales, Australia

In New South Wales, Australia, Gilsonite has also been used to reduce severe pavement deformation in a wide variety of high stress traffic situations. Gilsonite is generally applied at a concentration 0.25% by weight of total mix. Inspections after 6, 12, and 24 months have showed a significant reduction in shoving and rutting.

Gilsonite performance in Australia has been so positive that the Australian Asphalt Pavement Association (AAPA) recommends Gilsonite be used as a modifier for roundabouts to reduce pavement shoving.

14. Seattle, Washington, U.S.A.

At the Port of Seattle, in the northwestern USA, Gilsonite has been used in an area of extreme distress caused by heavily loaded "top pick" container movers. Gilsonite was added at a concentration equivalent to 8% by weight of binder. A 60/70-pen base was used on this project. The addition was made directly to a pug mill using meltable bags, which easily incorporated into the mix. The cycle time was increased by 15 seconds to ensure complete mixing.

The most stressed section of the Seattle pad was paved with two 2.5" lifts. Installation was smooth and uneventful, the material compacted well, and inspection showed that the aggregate was more thoroughly coated in the pavement containing Gilsonite. Gilsonite modified HMA exhibited superior rut and water resistance after the initial one-year inspection.

15. New Jersey Turnpike, U.S.A.

The New Jersey Turnpike has been using Gilsonite steadily for over five years. With up to 500,000 vehicles per day, of which 20% are trucks, the NJ Turnpike presents a unique challenge to pavement design. After unsuccessful attempts to use hard asphalts to reduce rutting and shoving, Gilsonite was used as a substitute for 10% of the asphalt. This almost doubled stability, and has resulted in excellent field performance. Rutting and shoving were virtually eliminated without creating a cracking problem. Increased pavement life of at least two years has been recorded.

C. Chemistry and Physical Properties of Gilsonite and Gilsonite-Modified Asphalt

Gilsonite is made up of very high molecular weight, oligomeric, polar polynuclear hydrocarbons. Because of the unique polymer-like structure of the Gilsonite asphaltenes it can significantly improve the quality of asphalt binder even at very moderate addition levels. Since Gilsonite is a natural asphalt it readily disperses into asphalt and forms a continuous, completely stable asphalt binder. However, for this to occur it is important that the product be incorporated at temperatures exceeding the Gilsonite softening point by 10° to 20°C (18° to 3 6°F) and that proper agitation is available to prevent the Gilsonite from settling out before it can be dispersed.

16. Formulation and Performance Characteristics of Gilsonite- Modified Asphalts

Gilsonite-Modified-Asphalts (GMAs) exhibit generally significantly improved high temperature properties. Because Gilsonite addition changes the oil-to-asphaltene content the low and intermediate temperature properties may potentially be adversely affected. However, when using the modifier at levels ranging between 1 to 4% in conventional asphalts our research indicates that the natural balance of the various asphalt constituents is maintained.

17. Formulation and Performance Characteristics of Gilsonite- Modified Hot Mix Asphalt

- **Improved Marshall Stability**: addition of Gilsonite can dramatically raise the stability of pavement mix. 8% Gilsonite (a typical level of addition) will increase Marshall stability by approximately 25% to 40%. This converts a standard pavement into a high performance pavement.
- **Water Sensitivity**: the use of Gilsonite offers another important benefit: reducing the water sensitivity of the mix. Tests were conducted with a granite gneiss known to be highly water sensitive. Marshall stabilities were tested both with a standard 30 minute immersion in 25°C water and with a 24 hour water immersion at 60°C. The data shown below indicates that the mix without Gilsonite never achieves an adequate wet stability level. Gilsonite addition, even at a modest 4% level, produces considerably higher wet stability values
- **Dynamic Modulus Studies**: Dynamic modulus testing shows that Gilsonite increases the complex module of hot mixes in a way that strongly suggests increased fatigue life in commercial practice. These tests evaluate the dynamic modulus of mixes modified with Gilsonite and with Gilsonite/polymer combinations. When used with polymers, Gilsonite appears to selectively increase modulus at high temperatures, which suggests an even higher level of improvement in pavement resistance to rutting and shoving.
- **Fatigue Studies**: The table below shows tests that were conducted at three temperatures and three frequencies, simulating fast-moving, moderate-moving and stop-and-go traffic conditions. From these data, an Asphalt Institute computer program was used to calculate estimated fatigue. While these calculations can only be considered a laboratory indicator of actual pavement performance under stressed conditions, the results are sufficiently encouraging to be reported. It is demonstrated how the pavement lifetime is forecast to increase approximately 25% due to Gilsonite modification. In commercial experience, the pavement lifetime increase is usually between 100% and 200% when rutting and shoving are the original causes of the pavement failure.

Frequency Hz	Temperature °C	Bitumen (70 Pen)	Bitumen 10% Gilsonite
16	4	13.2	17.1
4	4	11.1	14.6
1	4	8.9	12.9
16	25	4.2	7.4
4	25	3.1	6.1
1	25	2.0	4.6
16	40	1.4	3.4
4	40	0.8	2.5
1	40	0.5	1.6

- **Permanent Deformation Studies:** Conventional binders were compared with polymer-modified and with systems modified with a combination of polymer and Gilsonite. Our wheel tracking results suggest excellent deformation resistance and superior overall pavement performance. The test conditions included a wheel load of 70 kilograms passing over the sample at 21 rpms for 60 minutes at 60°C.The test was performed on a matrix of binders containing Gilsonite, SBS, EVA and their respective combinations as shown in the table below. All blends, (except #10) utilized a 70-pen base asphalt. The wheel tracking data shows that best results were obtained with Blend #3 (8% Gilsonite) and Blend # 5 (6% Gilsonite and 2% SBS). The latter even outperformed the blend containing 4% SBS (# 6).

Sample ID#	Base Asphalt	Gilsonite Content, %	Elastomer Content,%	EVA Content,%	Passes/mm Rut Depth	Pen @77F,dmm	Viscosity @60C, P
1	100%	0%	0%	0%	510	70	1,440
2	96%	4%	0%	0%	1,370	43	2,640
3	92%	8%	0%	0%	3,150	35	4,210
4	96%	2%	2%	0%	1,210	56	2,960
5	92%	6%	2%	0%	3,150	38	5,260
6	96%	0%	4%	0%	2,860	66	5,260
7	96%	2%	0%	2%	1,580	61	1,870
8	92%	6%	0%	2%	2,630	43	3,320
9	96%	0%	0%	4%	1,430	77	1,350
10	100%	0%	0%	0%	1,170	42	2,920

18. Laboratory Handling for Preparation of Gilsonite-Modified Asphalt

The asphalt should be heated to a temperature ranging between 190°C (374ºF) to 205°C (401°F). A paddle-mixer is sufficient and no high shear blending is required. We recommend reacting the blend for a minimum of two hours at the above-mentioned temperature. No additional modification steps are generally required

19. Viscosity and Penetration Graded Asphalts

As previously mentioned Gilsonite can significantly improve the high temperature properties of asphalt binders. Gilsonite increases the Ring & Ball Softening Point, the Absolute Viscosity and reduces the Penetration values of both neat and modified asphalt binders. Consequently, it also increases the high temperature stiffness and reduces the phase angle of the base asphalt

D. ROAD BITUMEN MODIFIED WITH NATURAL ASPHALT TRYNIDAD EPURÉ AND GILSONITE ADDITION

The objects of the research and analysis presented in the paper are composites prepared of 35/50 and 50/70 penetration grade bitumen, with the addition of Trinidad Epuré and Gilsonite natural asphalt. The aim of research is to evaluate the changes of rheological properties of composites as a result of those two modifiers addition. The research area includes tests of temperature susceptibility characterized by the penetration index PI value, the adhesion to the basalt and granite aggregates, the maximum tensile force determined by force-ductility method, resistance to low temperature cracking characterized by stiffness modulus and m-value determined by using Bending Beam Rheometer BBR.

20. Introduction

Trinidad Natural Asphalt is mined from Trinidad Pitch Lake, which is located nearby city La Brea on Trinidad Island, on the Caribbean Sea. This raw material separated from the surface of the lake is a natural mixture of: bitumen - 39.3%, minerals - 27.2%, water and volatile substances - 29.0 to 30.2% and bound water - 3.3%. It is purified through evaporation of free water and volatile materials and separation of mineral or organic pollutants in the form of stones and wood. The final product of this technology is pure asphalt called the Trinidad Epuré. It contains: natural bitumen - 53.0 to 55.0%, minerals - 36.0 to 37.0%, organic matter insoluble in CS_2 - 9.0 to 10.0%. Powder in the Trinidad Epuré is composed of particles <0.09 mm in an amount about 82% and grains 0,09-0,25 mm in an amount about 18%.

Many years of experience have shown benefits of addition the natural asphalt to the hot mix asphalt on their workability and compatibility. Professor Radenberg's publications show that the addition the Trinidad Epuré to asphalt improves its resistance to rutting. This additive to the hot mix asphalt is allowed to use lower temperature compaction. It is very beneficial from the point of view of surface technology and environmental friendliness. In Germany the Trinidad Epuré is used successfully as an additive for hot thin layers in many parts of the repair pavement. The purpose of use is to create favorable conditions for compacting hot thin layers, which is rapidly cooled by the rollers and the weather condition.

Gilsonite was discovered in 1860 in north-eastern part of Utah (USA) in the Uintah basin. The production of this unique material began in 1885, when Samuel H. Gilson characterizing ore called it his name. Gilsonite is a glossy, black, solid hydrocarbon resin similar in appearance to coal or hard asphalt. A special feature of Gilsonite, which significantly differ it from Trinidad Epuré is a very high content of pure bitumen in amount about 98%. This raw material is a natural mixture of: coal - 84.9% (aliphatic carbon - 68.3%, 31.7% of aromatic carbon), hydrogen -10.0%, nitrogen - 3.3%, sulfur - 0.3%, oxygen - 1.4% and other ingredients in amounts - 0.1%. This ore is crushed and delivered to customers in the form of granules of grain size 0/2 mm or powder.

Gilsonite is used in road construction as a performance-enhancing agent of hot mix asphalts. **This additive may partially replace using SBS polymers, what could reduce the cost of production of modified bitumen**. Gilsonite modified hot mix asphalts have higher stability, reduced deformation, reduced temperature susceptibility and increased resistance to water. Gilsonite is used in the form of solvent and emulsion as a surface sealant resistant to adverse weather conditions.

We do not have detailed knowledge of effects of changes the functional and rheological properties of composites as a result of those two modifiers addition.

21. Purpose And Scope Of The Research

Aim of this study is to get to know the impact of addition of natural asphalt Trinidad Epuré and Gilsonite, respectively marked with symbols TE and GIL in this paper, to change the following properties of bitumen 35/50 and 50/70:

- Temperature susceptibility characterized by the penetration index PI value, determined before and after aging according to the method RTFOT
- Adhesion to basalt and granite aggregate
- The maximum tensile force, determined by force-ductility method, at 10°C

- Stiffness modulus and m-value which characterize the resistance to low temperature cracking, determined by using Bending Beam Rheometer BBR at -8°C, -16°C, -24°C and -32°C before and after aging according to the RTFOT method

22. Methods And Results Of Research

Materials:
Two penetration grade bitumen 35/50 and 50/70 named base bitumen and natural asphalt Trinidad Epuré and Gilsonite were used in the research program.
Preparation of composites with the addition of TE was consisted of preheat containers filled with bitumen grade 35/50 to temperature of 175°C and bitumen grade 50/70 to temperature of 165°C. Next step was adding the natural asphalt TE in appropriate proportions. In order to dissolve the bitumen contained in the asphalt TE composites was heated at these temperatures. For homogenization the composites with the base bitumen and nature asphalt the laboratory mixer was used.
Preparation of composites with the addition of GIL was consisted of preheat containers filled with bitumen grade 35/50 and 50/70 to temperature 190°C. Next step was adding the natural asphalt GIL in appropriate proportions. In order to dissolve the bitumen contained in the asphalt GIL composites was heated at this temperature. For homogenization the composites with the base bitumen and nature asphalt a laboratory glass stick was used.
Obtained composites were marked by specifying the grade of base bitumen, type of additive (TE or GIL) and its content in the composite.
Example description of composites:

- 35/50 penetration grade bitumen with addition of 15% of Trinidad Epuré - marked as 35/50 + 15% TE,
- 50/70 penetration grade bitumen with addition of 7% of Gilsonite - marked as 50/70 + 7% GIL.

Temperature susceptibility:
To evaluate the temperature susceptibility of tested specimens, the following properties were determined:

- Penetration at 25°C - according to EN 1426,
- Softening Point according to the method of "Ring and Ball" - according to EN 1427.
- Penetration Index (PI) values (Figures 1 and 2) were calculated using the formula (1) based on the results of determination of penetration at 25°C and softening point:

$$PI = \frac{1952 - 500 \cdot \log(Pen25) - 20 \cdot T_{R\&B}}{50 \cdot \log(Pen25) - T_{R\&B} - 120} \quad (1)$$

where: Pen25 - Penetration at 25°C, 10-1 mm TR&B - Softening Point, °C
The detailed results of determination of penetration at 25°C and softening point for Trinidad Epuré are presented by the authors in an article.

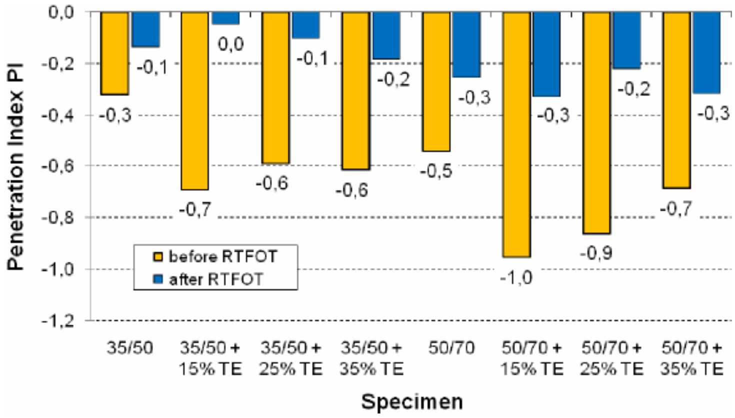


Figura 1: Penetration index PI values before and after RTFOT - specimens containing TE addition

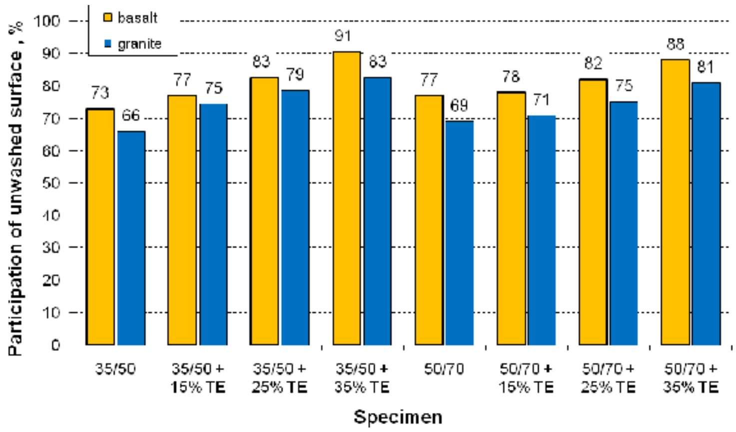


Figura 2: Penetration index PI values before and after RTFOT - specimens containing GIL addition

Good adhesion of bitumen to the surface of mineral aggregates is a very important factor for the durability of asphalt pavements

Bitumen adhesion to aggregates was assessed on the basis of results of cooking test carried out in accordance with PNB-06714-22. The aggregates with different acidity: basalt and granite, were used in the research program

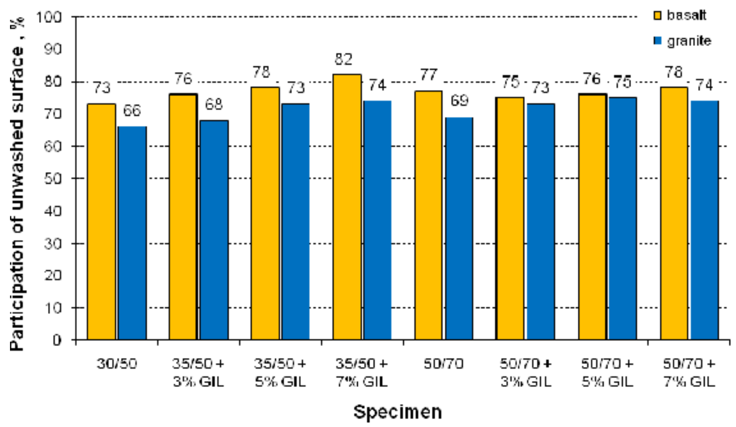


Figura 3: Participation of surface covered with bitumen (unwashed) on basalt and granite aggregates (computer evaluation) - specimens containing TE addition

In order to achieve a better accuracy of measurement compared to the standard method, the evaluation using "computer test" was carried out. This method has been described by the authors in the paper [7]. Results of adhesion test are shown in Figure 3

Force-ductility method

The investigation was conducted using ductilometer at 10°C Determined values of maximum tensile force are presented in Figures 4 and 5.

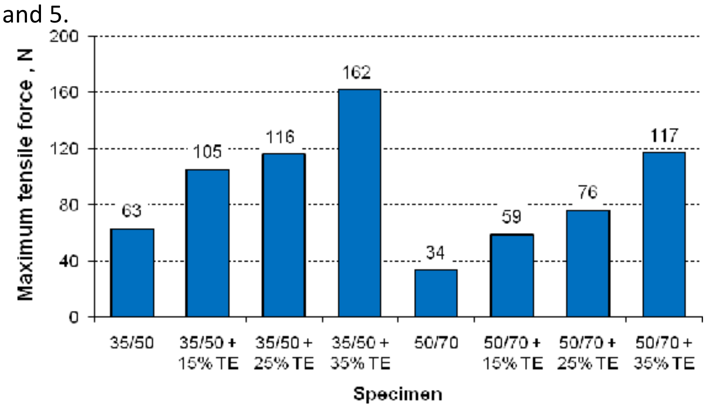


Figura 4 : Maximum tensile force values - specimens containing TE addition

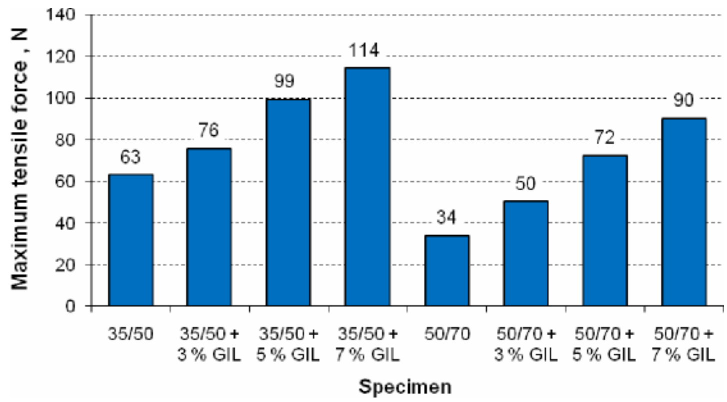


Figura 5: Maximum tensile force values - specimens containing GIL addition

Bending Beam Rheometer (BBR) test

The research was conducted in Bending Beam Rheometer BBR at -8°C, -1 6°C, -24°C and -32°C before and after RTFOT according to EN 14771. Stiffness modulus values Sm(t) expressed in Pascals were calculated by the following formula:

$$S_m(t) = \frac{Pl^3}{4bh^3\delta(t)} \quad (2)$$

where:

P – specimen load; P = (980±50) mN

l – distance between supports; l = 102 mm

b – specimen width; b = 12,7 mm

h – specimen height; h = 6,3 mm

8(t) – specimen deflection at the time t

The m-values were calculated in accordance with the rules described in EN 14771, as the ratio of the logarithm of stiffness Sm(t) to the logarithm of time of the load t, according to the formula:

$$m(t) = \frac{d \log S_m(t)}{d \log(t)} \quad (3)$$

Figures 7 and 8 show examples of stiffnes moduli and m-values determined at -16°C specimens containing TE addition.

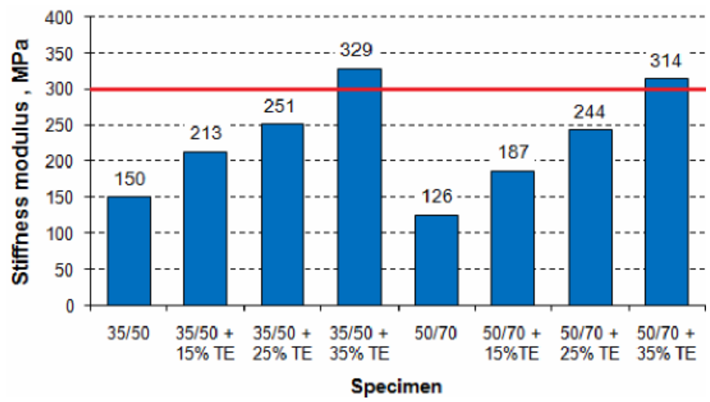


Figura 6: Stiffness modulus values determined at -16°C - specimens containing TE addition

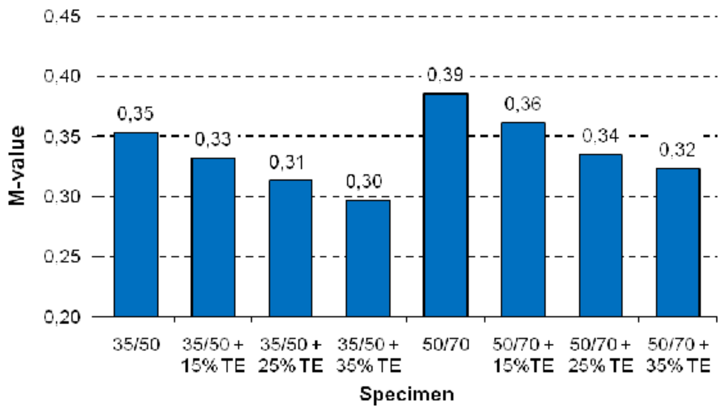


Figura 7: M-value values determined at -16°C - specimens containing TE addition

23. Discussion

Gilsonite additives have a varied impact on the temperature susceptibility of the composites. At Figure 1 it can be seen that the addition of TE causes a decrease in penetration index PI. Differences of values of penetration index for composites with harder bitumen 35/50 are not significant, while for the softer bitumen 50/70 they are larger. As a result of the RTFOT aging process penetration index is increased. It can be seen that the values of PI of base bitumen and composites after RTFOT do not differ significantly. GIL additive increases penetration index value (Figure 2). Larger increase of PI values has been observed in the case of composites with harder bitumen 35/50. Together with increasing the GIL additive content the value of PI increases. As a result of the RTFOT aging process the values of penetration index PI are increased. It can be seen greater increase for the composites containing 35/50 bitumen.

The results of research show that the addition of road bitumen 35/50 and 50/70, improves the adhesion to the surface of mineral aggregates. In Figure 2 it can be seen that it is a larger part of unwash surface with asphalt when harder bitumen was used. The study shows that the addition of Gilsonite does not significantly improve the adhesion to the surface of mineral aggregates (Figure 3).

Additives of Trinidad Epuré and Gilsonite for road bitumen 3 5/50 and 50/70 affect the increase of the maximum tensile force of the tested composites. Figure 5 presents composites with addition of TE. It can be seen that this additive affects greater increases for the composites with harder bitumen 3 5/50. GIL additive (Figure 6) affects increase of the maximum tensile force of the composites with softer bitumen 50/70.

Analysis of the results obtained in the Bending Beam Rheometer (BBR) at -8°C, -16°C, -24°C and -32°C before and after RTFOT aging process showed that Trinidad Epuré and Gilsonite additives affect increase of the stiffness modulus. Performed in Figure 7 line meaning the value 300 MPa of stiffness modulus indicates excessive stiffness of the composites with the addition of 35% TE at -16°C. It may be a reason of a high sensitivity to low temperature cracking. In Figure 8 it can be seen that the conventional measures of rigidity (m-value) presents for the TE before the RTFOT aging process at temperature -1 6 °C complies the requirements and there are less than 0.3 according to the recommendation. Analysis of the results of critical temperature for base bitumen and composites showed that for both TE and GIL additives the critical temperature increases lower when a softer bitumen 50/70 was used. As a result of the RTFOT aging process the critical temperature was increased. It can be seen lower increase in the critical temperature when the GIL additive was used.

Based on performed research of the road bitumen penetration grade 3 5/50 and 50/70 and the obtained composites with the addition of natural asphalt TE and GIL, and the discussion we can formulate the following conclusions:

- additives of natural asphalt TE and GIL have a varied impact on the temperature susceptibility of the obtained composites. After the RTFOT aging process the impact can be assessed positively (increase of the PI value). It can also be stated that using GIL additive is more beneficial
- additive of TE to road bitumen 35/50 and 50/70 improves the adhesion to the surface of mineral aggregates. Addition of GIL additive does not improve significantly the adhesion of bitumen to the surface of aggregates. It can also be stated greater part of unwashed surface when harder bitumen 35/50 is used

- additive of TE affects hardening in the case of bitumen 3 5/50 and GIL additive – in the case of bitumen 50/70
- additive of TE and GIL to road bitumen 3 5/50 and 50/70 increased critical temperature. It was observed a greater increase of the critical temperature for a bitumen - 50/70. It can also be stated lower rise of the critical temperature using the GIL additive.

E. Investigations into the behaviour of asphalt binders with and without the Gilsonite additive

Within the framework of the research project that is documented here, the influence of the natural asphalt Gilsonite on its utilization (stiffness, coldness and fatigue behavior) should be observed, whilst using 30 M.-% asphalt granulate in asphalt binder. Research on four different asphalt binder variants that have impact on the stiffness, coldness and fatigue behavior have been made, and the findings have been evaluated and interpreted.
Two variants with and without Gilsonite should be used, where the grading curves should follow the "Grit mastic principle", and two variants with and without Gilsonite should be used, where the grading curves should follow the "Concrete principle".
The following stone aggregates have been used in the preparation of the asphalt variants that were to be investigated, in addition to asphalt granulate of the asphalt grit plant Altona:
Filler (0/0,063): Limestone powder (Hehlen, D) – Variants No. 1 to No. 4

fine stone aggregate (0/2):	Rhyolite (Flechtingen, D) – Variants No. 3 and No. 4
fine stone aggregate (0/2):	Diabase (Huneberg, D) – Variants No. 1 and No. 2
coarse stone aggregate (2/5):	Diabase (Huneberg, D) – Variants No. 1 to No. 4
coarse stone aggregate (5/8):	Diabase (Huneberg, D) – Variants No. 1 to No. 4
coarse stone aggregate (8/11):	Rhyolite (Flechtingen, D) – Variants No. 3 and No. 4
coarse stone aggregate (8/11):	Diabase (Huneberg, D) – Variants No. 1 and No. 2
coarse stone aggregate (11/16):	Rhyolite (Flechtingen, D) – Variants No. 3 and No. 4
coarse stone aggregate (11/16):	Diabase (Huneberg, D) – Variants No. 1 and No. 2

In summary, it should be pointed out that the findings that are reported in the text below have been found for the following four asphalt variants:

- No. 1: Split mastic binder AC 16 as per EP No. 1/232/2011 with 30 M -% asphalt granulate and added bitumen of the kind 10/40-65 A-RC
- No. 2: Split mastic binder AC 16 as per EP No. 1/384/2011 with 30 M -% asphalt granulate and added bitumen of 90 % 50/70 and 10 % Gilsonite
- No. 3: Asphalt binder AC 16 Hmb as per EP No. 1/662/2011 with 30 M -% asphalt granulate and added bitumen of the kind 10/40-65 A-RC
- No. 4: Asphalt binder AC 16 Hmb as per EP No. 1/661/2011 with 30 M -% asphalt granulate and added bitumen of 90 % 50/70 and 10 % Gilsonite

24. General information about the calculated prognosis of expected utilization periods

Special software for the dimensioning of traffic surfaces of asphalt should be used to be able to estimate the calculated utilization periods of lane mountings where the various asphalt binder variants would be applied.
Amongst others, the layer build-up of the construction as well as the thicknesses of the layers and the stiffness modules of the individual asphalt layers are needed as initial input parameters.
The measuring program mentioned above calculates, amongst others, especially the safety of the mounting versus the forming of fatigue cracks. The value is expressed as a percentage of the consumed resistance to the forming of fatigue cracks. A value of 100 % and higher means that the mounting cannot withstand the forces.
According to the theories of applied mechanics, the forming of fatigue cracks begins at the point of the construction where maximum tensile bending stress occurs.
In case of mechanical stress of an asphalt traffic lane construction caused by traffic, the maximum tensile bending stress should be expected at the underside of the lower layer of asphalt underneath the load application surfaces of the wheels.
This correlation is visually presented in pictures No. 8 and No. 9.

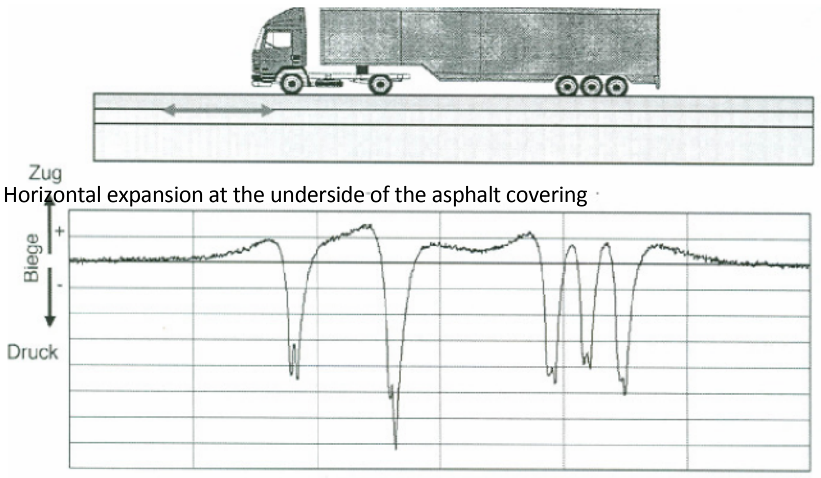


Figura 8: Mechanical stress of an asphalt covering layer

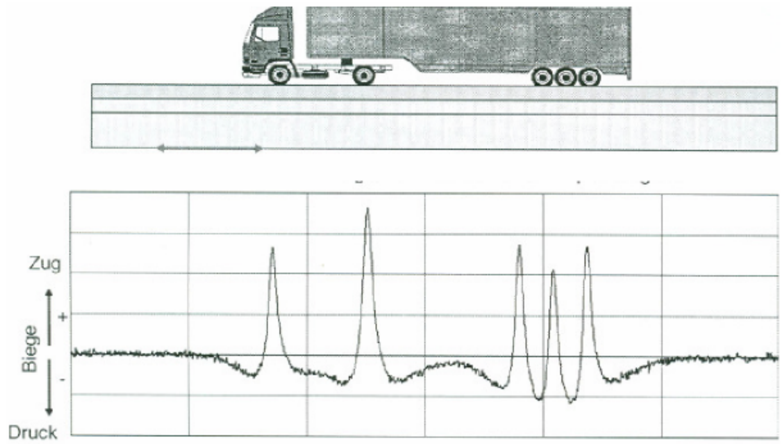


Figura 9: Mechanical stress of an asphalt bearing layer (lower asphalt layer)

In the situation at hand, it should be assumed that the asphalt binder and subsequently a covering layer are applied to an already cracked asphalt bearing layer, so that the asphalt binder must effectively be treated as the lower asphalt layer in case of fatigue.

By superimposing the mechanogenic tensions from traffic and the cryogenic tensile stresses as described above that emanate from impeding the thermal shrinking when the asphalt layers cool off, the value of the maximum bending tensile stresses at the underside of the lower asphalt layer may increase, which can cause accelerated forming of fatigue cracks. This stress situation is determinant for calculating the consumed resistance to the forming of fatigue cracks over the transverse of the traffic lane and consequently, in addition to knowledge of the layer build-up as well as the thicknesses of the layers and the stiffness modules of the individual asphalt layers, finding the cryogenic tensile stresses and fatigue function of the lower asphalt later – i.e., here the asphalt binder layer – is necessary.

In terms of the influence of the cryogenic tensile stresses, the dimensioning program considers the course of the temperature gradient through the transverse thickness of the traffic lane, i.e. the rising of the temperatures from the top of the traffic lane with increasing depth.

25. Creation of samples

To be able to find in the laboratory the parameters of the materials as listed above for the asphalt binder variants that must be investigated, asphalt samples had to be prepared that were bored resp. sawn out of

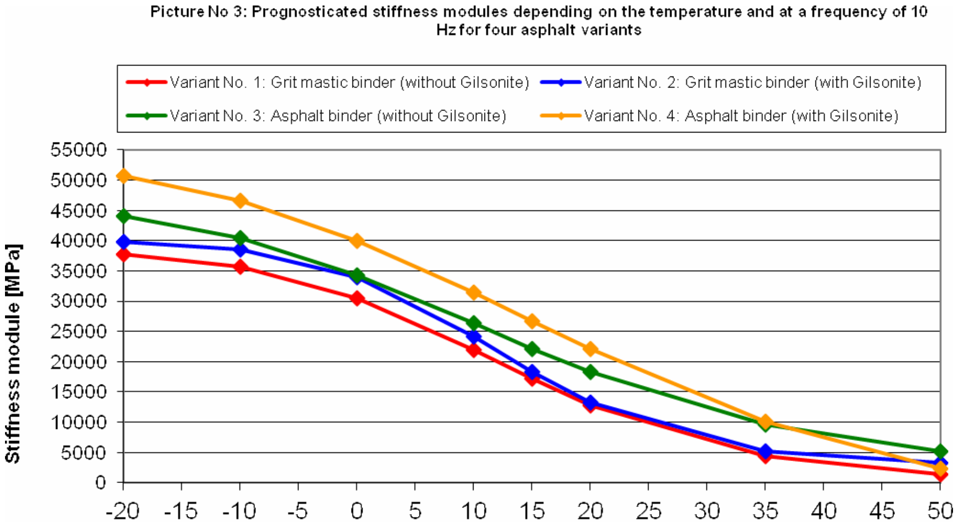
asphalt specimen plates that were created by means of a rolling compactor (WSV) in accordance with the Technical Test Regulations for Asphalt TP Asphalt-StB Part 33.
Cylindrical samples with a diameter of around 100 mm and a height of around 40 mm were needed for determining the stiffness modules and the fatigue functions of the four asphalt binder variants, which was done with the aid of Indirect tension test on cylindrical specimens (IT-CY).
The cryogenic tensile stresses were determined through thermal stress restrained specimen test (TSRST) in accordance with the Technical Test Instruction Behavior of Asphalts at Very Low Temperatures, edition 1994. Prismatic samples with measurements of around 50 x 50 x 160 mm (height x breadth x length) were needed for the appurtenant investigations.
Additionally, verification tests as per Table 26 of the Supplemental Technical Terms and Conditions for Building Traffic Surface Mountings from Asphalt ZTV Asphalt-StB 07 were carried out on coated aggregate created in the laboratory for the four variants that were to be observed.
3.0 Investigation findings / parameters of materials 3.1 Asphalt properties
Apart from asphalt properties that describe stiffness, coldness and fatigue behavior, the ring and ball weakening spots of the regained binders as well as the further technical properties, such as specific density, gross density and cavity content, were determined on the basis of the laboratory mixtures of the coated aggregate compounds of the four asphalt binder variants that were to be observed after extraction.
The reported findings for all four variants agree with the values given for the initial test resp. the technical terms and conditions.

26. Stiffness behavior

Investigations that address stiffness behavior were carried out by means of Indirect tension test on cylindrical specimens (IT-CY).
A stiffness module temperature function is determined at various testing temperatures on the basis of so-called multi-stage experiments with variation in the test frequency.
For each testing temperature – here four temperature levels – two samples were available. For each sample, the elastic horizontal expansions for the various load frequencies were successively determined and the stiffness modules calculated.
The prognosticated stiffness modules that are relevant for calculated dimensioning, depending on the temperature, are shown in summary for the four variants in Table No. 1 and graphically presented in Picture No. 3.

TAB1. Summary of investigation findings of stiffness behavior

	Prognosticated stiffness module [MPa]			
Temperature [SC]	Variant No. 1	Variant No. 2	Variant No. 3	Variant No. 4
-20	37790	39870	44024	50786
-10	35633	38506	40439	46554
0	30499	33932	34352	39975
10	21912	24086	26319	31380
15	17153	18277	22162	26713
20	12801	13201	18273	22081
35	4474	5229	9606	10083
50	1488	3300	5215	2302



27. Coldness behavior (cryogenic tensile stress)

For the most realistic calculation as possible of consumed resistance to forming of fatigue cracks of a traffic lane transverse, knowledge of the cryogenic tensile stress depending on the temperature is required, especially for the lower asphalt layer.

The cryogenic tensile stress is determined at prismatic samples through thermal stress restrained specimen test (TSRST) as per the technical testing instruction "Behavior of Asphalts at very low temperatures", edition 1994.

With the thermal stress restrained specimen test (TSRST), the stress on asphalt is simulated under weather-related negative changes in temperature.

The sample is continuously cooled, whilst the length is being kept constant. In order to be able to conduct the experiment in a time that is economical in a laboratory, a temperature rate of T = 10 K/h is laid down as cooling rate as per the test instruction mentioned above. Because thermal shrinking is avoided by keeping the length constant, there ensues in the sample increasing tension, that is described as cryogenic - so-called cooling-related - tensile stress.

If, when cooling a sample that is fully prevented from expanding, the cryogenic tensile stress leads to failure of the asphalt by tearing apart because of exceeding the tensile strength, the occurring tension is designated as break tension and the concomitant temperature as break temperature.

The developing of cryogenic tensile stress as a function of temperature as well as the break tension and break temperature have been determined for the four asphalt variants to be observed.

The findings may be found in Test Reports No. 1/384/2011-3 and No. 1/661/2011-3 (see Attachment 5.0).

The cooling non-linearly increasing developing of cryogenic tensile stress as a function of temperature for the four variants is graphically presented in Picture No. 4.

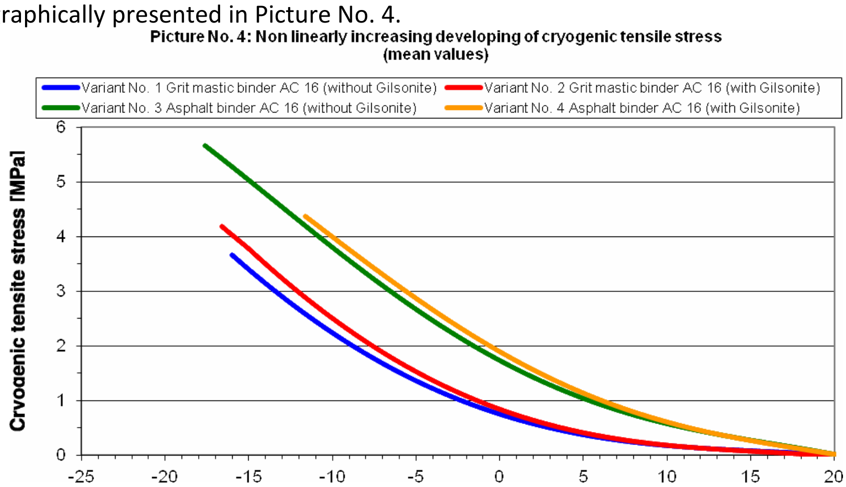


Table No. 2 shows a summary of the findings of the thermal stress restrained specimen test (TSRST) (mean values of the cryogenic tensile stresses at selected core temperatures as well as of the break temperatures and break tensions) of the four asphalt variants to be observed.

TAB. 2: Summary of the investigation findings of coldness behavior (mean values)				
Cryogenic tensile stress [MPa] at a core temperature in °C	Variant No. 1 Split mastic binder (without Gilsonite)	Variant No. 2 Split mastic binder (with Gilsonite)	Variant No. 3 Asphalt binder (without Gilsonite)	Variant No. 4 Asphalt binder (with Gilsonite)
15	0.080	0.070	0.267	0.268
5	0.372	0.408	1.030	1.136
- 5	1.360	1.523	2.661	2.869
-10	2.239	2.499	3.795	3.994
Break tension [M Pa]	3.723	4.064	5.685	4.458
Break temperature [°C]	- 20.2	- 20.3	- 21.9	- 16.0

28. Fatigue behaviour

Fatigue functions must be set up for the asphalt binder variants for the calculated prognosis of the utilization periods that can be expected.
Amongst others, fatigue behavior of asphalt can be found in accordance with the FGSV work instruction for determining de stiffness and fatigue behavior of asphalts, with the splitting and erectile tension experiment as initial value for the dimensioning AL-Sp-ASPHALT 09.
The load device that is required for that is schematically presented in Picture No. 5.
In the splitting and erectile tension experiment, cylindrical samples are tested by mounting the samples in a load device as per Picture No. 5 with the possibility of measuring horizontal expansion and by repeatedly dynamically charging the samples in a test machine via two pressure strip by means of sinusoidal impulses that simulate axle pressure.
The initial elastic expansion that can be determined from the horizontal expansion measurement and the stress-cycle number NMakroriss are recorded as results.
The stress-cycle number is considered to have been reached when a major crack occurs in the sample.

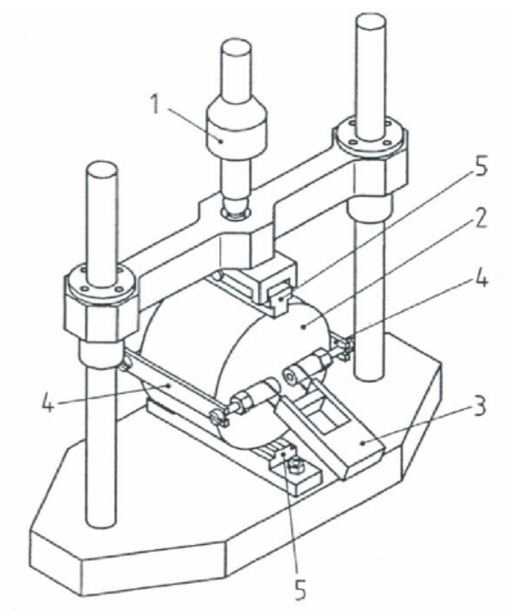
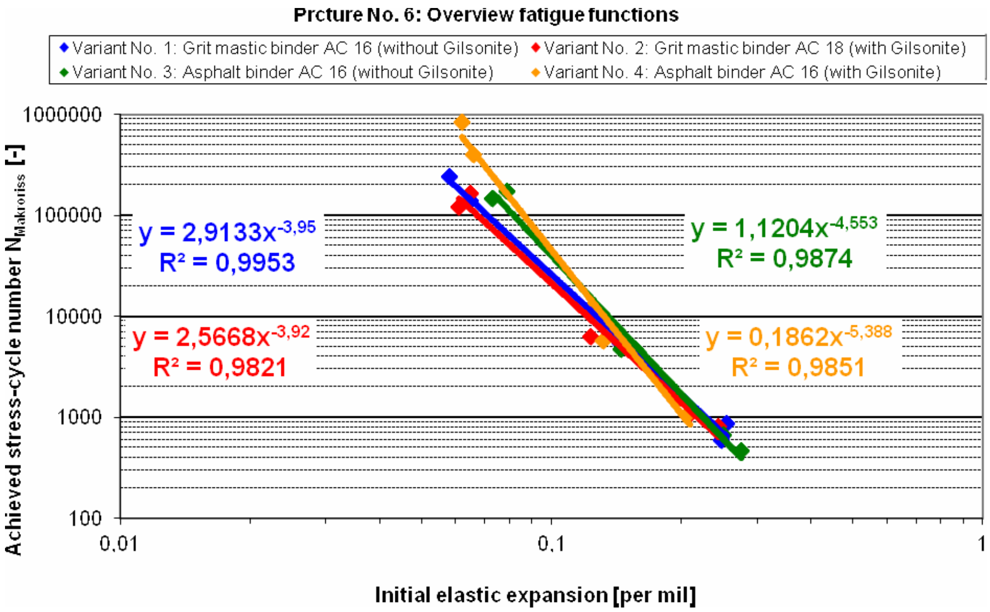


Figura 9: Legend: 1. Load cell 2. Asphalt test sample 3. Expansion measuring device 4 .Deformation strip 5. Pressure strip

For entering a fatigue function that is based on the findings of Indirect tension test on cylindrical specimens (IT-CY), a mathematical correlation between the initial elastic expansion and the stress-cycle number NMakroriss is required for the calculated prognosis of the utilization periods that may be expected.
The findings determined for the asphalt binder variants and the fatigue functions that are derived there from are documented in Test Reports No. 1/384/2011-1 and No. 1/661/2011-1.
The findings that have been determined from the fatigue experiments that have been carried out for the four asphalt variants are graphically presented in summary in Picture No. 6.



29. Prognosis of calculated expected utilization periods

The following initial parameters must be taken into account for prognosticating the utilization periods that can be calculated to be expected:

- Average daily heavy goods traffic
- Climatic conditions of the environment
- Layer build-up - layer thicknesses
- Kinds of materials
- Parameters of the materials
- Asphalt layers
- Stiffness modules
- Cryogenic tensile stress of the lower asphalt layer -Fatigue function of the lower asphalt layer
- Hydraulically bound layers / solidification (if available) -Layer module
- Unbound bearing layer -Load-carrying capacity value EV2
- Planum
- Load-carrying capacity value EV2
- Need for safety

In the case at hand, within the framework of an example calculation of traffic load that would necessitate a dimensioning as per Construction Class II under resp. Design Directive 1 of the Free and Hanseatic City of Hamburg, possible effects on the parameters of materials that have been determined for the four asphalt binder variants that are being observed should be subjected to a comparison against the utilization period that is calculated to be expected.

The following values are used as bases for the further calculations:

Average daily	
heavy goods traffic volume	DTVsv = 175 Vehicles/24 h
Traffic lane width	> 3.75 m
Highest longitudinal gradient	≤ 2%
Road class	Federal motorway
Axle count factor	fA = 4.2 as per resp. ER 1
Load spectrum quotient	qBm = 0.26 as per resp. ER 1
Number of lanes that are captured by average daily traffic volume	1

Average annual increase of heavy goods traffic	= 0.03 as per resp. ER 1 (no increase already in the 1st year of the observation period)
> B-number = 3.318 * 106 equivalent 10 t axle passages (for a utilisation period of 30 years) > Construction Class II as per resp. ER 1	

In terms of climatic conditions of the environment, an overall thickness for the frost-resistant superstructure of 70 cm as well a distribution of frequency of the surface temperatures for Zone 1 should be applied for the calculation by means of software.
To be able to capture the influence of fatigue, stiffness and coldness behavior of the investigated asphalt binder variants on the utilization period that can be calculated to be expected, it is assumed that the existing asphalt bearing layer is already cracked
With an eye to required build-up for Construction Class II, the following layer build-up is used for the calculations:

- 4 cm asphalt covering layer (parameters of materials: calibration asphalt of the covering layer from)
- 8 cm asphalt binder; investigated variants No. 1 to No. 4
- on cracked asphalt bearing layer (10 cm) (parameters of materials from Hansa-Nord-Labor database)
- 20 cm solidification with layering module of 2,000 MPa
- 28 cm frost protection layer with EV2 = 120 MPa
- on plenum with EV2 = 45 MPa

The need for safety of the RStO 01 is heeded for the calculations to be done.
In terms of the criterion "Sufficient Resistance to Forming of Fatigue Cracks at the Underside of the Asphalt Binder Position" by means of, the following utilization periods that can be calculated to be expected could be determined with the initial parameters and assumptions that have been applied here as well as with the stiffness modules and fatigue functions as well as the cryogenic tensile stresses that are listed in Test Reports No. 1/384/2011-1 to 3 and No. 1/661/2011-1 to 3.

- Build-up with Variant No. 1: Split mastic binder AC 16 ;10/40-65 A-RC": 21 years
- Build-up with variant No. 2: Split mastic binder AC 16 "50/70 + Gilsonite": 22 years
- Build-up with variant No. 3: Asphalt binder AC 16 B Hmb "1 0/40-65 A-RC": 26 years
- Build-up with variant No. 4: Asphalt binder AC 16 B Hmb "50/70 + Gilsonite": 29 years

30. Evaluation and interpretation of Stiffness Behavior

To be able to determine possibly present significant differences in the stiffness behavior of the four different asphalt binder variants, in respect of the stiffness modules that were determined with different temperatures and a frequency of 10 Hz, statistical-mathematical procedures (multiple mean value comparisons and LSD tests) have been applied, for dimensioning a frequency of 10 Hz is determinant. Therefore, the statistical tests have been carried out with stiffness modules that have been determined with a frequency of 10 Hz.
For a comparative assessment of the stiffness modules, first the temperature level must be followed up via a simple variance analysis of the question, whether the respective mean values of the variants that have been investigated here are the same in a statistical sense, i.e. can be allocated to the same population.
Verification of the equality of the stiffness modules for the four tested variants by means of simple variance analysis is given separately from each other for the observed temperature levels of –10 °C, 0 °C, 10 °C, as well as 20 °C.
The question should be pursued which means values or which groups of mean values are different from each other. For that purpose, the mean values of investigated variants are ordered by descending size and it is tested, whether the neighboring mean value show a greater Difference A than the least significant difference (= LSD). When A < LSD, the hypothesis of equality of neighboring mean values cannot be ignored.
That means that those mean values are then underlined by a common line.
The gained data material is statistically applied through the following procedure on the basis of a confidence level of s = 0.95 (95 %), i.e., a margin of error resp. excess probability of a = 0.05 (5 %).

Multiple mean value comparison for the parameter: Stiffness module (-10 °C; 10 Hz)

Variant No.	30425	30998	30965	38317	38767	39395
Variant No.	34189	36167	36486	37447	33801	35390
Variant No.	41132	38991	39464	39324	40486	39249
Variant No.	45332	47212	46454	44524	46255	4584

Mean value of variant No. 1 = 34811
Standard deviation = 4416.394657

Mean value of variant No. 2 = 35580
Standard deviation = 1399.065116

Mean value of variant No. 3 = 39774
Standard deviation = 841.239720

Mean value of variant No. 4 = 45938
Standard deviation = 934.277618

Simple variance analysis:

Overall mean value	= 39025.791667	N = 24
Median mean	= 39025.791667	
Q within	=115212419.500000	(FG2 = 20)
Q between	= 467825248.458333	(FG1 = 3)
Q overall	= 583037667.958333	(FG = 23)
Standard dev. betw. the var.	= 5098.067436	
Standard dev. within the var.	= 2400.129366	
Variance within the variants overall	= 5760620.975000	
Standard dev.	= 5034.825104	

Test quotient F* =27.070302 > 3.100000 (Alpha = 0.05)^

The difference of at least one mean value is significant.

****

LSD test:

Tabular value t(n-k)= 2.087000 with n-k = 20

Variant No.	ni	Sorted mean values	Delta	LSD	
4	6	45938	6163.333333	2891.987906	threshold homogeneous groups
3	6	39774	4194.333333	2891.987906	threshold homogeneous groups
2	6	35580	768.833333	2891.987906	
1	6	34811			

Figura 10: Table No. A1: Statistical evaluation of the stiffness module parameter at –10 °C and 10 Hz multiple mean value comparison and LSD test for four asphalt binder variants.

From Table No. A1 can first be gleaned that the multiple mean value comparison expresses that the difference of at least one of the four mean values for the stiffness module is significant at a temperature of –10 °C and a frequency of 10 Hz.
For Variant No. 4 (asphalt binder with Gilsonite), the stiffness module shows a significantly higher value at a temperature of – °C and a frequency of 10 Hz than for all other investigated variants. For Variant No. 3 (asphalt binder without Gilsonite), the value for the parameter mentioned in the last sentence is again significantly greater than for both Variants No. 1 and No. 2 (Split mastic binders without and with Gilsonite).
No significant difference could be shown between the mean vaklues for Variants No. 1 and No. 2 (Split mastic binders without and with Gilsonite).
That means that Variants No. 1 and No. 2 (Split mastic binders without and with Gilsonite) can be gathered into one population in a statistical sense in respect of the stiffness module parameter at – 10 °C and a frequency of 10 Hz.
Other than that, the findings of the assessment by means of statistical-mathematical procedure for the stiffness modules should be summarily presented in Table No. 3.

Summary presentation of the assessment findings by means of statistical-mathematical procedure for stiffness modules.

Calculation run No.	Parameter	Significant differences at least one mean value available?	Nr. 1	Homogeneous Nr. 2	group Nr. 3	Nr. 4
1 (see also table No. Al Attachment 7.0)	Stiffness module at - 10 °C; 10 Hz	yes	Variant No 4	Variant No. 3	Variant No.2; Variant No. 1	---
2 (see also table No. A2 Attachment 7.0)	Stiffness module at 0 °C; 10Hz	yes	Variant No. 4	Variant No. 3; Variant Nr. 2: Variant No. 1	---	---
3 (see also table No. A3 Attachment 7.0)	Stiffness module at 10 °C; 10 Hz	yes	Variant No. 4	Variant No. 3	Variant No. 2 Variant No. 1	---
4 (see also table No. A4 Attachment 7.0)	Stiffness module at 20 °C; 0Hz	yes	Variant No. 4	Variant No. 3	Variant No. 2	Variant No. 1
Variant No. 1: Split mastic binder without Gilsonite			Variant No. 2: Split mastic binder with Gilsonite			
Variant No. 3: Asphalt binder without Gilsonite			Variant No. 4: Asphalt binder with Gilsonite			

Generally, it may be assumed that on condition of very similar fatigue behavior, several variants have hardly any impact on a calculated utilization period when there are no or only very minor differences in the stiffness behavior of these variants. If, however, the stiffness models of a variant are significantly greater, the elastic expansions are at a comparatively lower level, causing the number of maximum bearable load cycles to increase in practice and a longer expected calculated utilization period to be prognosticated.
Additionally, at three of four temperatures for Variant No. 3, significant greater values for the stiffness modules could be determined in comparison to Variants No. 1 and No. 2 (see table number three).
Only at one of four tested temperatures (20 °C), the stiffness modules of Variants No. 1 and No. 2 significantly differ from each other. At this temperature, the stiffness module of Variant No. 2 is at a significantly higher level than of Variant No. 1 (see Table No. 3).
That leads to the conclusion that the findings stated in Section No. 4 for the various utilization periods but can be calculated to be expected when observing the four different asphalt variants as asphalt binder layers can be explained by the mostly significant differences in stiffness behavior, when initially a virtually identical fatigue behavior of asphalt variants No. 1 to No. 4 is assume.
The largest utilization period of 29 years that can be calculated to be expected was detected with a utilization period of 26 years that can be calculated to be expected with a layer build-up with Variant No. 4 (significantly higher stiffness modules at all four temperatures compared to all other variants), followed by a layer build-up

with Variant No. 3 (significantly greater stiffness modules compared to Variants No. 1 and No. 2 at three of four tested temperatures).

For a layer build-up with Variant No.1 as asphalt binder layer, a calculated utilization period of 21 years and for a layer build-up with Variant No. 2 a period of 22 years could be prognosticated, whilst it is clear from Table No. 3 that the materials of both these latter mentioned variants in the majority of cases show significantly lower stiffness modules than for the asphalts of Variants No. 3 and No. 4.

It should, moreover, be pointed out that Variant No. 2 shows at least at one tested temperature a significantly higher stiffness module and at the other temperatures tends to show higher stiffness modules than for Variant No. 1.

On the assumption of virtually identical fatigue behavior of Variants No. 1 and No. 2, the one- year shorter utilization period that can be calculated to be expected can also be explained by the detected differences in stiffness behavior with a layer build-up with Variant No. 1, compared to a layer build-up with Variant No. 2.

31. Coldness behavior (cryogenic tensile stress)

On the one hand, the coldness flexibility, i.e. the resistance to crack forming of an asphalt because of coldness, must the estimated to be greater the lower the values for the break temperatures are and the higher the values for the break tensions are that could be determined by the thermal stress restrained specimen test (TSRST).

On the other hand, high break tensions are also an indication for a stronger increase of cryogenic tensile stress when cooling. The maximum existing tensile bending stress in a traffic lane mounting which is composed of mechanogenic and cryogenic tensile stress, when the thermally induced tensile stress is comparatively higher. From that, lower resistance to the forming of fatigue cracks can result compared to a material with lower cryogenic tensile stress, which can express itself in a shorter utilization period that can be calculated to be expected. Subsequently, the statistical tests should be applied to the break temperature and break tension parameters, in order to evaluate the investigations into coldness behavior of the four tested variants.

The simple variance analyses of the multiple mean value comparisons express that the differences are at least always significant for one of the mean values of the break temperature and break tension parameters (see below Table No. 4 and No. 5).

Multiple mean value comparison for the parameter: Break temperature

Variant No. 1: -20.3 -20.0
Variant No. 2 : -20.1 -20.4
Variant No. 3 : -21.8 -21.9
Variant No. 4 : -16.2, -15.8

Mean value of variant No. 1	= -20.2
standard deviation	= 0.070711
Mean value of variant No. 2	= -20.3
standard deviation	= 0.212132
Mean value of variant No. 3	= -21.850000
standard deviation	= 0.070711
Mean value of variant No. 4	= -16.0
standard deviation	= 0.282843

Simple variance analysis:

Overall mean value	= -19.587500 N = 8
Median mean	= -19.587500
Q within	= 0.135000 (FG2 = 4)
Q between	= 37.733750 (FG2 = 3)
Q overall	= 37.868750 (FG2 = 7)
Standard dev. betw. the var.	= 2.507780
Standard dev. within the var.	= 0.183712
Variance within the variants	= 0.033750
Overall standard dev.	= 2.325902

Test quotient F* =372.679012 > 6.590000 (Alpha = 0.05)^

The difference of at least one mean value is significant.
****

LSD test:

Tabular value t(n-k)= 2,776000 with n-k = 4

Variant No.	ni	Sorted mean values	Delta	LSD
4	2	-16,0	4.250000	0,509984 threshold homogeneous groups
1	2	-20,2	0.100000	0,509984
2	2	-20,3	1.600000	0,509984 threshold homogeneous groups
3	2	-21,9		

Figura 11: Table No. 4:Statistical evaluation of the break temperature parameter of multiple mean values comparison and LSD test for four asphalt variants.

Multiple mean value comparison for the parameter: Break tension

Variant No. 1: 4.062 3.384
Variant No. 2 : 4.055 4.073
Variant No. 3 : 5.511 5.858
Variant No. 4 : 4.652 4.264

Mean value of variant No. 1	= 3.723	
standard deviation	= 0.479418	
Mean value of variant No. 2	= 4.064	
standard deviation	= 0.012728	
Mean value of variant No. 3	= 5.685	
standard deviation	= 0.245366	
Mean value of variant No. 4	= 4.458	
standard deviation	= 0.274357	

Simple variance analysis:

Overall mean value	= 4.482375	N = 8
Median mean	= 4.482375	
Q within	= 0.365481	(FG2 = 4)
Q between	= 4.394773	(FG1 = 3)
Q overall	= 4.760254	(FG2 = 7)
Standard dev. betw. the var.	= 0.855840	
standard dev. within the var.	= 0.302275	
variance within the variants	= 0.091370	
overall standard dev.	= 0.824643	

Test quotient F* =16.032860 > 6.590000 (Alpha = 0.05)^

The difference of at least one mean value is significant.
****

LSD test:

Tabular value t(n-k)= 2,776000 with n-k = 4

Variant No.	ni	Sorted mean values	Delta	LSD	
3	2	5.685	1.226500	0.839115	threshold homogeneous groups
4	2	4.458	0.394000	0.839115	
2	2	4.064	0.341000	0.839115	
1	2	3.723			

Figura 12: Table No. 5: Statistical evaluation of the break tension parameter of multiple mean values comparison and LSD test for four asphalt variants.

Tables No. 4 and No. 5 show that for Variant No. 3 (asphalt binder without Gilsonite) a significantly lower break temperature and a significantly higher break tension than for all other investigated variants was detected.
That means that for Variant No. 3, the coldness flexibility is significantly more favorable, i.e. the resistance to the forming of coldness cracks should be assessed significantly higher than for the other three variants.

Nevertheless, for reason of the significantly higher break tension and the in this connection relatively higher cryogenic tensile stress, a significantly greater negative influence on resistance to fatigue crack forming resp. on the utilization period that can be calculated to be expected must be assumed for Variant No. 3.
It can also be learned from Table No. 4 that the mean values for the break temperature parameter do not differ significantly between Variants. No. 1 and No. 2 (grit mastic binding without and with Gilsonite), but are at a significantly lower level than for Variant No. 4 (asphalt binder with Gilsonite).
That leads to the conclusion that in respect of coldness flexibility, i.e. resistance to coldness crack forming, Variant No. 4 has come out significantly less favorably than Variants No. 1 and No. 2.

32. Fatigue behavior

Compared to another asphalt variant, the fatigue behavior of an asphalt variant has a tendency of having to be assessed more favorably as the e.g. through a splitting and erectile tension experiment as per [5] determined stress-cycle number NMakroriss comes out higher with the same initial elastic expansion.
The following observations should be taken into account for a comparative evaluation of fatigue behavior of the four investigated variants and for discovering possible influences of different fatigue behavior on the utilization periods that have been determined to be expected in the example calculation.
For dimensioning asphalt mounting in Temperature Zone 1 as per RDO As[halt 09 as well as in the example calculation here at hand (see Chapter 4.0), load case combinations of more than 75 % for surface temperature between 2.5 °C and 22 °C are used.
For the temperature range, the following tensile bending expansion ranges with a depth of 12 cm below the top of the traffic lane (underside asphalt binder layer) can be calculated by means of [3] for layer build-ups with the four investigated variants, whilst applying the framework condition:

- Build-up with Variant No. 1 (Split mastic binder without Gilsonite): 0.062 ‰ to 0.088 ‰
- Build-up with Variant No. 2 (Split mastic binder with Gilsonite): 0.060 ‰ to 0.088 ‰
- Build-up with Variant No. 3 (Split mastic binder without Gilsonite): 0.059 ‰ to 0.080 ‰
- Build-up with Variant No. 4 (Asphalt binder with Gilsonite): 0.056 ‰ to 0.076 ‰

When it is considered that these expansion ranges are used in over 75 % of the load case combinations in the dimensioning calculations and the appurtenant achieved stress-cycle numbers NMakroriss for the individual four variants are tapped from Picture No. 6 for these expansion ranges, it can be seen that, in case it is applied, the mostly determinant fatigue behavior (in the expansion range between around 0.06 and 0.09 ‰) of asphalt binder Variants No. 3 (without Gilsonite) and No. 4 (with Gilsonite) can be better estimated in terms of a higher utilization period that can be calculated to be expected than in case of the Split mastic binder Variants No. 1 (without Gilsonite) and No. 2 (with Gilsonite).
Whilst the fatigue behavior of the split mastic binder variants No. 1 and No. 2 in this expansion range can be classified as practically being more or less of equal value, the fatigue behavior of Variant No. 4 (asphalt binder with Gilsonite) is showing growing advantages with decreasing expansion compared to Variant No. 3 (asphalt binder without Gilsonite).

33. Summary

On the basis of the determined results from the investigation, additionally, calculations by means of software for the dimensioning of asphalt mountings for traffic surfaces should be done in order to be able to show possible impact on utilization periods that can be calculated to be expected by using the asphalt binder variants that were to be observed.
Usage behavior was addressed to four different asphalt binder variants

- Variant No. 1: Split mastic binder without Gilsonite and 10/40-65 A-RC as per initial test No. 1/232/2011
- Variant No. 2: with Gilsonite and 50/70 as per initial test No. 1/384/2011
- Variant No. 3: Asphalt binder AC 16 B S resp. AC 16 B Hmb without Gilsonite and 10/40-65 A-RC as per initial test No. 1/662/2011
- Variant No. 4: Asphalt binder AC 16 B B S resp. AC 16 B Hmb with Gilsonite and 50/70 as per initial test No. 1/661/2011) by means of Indirect tension test on cylindrical speciments (IT-CY) (stiffness and fatigue) as well as thermal stress restrained specimen test (TSRST) (coldness).

By working this research project, the following knowledge could be gained:

1. Control test on mixtures created in the laboratory showed that the determined findings agreed for all variants with the values given in the initial tests resp. the technical terms and conditions.

2. In an example calculation by means of [3], for a traffic lane build-up that must be selected in accordance with Design Directive No. 1 (ER 1) of the Free and Hanseatic City of Hamburg for Construction Class II and that shows a concomitant use by traffic, the following utilization periods that can be calculated to be expected have been determined, with the aid of the determined material parameters, by applying the four tested variants as asphalt binder layer under the selected framework conditions and on the assumption that the asphalt layers are laid on an already cracked bearing layer.

- Build-up with Variant No. 1 (Split mastic binder without Gilsonite): 21 years
- Build-up with Variant No. 2 (Split mastic binder with Gilsonite): 22 years
- Build-up with Variant No. 3 (Asphalt binder without Gilsonite): 26 years
- Build-up with Variant No. 4 (Asphalt binder with Gilsonite): 29 years

3. The slightly higher utilization period of one year that can be calculated to be expected with a build-up with split mastic binder with Gilsonite (Variant No. 2) compared to a build-up with split mastic binder without Gilsonite (Variant No. 1) merely results from a significantly higher stiffness module at one of four test temperatures at next to identical fatigue behavior in the expansion range that is relevant for the application. Moreover, no significant differences in coldness behavior could be shown between Variants No 1 and No. 2.

4. For the asphalt binder variants No. 3 resp. No. 4, independently of the application of the natural asphalt Gilsonite compared to the split mastic binder variants No. 1 and No. 2, larger stiffness modules could be extracted at three resp. four of four test temperatures as well as advantages of the fatigue behavior in the determinant expansion range for the selected example calculation. On the basis of these correlations, the above-mentioned values that are higher by four to eight years could be prognosticated for the utilization periods that can be calculated to be expected.

5. For the asphalt binder variant with Gilsonite and with base bitumen of the 50/70 kind (Variant No. 4), compared to the asphalt binder without Gilsonite with base bitumen of the 10/40-655 A kind (Variant No. 3), a utilization period that can be calculated to expected of three extra years can be calculated in an example calculation for an otherwise identical layer build-up and the same traffic use. This can be explained through significantly larger stiffness modules at all four test temperatures, more favorable fatigue behavior in the relevant expansion range and significantly lower break tension, which agrees with lower cryogenic tensile stress, for asphalt binder variant No. 4 with Gilsonite, compared to asphalt binder variant No. 3 without Gilsonite.

6. On the basis of the findings at hand, it is recommended to apply both Split mastic binder Variants No. 1 and No. 2 with and without Gilsonite as well as Asphalt binder Variant No. 3 without Gilsonite in the Frost Impact Zones I as well as II and Asphalt binder Variant No. 4 only in Frost Impact Zone I (see also Test Reports No. 1/384/2011-3 and No. 1/661/2011-3; Attachment 5.0). This recommendation is made on the basis of significantly more favorable coldness flexibility, i.e. significantly greater resistance to coldness crack forming of the three first mentioned variants compared to Asphalt binder Variant No. 4 with Gilsonite.

7. In conclusion, for the sake of completeness it should be mentioned that for a layer build-up with the Calibration Asphalt Binder of the RDO Asphalt 09 under otherwise identical framework conditions and assumptions made by means of [3], a utilization period that can be calculated to be expected of 18 years is prognosticated, so that it can be stated that all four tested asphalt binder variants have done better in terms of the example dimensioning calculation than the calibration asphalt binder and for the asphalt binder variant with Gilsonite a value that is higher by 11 years was calculated for the utilization period that can be calculated to be expected.

F. Assessment of the asphalt binder layer modified by Gilsonite after 7 years of operating life in Austria

34. Information About The Asphalt Construction

In 2003 the asphalt construction in the road section of km 157,100 — km 162,500 in direction of Linz of A9 Pyhrn Motorway has been in parts placed newly.

The following three-layers-asphalt construction has been placed in the 1st traffic lane. The asphalts are described in accordance with the regulative of the Austrian Standard B 35801:2009 (EN 13108-1:2008) and of the Austrian Standard B 3584-1:2009 (EN 13108-5:2008).

Layer	Type of asphalt mixture	thickness, mm
Asphalt surface layer	SMA 11 PmB 45/80-65, S3, G1	30
Asphalt binder layer	AC 22 binder ...1>2)	70
Asphalt base course	AC 32 base 50/70, T1, G4	70

The asphalt binder layer in the section of km 157,100 — km 158,250 was manufactured basing on an asphalt mixture modified by natural asphalt Gilsonite. Considering requirements of the Austrian Standard B 3580-1:2009 this asphalt binder layer can be described as AC 22 binder 70/100, H2, G4, Gilsonite

In the following road section of km 158,250 — km 162,500 the asphalt binder layer was manufactured basing on polymer modified bitumen. Basing on the Austrian Standard B 3580-1:2009 this asphalt mixture can be described as

- AC 22 binder PmB 45/80-50, H1, G4
- There is an asphalt base course below the three-layers-asphalt construction, whose service life is approx. 25 years.
- In the 2nd traffic lane as well as in the emergency lane mostly only the asphalt surface layer has been newly placed.

35. Documentation Of The Status Display Of The Asphalt Construction

Traffic load caused by heavy vehicles: the actual results of the traffic census carried out by ASFINAG in September 2010, show that the number of heavy vehicles in direction of Linz (total weight of vehicles > 3,5 to) is 1.066 per day. So basing on the guidelines of the Austrian Standard and Regulations for Roads RVS 03.08.63:2008 regarding the traffic volume the highest load class S is to be assigned to this road section of A9 Pyhrn Highway (calculated allowed load repetitions within the service life time of 20 years is 10 x 106).

Comparative assessment of the asphalt constructions: rut depth in the 1st traffic lane In the road section of km 157,100 — km 158,250 (asphalt binder layer: Gilsonite) as well as in the road section of km 158,250 — km 162,500 (asphalt binder layer: PmB 45/80-50) the depth of the ruts of < 4 mm was detected in the lst lane.

In order to determine the dimensions of the actually existing ruts measurements were carried out in the area of both wheel tracks in the 1st traffic lane by means of a 2 m - leveling rod and a measuring wedge. The measurements in the total widths of the traffic lane were carried out using the measurement device planum. These measurements occurred at an interval of approx. 100 m.

During the measurements in the wheel tracks the following rut depths were detected: road section of km 157,100 — km 158,250. Asphalt binder layer: modified by Gilsonite

Cross section	Rut depth, Left wheel track	mm Right wheel track
km 158,100	3	0
km 157,900	2	1
km 157,800	2	0
km 157,600	2	0
km 157,400	3	0
km 157,300	4	0
Average	2,7	0,2

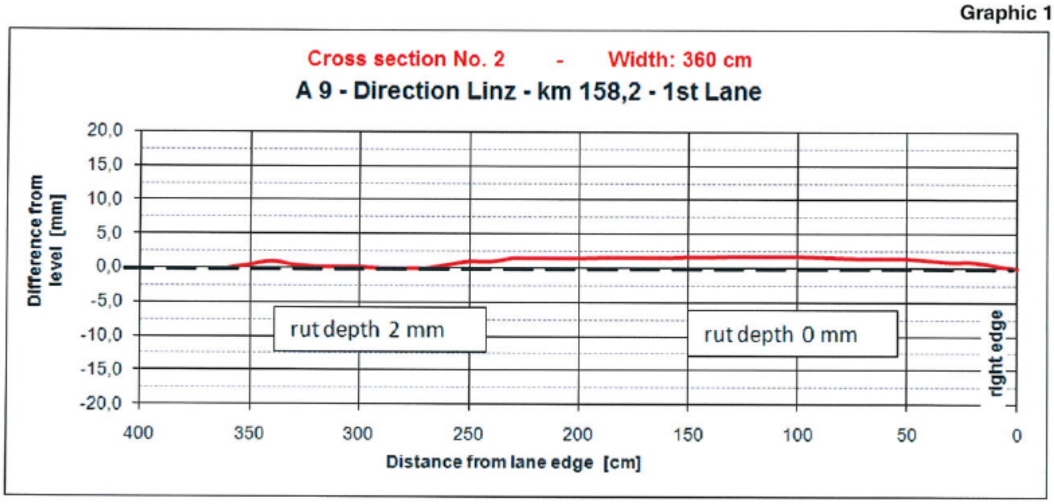
Road section of km 158,250 — km 162,500: asphalt binder layer: modified by PmB 45/80-50

Cross section	Rut depth, Left wheel track	mm Right wheel track
km 159,500	2	0
km 159,400	2	2
km 159,300	4	4
km 159,100	2	0
km 159,000	4	3
km 158,800	2	0
km 158,700	2	0
km 158,600	2	0
km 158,400	2	0
km 158,300	2	1
Average	2,4	1,0

Results of measurement by means of planum. At the measurements by planum unevenness in cross direction was measured in the whole width of the traffic lane of 360 cm — 370 cm.
The measurement results can be interpreted as follows: Road section of km 157,100 — km 158,250: in this road section five cross sections were measured.
The deepest recorded rut in the cross sections is approx. 3,0 mm. The graphics below demonstrate the status display of the pavement surface.

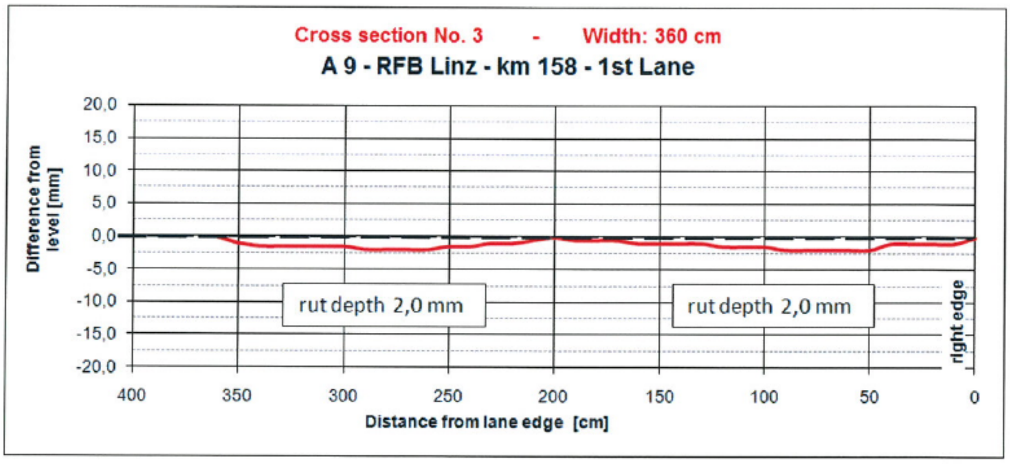
Asphalt binder layer: modified by Gilsonite

Graphic 1



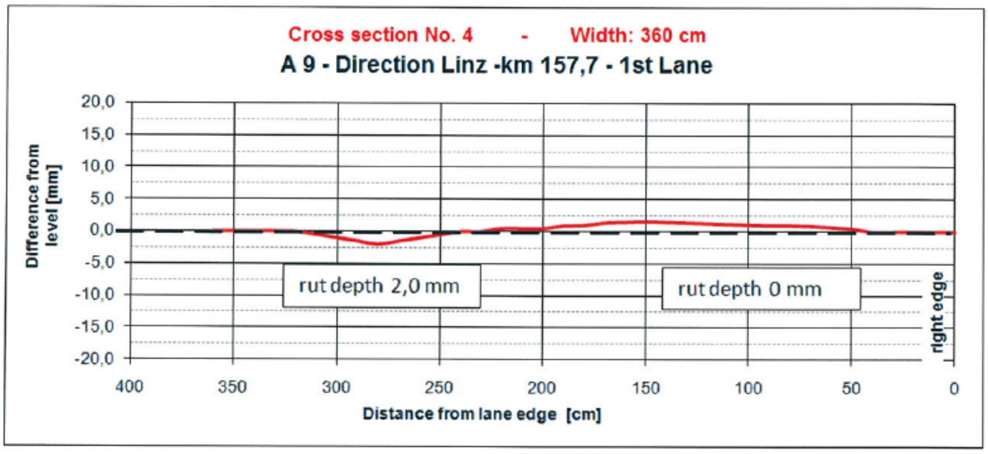
Asphalt binder layer: modified by Gilsonite

Graphic 2



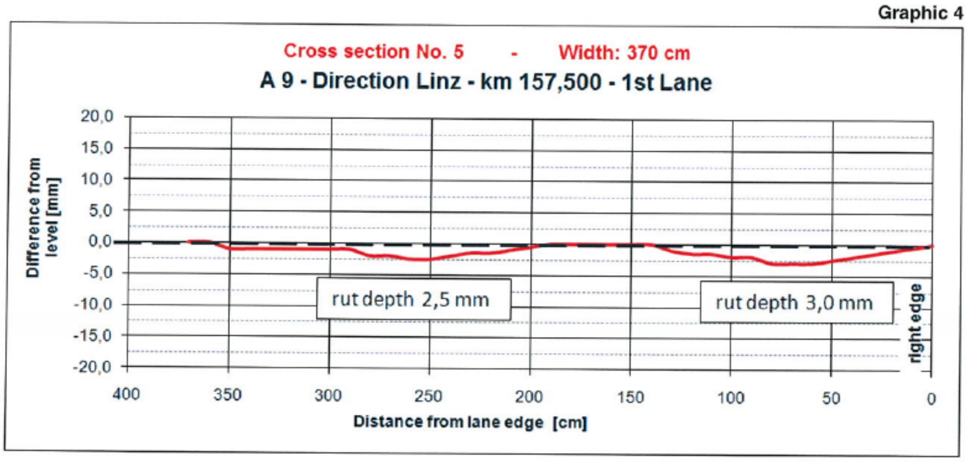
Asphalt binder layer: modified by Gilsonite

Graphic 3



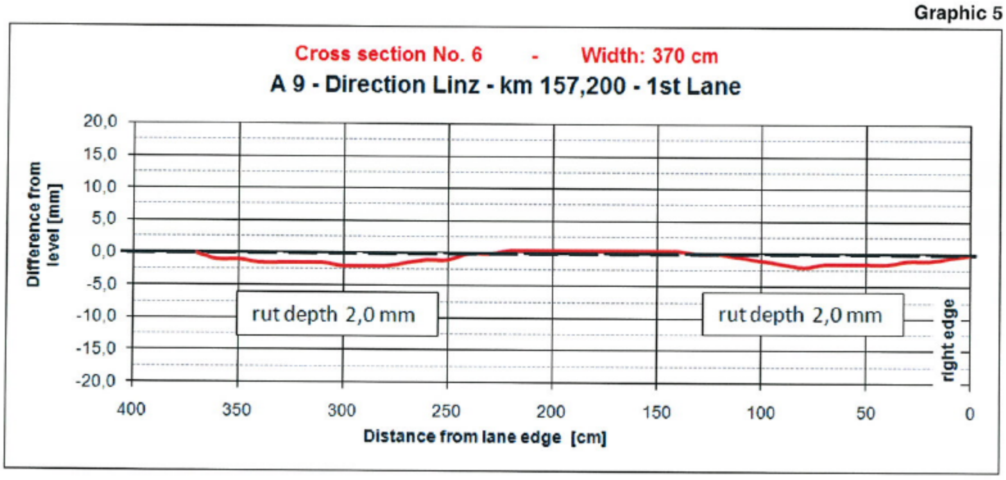
Asphalt binder layer: modified by Gilsonite

Graphic 4



Asphalt binder layer: modified by Gilsonite

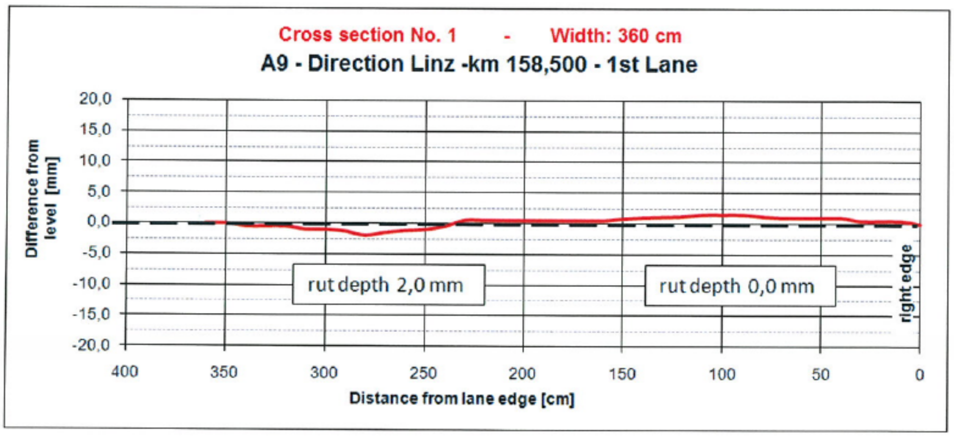
Graphic 5



Road section of km 158,250 — km 162,500: in this road section three cross sections were measured. The deepest rut in the measured cross sections is ca. 3,5 mm. The graphics below present the actual status display of the pavement surface.

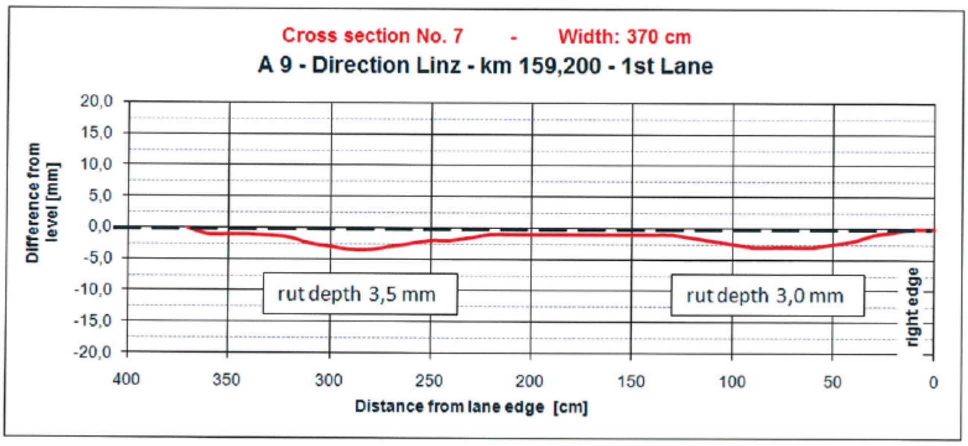
Asphalt binder layer: modified by PmB 45/80-50

Graphic 6



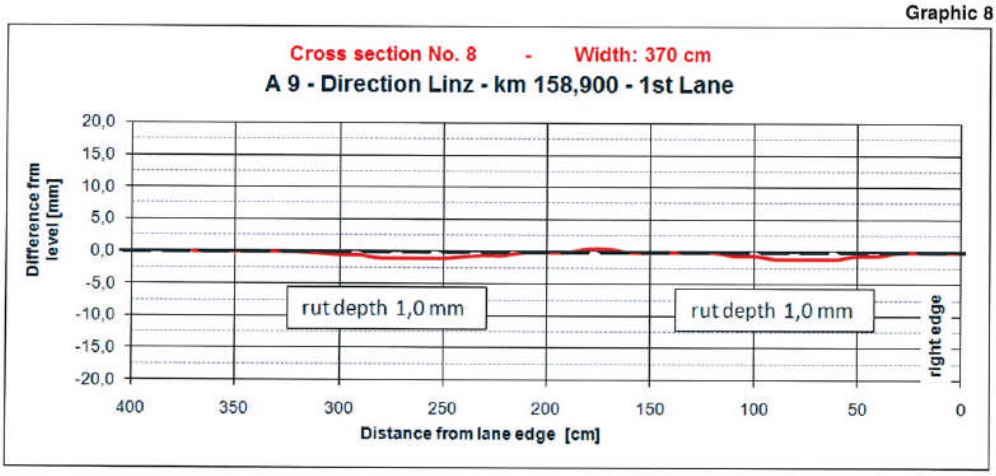
Asphalt binder layer: modified by PmB 45/80-50

Graphic 7



Asphalt binder layer: modified by PmB 45/80-50

Graphic 8



36. Crack Formations In The 1st Lane

As mentioned above, three layers of the asphalt construction have been renewed only in the 1st traffic lane. In the emergency lane as well as in the 2nd traffic lane mostly the asphalt surface layer has been replaced.
During the replacement of the asphalt binder layers no measures were taken in order to seal joints to the 2nd traffic lane and to the emergency lane (e.g. by placing bituminous joint filling). Only the longitudinal joints between the asphalt surface layer of the 1st and the 2nd lane have been sealed using bituminous joint filling. The longitudinal joint of the asphalt binder layer has been placed shifted in relation to the longitudinal joint of the asphalt surface layer.
During the inspection of the road section was detected that the longitudinal joints of the asphalt binder layer opened in some areas. The open joints of the asphalt binder layer to the asphalt layers in the 2nd traffic lane as well as in the emergency lane caused reflection cracks in the asphalt surface layer.
These reflection cracks in the asphalt surface are shown in the road section with the asphalt binder layer modified by Gilsonite, but they are obvious also in the section, where the asphalt binder layer was manufactured using polymer modified bitumen.

Figura 13: Photos 1 and 2 below demonstrate an open joint as a reflection crack in the asphalt binder layer at the left edge of the 1st traffic lane.

A similar status display is evident also in the emergency lane. The open joint of the asphalt binder layer caused a reflection crack in the asphalt surface.

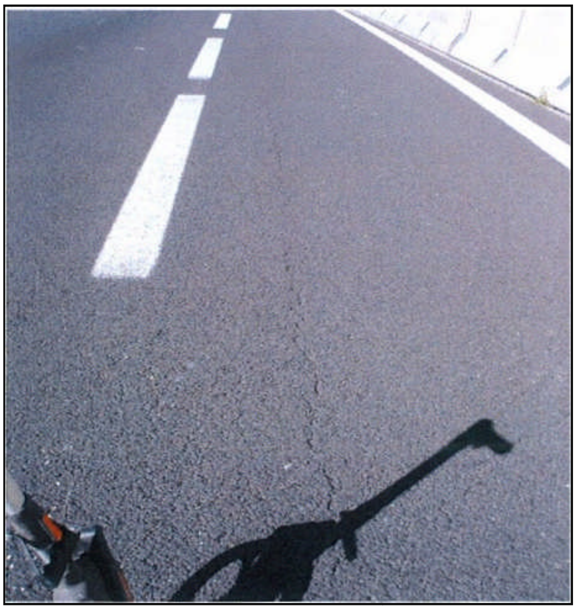


Figura 14: Photo 4

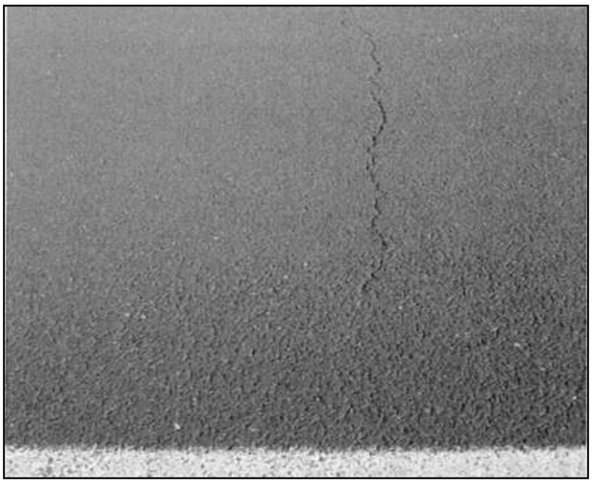


Figura 15: Photo 3

In the area of the emergency lane some cracks were detected in cross direction. These cracks document the ageing of the asphalt layers below the asphalt surface newly constructed in 2003.
The crack formations mentioned above, are not related to the qualitative characteristics of the placed asphalt binder layers, which are to be evaluated.
This evaluation took place only in order to refer the cracks appeared on the pavement surface, to their matters.

37. Assessment Of The Asphalt Binder Layers

At the initial test of both asphalt binder layer types

- AC 22 binder 70/100, H2, G4, Gilsonite
- AC 22 binder PmB 45/80-50, H1, G4

The resistance of asphalts to deformation was assessed.
Within an acceptance test the resistance to deformation of the asphalt binder layer modified by Gilsonite, was assessed. The results of these tests showed that both asphalt binder layers are very resistant to deformation. The results of these material tests are confirmed in practice also through the performance characteristics of the asphalt binder layers.
Taking into amount the high frequency of the heavy vehicles (load class S) it was noticed that the maximum depth of the ruts on the surface of the asphalt construction after seven years of operating life is 4,0 mm. Such ruts in the range of 4,0 mm were detected only at some measured areas and cannot be valid as representative for both road sections (average rut depth < 3 mm).
From this status display can be derived that the asphalt binder layer modified on the basis of the natural asphalt Gilsonite:

- shows a resistance to deformation, which is sufficient for high traffic load;
- shows a resistance to deformation comparable with the one of the asphalt binder layer manufactured on the basis of the polymer modified bitumen.

In both road sections no any cracks were detected which would be caused by the asphalt binder layer.

G. Report over the evaluation of characteristic binder values determined on standard Bitumen types with different Gilsonite natural asphalt modifications.

Values of several selected binder for the standard bitumen types 70/100 and 160/220 have been determined. As a comparison, the same values set for the bitumen types should be determined when using different parts of Gilsonite modification.

38. Carried Out Testing

As per order, the following tests were carried out on the standard bitumen types and/or on the bitumen modified with natural asphalt:

Bitumen Types 70/100 and 160/220 ex OMV AG:

1. Penetration at 25° C according to EN 1426
2. Softening point with Ring Lind Ball according to EN 1427
3. Breaking point according to EN 12593
4. Elastic Recovering according to ONORM C9219

Gilsonite modified Bitumen Types:

1. Gilsonite parts of 7%, 10% and 13% were added to the standard bitumen types 70/100 and 160/220.
2. Then, the same binder values were determined as for standard bitumen types.

After the tests, the penetration index according to EN 12591 was determined, along with the application span (plastic span) as difference between softening point with ring and ball and breaking point.

The product Gilsonite consists approx. 99 M-% of soluble parts (Bitumen) and to approx. 1 M-% of mineral fillers. Due to these fillers, the thin bitumen layer may break too early in the cooling phase during the bitumen testing "Breaking Point".

For this reason the following tests were carried out on 2 standard Bitumen types with 13% Gilsonite modification and on 2 polymer modified Bitumen used for the construction of asphalt base courses.

- Dissolving of the binder in the solvent Toluene.
- Centrifuging of the Toluene-Binder mixture in the cold extraction equipment
- Recovery of the Bitumen out of the solution according to ONORM B3689-2
- Determination of the Breaking Point of the recovered Bitumen according to EN 12593

The Breaking Points of the 2 Bitumen types PmB 30-50 and 60-90 were also determined before they were dissolved in Toluene. These Bitumen types were also attained from OMV.

39. Test Results

The following tables contain the results of the carried out testing

Table 1

Description	Standard	Unit	Limit according to EN 12591	A OMV 70/100 Value	1 70/100 7% Uintaite Value	2 70/100 10% Uintaite Value	3 70/100 13% Uintaite Value
PEN 25°C	EN 1426	1/10 mm	70 – 100	81	32	27	23
SRB	EN 1427	°C	43 – 51	46,0	58,0	59,3	61,0
Breaking Point	EN 12593	°C	max. -10	-19	-5	-4	-3
Elast. Rec.	ÖN C 9219	%	-	11	14	16	17
Appl. Span	-	°C	-	65	63	63	64
PI	EN 12591	-	-	-1,1	-0,4	-0,5	-0,5

Table 2

Description	Standard	Unit	Limit according to EN 12591	B OMV 160/220 Value	4 160/220 7% Uintaite Value	5 160/220 10% Uintaite Value	6 160/220 13% Uintaite Value
PEN 25°C	EN 1426	1/10 mm	160 - 220	175	62	45	40
SRB	EN 1427	°C	35 – 43	39,6	50,4	54,2	54,8
Breaking Point	EN 12593	°C	max. -15	-21	-12	-9	-5
Elast. Rec.	ÖN C 9219	%	-	15	15	15	17
Appl. Span	-	°C	-	61	62	63	60
PI	EN 12591	-	-	-0,8	-0,6	-0,5	-0,6

Table 3

Description	Standard	Unit		3 70/100 13% Uintaite Value	6 160/220 13% Uintaite Value	C PmB 60-90 Value	D PmB 30-50 Value
Breaking Point	EN 12593	°C		-3	-5	-24	-19
Breaking Point *	EN 12593	°C		-6	-9	-18	-11

A graphic of the results and a mathematical depiction in the form of a regression equation are included in the Following pictures below.

40. Conclusion

The carried out testing and the results clearly prove the stiffening characteristics of Gilsonite natural asphalt. A clear correlation could be defined between the values of Penetration at 25° C, Softening point with Ring and Ball and the Breaking point and the modification degree with Gilsonite. These correlations were also significant for the tested initial bitumen types 70/100 and 160/220. Emphasis must be made upon the fact that the determined correlations are valid only for the initial Bitumen sorts ex OMV-Refinery. Other Bitumen types of the same penetration class and/or standard can show other distinctions as a result of the use of different raw oils and production methods. In this case, it would be more sensible to analyze the initial Bitumen ex OMV-Refinery and to administrate these results in a database. This database should then be expanded with the results of further testing, so that when using other bitumen types in the future, a better and/or purposeful forecast can be made in regard to the resulting Bitumen characteristics.

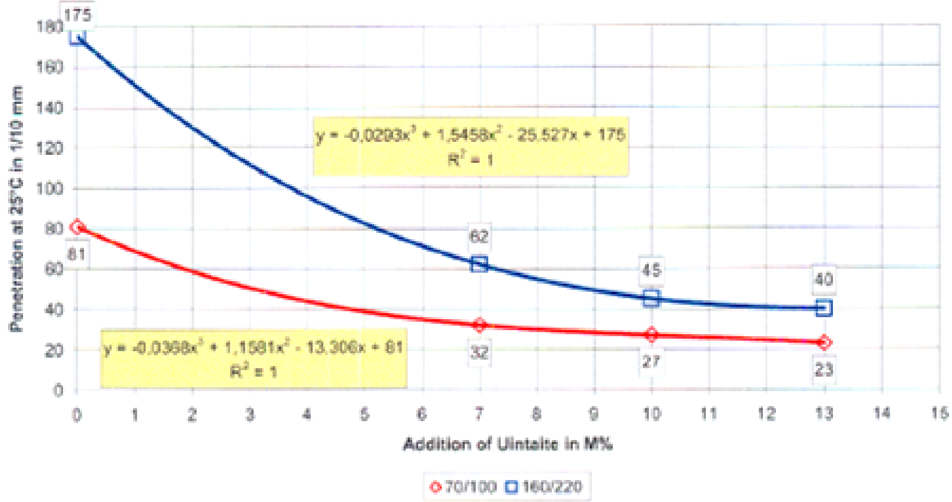
Regarding the change of the Softening Point with Ring and Ball and the Breaking Point in correspondence to the degree of Gilsonite modification, these values vary only insignificantly when adding more than 10% of the natural asphalt to the Bitumen. This clearly shows that a high modification with Gilsonite natural asphalt would only have a minor positive influence upon the quality of the asphalt mixture. Further use-oriented asphalt testing would be necessary in order to prove whether the conclusion, which was only made in regard to the testing on the binder component, also applies to the characteristics of the asphalt mixture.

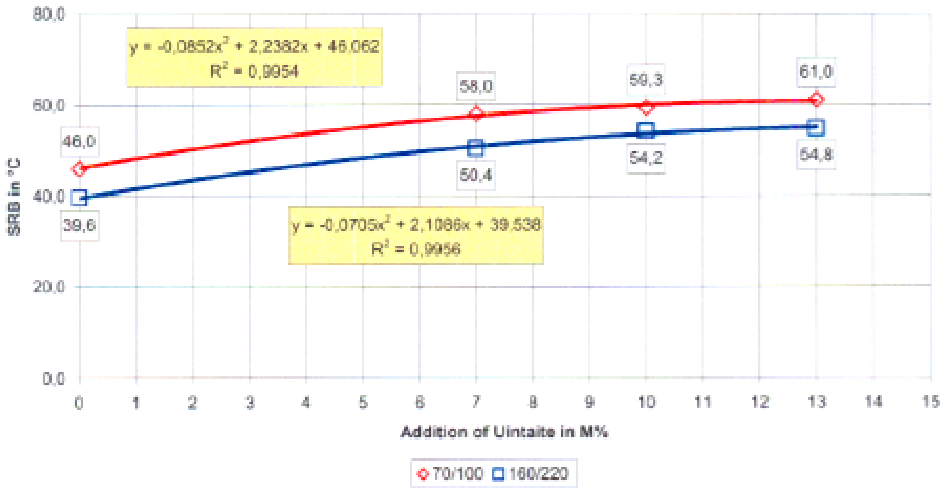
The estimates regarding cracking at low temperatures can be made according the Finnish Standard „Finnish Asphalt Specifications 1995", This Standard splits the to be expected temperatures into 2 classes (-35°C Class I, -25°C Class II) and defines limits for the indirect tensile strength of the test specimens at -2°C from 2,8 MPa (Class I) and 5 4,1 MPa (Class II).

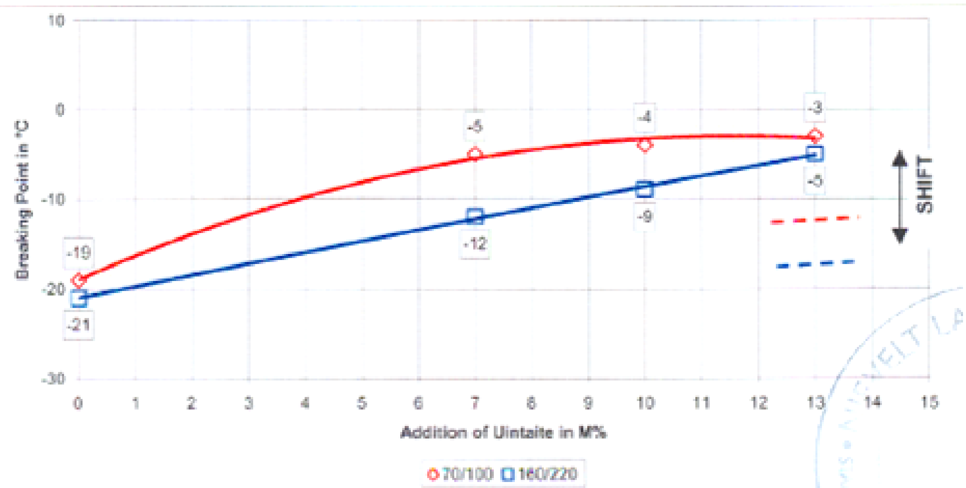
The used initial Bitumen 70/100 and 160/220 have an application span of 65° and/or 61° C, which at the first look can not be increased with modification with Gilsonite. But, through testing it was proven that the Breaking Point is strongly influenced through the filler content of approx. 1% in the natural asphalt. Through cold extraction with the solvent Toluene and then the recovery of the Bitumen and new determination of the

Breaking Point, an improvement of the Breaking Point could be determined in comparison to the usual polymer modified binders. As a result, with a 13% natural asphalt modification, the rising of the application span of approx. 10° C was determined.

Logically, the use of initial Bitumen 160/220 instead of 70/100 improves the low temperature characteristics of the resulting binder. Which influence the softer binder has upon the deformation characteristics of asphalt has not been tested. Therefore, we suggest the carrying out of rut testing with an initial Bitumen of 160/220 with a 10% modification with Gilsonite.







H. Report Regarding the Results and the Condition of the with Gilsonite - Natural Asphalt modified bituminous Base Course

after the first Winter Period A9 Pyhrn Autobahn Construction Site Hinkelwald 2003, RFB Linz

This Report is regarding the results from the mix design and control testing executed upon the bituminous base course constructed with the natural asphalt Gilsonite in the Year 2003. Furthermore, the present section of the Construction Site Hinkelwald of the Pyhrn Motorway was surveyed and then evaluated.

The above mentioned construction site in which the binder layer of the bituminous construction was constructed with Bitumen of the Type 70/100 modified with natural asphalt. As surface layer a 3 cm thick noise reduced stone mastix asphalt (SMA 11-LM) was paved. In this case, natural Asphalt with a soluble portion 99 vol. % of bitumen has to be used. OSAG also defined the amount of natural asphalt with 10 vol.-% in reference to the optimal binder content from the mix design.

The suitability of the BT 22 HS Asphalt Mixture modified with Gilsonite - Natural Asphalt has to be proven according to the technical specifications through an extended mix design. For this purpose a comparable asphalt mixture using an elastomeric modified Bitumen Type PmB 60-90 as binder was worked out. This mixture had nearly identical volumetric values as the mixture with natural asphalt.

The paving of the BT 22 HS layers using different binder systems (with Bitumen 70/100 and Gilsonite or with PmB 60-90) was executed in the Construction Site Hinkelwald by the Contractor in the first traffic lane and in a layer thickness of 7 cm.

The asphalt mixture with the Gilsonite - Modification was paved in the section between km 158,250 and km 157,100.

41. Extended Mix Design

The mix design for this asphalt mixture was set up through the Contractor. In revision to the requirements stated in RVS 8S.01.41, the Bitumen used was not that stated in ON B 3613 or ON B 3614, but much rather Bitumen 70/100 according to EN 12591 and Gilsonite Natural Asphalt as stated by OSAG in technical specifications.

According to the technical specifications, the following reference values were to be investigated:

1. Resistance to Deformation according to RVS 11.065, Part IV
2. Indirect Tensile Strength using 3 different testing temperatures according to EN 12697-23

The above mentioned tests were comparatively executed for the following asphalt mixtures:

1. BT 22 HS - Bitumen 70/100 with 10 vol.-% Gilsonite Natural Asphalt
2. BT 22 HS - Bitumen PmB 60-90

The comparability of these mixtures was proven through the use of comparative volumetric reference values within the mix design. Only carbonic aggregates (limestone) from the area of Graz were used for the production of the asphalt mixture.

42. Extended Acceptance Test

Tests were executed in this section of the Construction Site Hinkeiwald 2003 according to the relevant guidelines:

1. Requirements for the Asphalt Mixture - RVS 8S.01.41
2. Requirements for the Asphalt Mixture - RVS 8S.04.11

Furthermore, in agreement with OSAG, the following testing of the Asphalt Mixture BT 22 HS – Gilsonite were executed:

1. Resistance to Deformation according to RVS 11.065, Part iV
2. Indirect Tensile Strength using 3 different testing temperatures according to EN 12697-23 (without determination of the failure strain)

43. Summary Of The Results From The Executed Tests And Inspections

The optimal total binder content was defined as 4,6 % by mass and this was confirmed by OSAG. Correspondingly, the content of Gilsonite in the asphalt mixture amounts to approx. 0,5 % by mass. The natural asphalt was dosed out of sacks, in accordance to the exact charge weight of the asphalt mix, directly into the mixer of the mixing plant.

Resistance to Deformation of the BT 22 HS — Layers

The results of the rut tests executed within the extended mix design and control tests are stated in the following Table 1. The test results were compared with the requirements stated in RVS 8S.01.41.

Type of Test	Rut Depth in 'Yo		
	BT 22 HS B70/10 + Gilsonite	BT 22 HS PmB 60-90	Requirement according to RVS 8S.01.41
Mix Design	3,5 *)	3,4 *)	< 7
Acceptance Test	2,8 *)	-	-
Rut depth measured in a testing slab with a thickness of approx. 100 mm			

Indirect Tensile Strength of the BT 22 HS — Asphalt Mixture

The following table 2 shows the results of the indirect tensile strengths attained at different testing temperatures. The test values were attained for the mix design as well as for the acceptance test.

Table 2

Type of Test/Mixture Type	Test Temperature in °C					
	-20°C		0°C		+20°C	
	Indirect Tensile Strength	Failure Strain	Indirect Tensile Strength	Failure Strain	Indirect Tensile Strength	Failure Strain
	N/mm2	mm	N/mm2	mm	N/mm2	mm
Mix Design BT 22 HS PmB 60-90	4,7	1,9	3,3	2,7	0,7	3,2
Mix Design BT 22 HS Gilsonite	4,7	1,6	3,5	2,2	1,0	3,0
Acceptance Test BT 22 HS Gilsonite	3,6	-	3,4	-	2,3	-

44. Acceptance Test for the Asphalt Mixture

3 asphalt mixture tests were executed during the construction works of the BT 22 HS — Gilsonite Mixture layer. The results of the tests show that 2 of the 3 tested samples had a void content of 6 vol.-%. These values are out of the limits according to the RVS 8S.01.41. For these 2 samples the binder content, taking the requirements of the mix design, was within the tolerance level stated in RVS 8S.01.41.

The requirements of the Marshall-Stability and Particle Size Distribution were completely fulfilled for all three tested asphalt mixtures. The Marshall-Stability was much higher during the acceptance tests in comparison to the values from the mix design.

45. Acceptance Test for the Layer

For this section of the A9 Pyhrn Autobahn 4 drilling cores were excavated in order to determine the layer thickness and the bulk density of the "Gilsonite Layer". The executed layer thickness measurements show that the layer was partly constructed thinner than the 7,0 cm layer thickness defined as per contract.

The other reference values, such as void content and relative density, fun all the requirements stated in RVS 8S.04.11, with the acceptance of one void content value which exceeds the requirements.

46. Visual Evaluation of the Surface Condition

During the section inspection on 24.05.04 no visible differences could be determined between those sections constructed with highly stable bituminous base courses with PmB 60-90 or Bitumen 70/100 with Gilsonite.

No deformations (measured rut depth throughout the testing was 0 mm) and crack formations were visible throughout the total section of the SMA 11 - LK S, LM - Layer. A photo documentation of the section in which the BT 22 HS Layer was constructed with Gilsonite is included in Enclosure 6.

47. Conclusions

Through the results of the extended Mix Design and the Acceptance Tests along with the visual inspection after the first winter period, the following conclusions can be made taking into consideration the comparative tests (PmB 60-90 or Bitumen 70/100 with Gilsonite):

Binder Demand: in comparison with base courses with elastomeric modified binders, highly stable base courses with Gilsonite have a slightly higher binder demand due to higher viscosity.

This fact could not yet be proven through the Mix Designs set up by the contractor's laboratory. The acceptance tests show an excision in the void content of the Marshall sample and an elevation of the Marshall stability which should not be neglected. This may be due to the fact that the asphalt mortar becomes highly viscous when the asphalt is once again heated in the Laboratory.

Rut Resistance: The tests regarding rut resistance show a comparatively high resistance against rutting for the different mixtures of the Mix Design. The deformation resistance of an asphalt mixture modified with Gilsonite is higher than that of a BT 22 HS mixture produced with PmB 60-90.

In reference to the requirements of the deformation resistance, it can clearly be stated, that the present BT 22 HS — Asphalt Mixture produced with 70/100 and the Natural Asphalt Gilsonite, fulfil the requirements of RVS 8S.01.41.

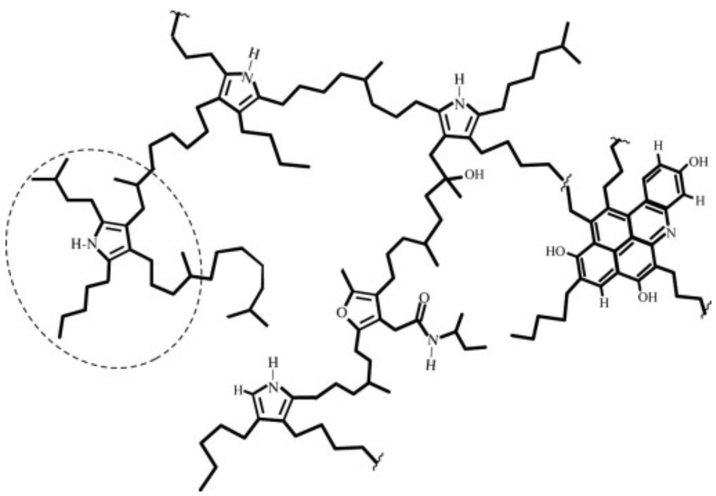
Indirect Tensile Test: The results of the indirect tensile strengths, attained during the mix design and the acceptance testing, can only partially be compared, because the bulk density of the test samples differed greatly (increase in viscosity of the asphalt mortar during renewed warming).

The executed indirect tensile tests (Mix Design) show comparative strengths for the 2 investigated asphalt mixtures during testing temperatures from -20°C to 0°C. With a testing temperature of 30°C the indirect tensile strength of the asphalt modified with natural asphalt is approx. 45% greater than the strength of the BT 22 HS asphalt mixture, which is produced with PmB 60-90.

During acceptance testing, as well as mix design, a variation of the indirect tensile strengths during different testing temperatures show a comparison regarding the level of the viscous- elastic characteristics of the construction material. The asphalt produced in the asphalt mixing plant is less temperature sensible in comparison with those mixtures produced in the laboratory.

Workability: it is possible to lay a bituminous base course mixture modified with natural asphalt without any additional working processes with a finisher and then compacting it by roller. The assumption can be made that the level workability will be of comparison with that of a PmB modified, highly stable bituminous asphalt base course mixture.

Use-oriented Characteristics: the surface of the asphalt construction showed no signs of faulty cold-resistance after the first winter period. Regarding the requirements of deformation-resistance, the assumption can be made that the BT 22 HS — Layer, produced with Bitumen 70/100 and Gilsonite is more favorable, that is in regard to its characteristic of deformation-willingness, in comparison to the mixture produced with PmB 60-90.



Prepared on December 18th, 2012 in Italy and subsequently revised

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Notice: all the information in this document has not a scientific value. The only purpose is to inform with generic data.