

The Bitumen Additive for Highly Stable Easily Compactible Asphalts

1. SASOBIT®

What is SASOBIT®?

SASOBIT® is a long-chain aliphatic hydrocarbon that is produced by Sasol Wax in South Africa using the Fischer-Tropsch process. Its molecular chain length lies in the range of 40 to more than 115 carbon atoms. In contrast the molecular chain lengths of paraffins naturally found in bitumen range from 22 to 45 carbon atoms. This explains why SASOBIT® has quite different physical properties to the paraffins normally present in bitumen. Therefore, they are not directly comparable. The melting point range of SASOBIT® is between 70°C - 115°C.

How does SASOBIT® work?

SASOBIT® is completely soluble in bitumen at temperatures in excess of 115°C. It forms a homogeneous solution with base bitumen on stirring and produces a marked reduction in the bitumen's viscosity. This enables mixing and handling temperatures of the asphalt to be reduced by 10 – 30°C. Temperature reductions of up to 50°C can be reached by process optimisation between the mixing plant and paving (Fraport Runway North).

This in turn results in a significant reduction of bitumen fumes emissions and CO₂ (= energy savings) during such operations.

During cooling the SASOBIT® crystallizes out and forms a lattice structure in the bitumen which increases the asphalt stability.

Packaging

SASOBIT® in Pastillen

600 kg big bags on pallets

20 kg PE bags shrink-wrapped on 720 kg pallets

2 to 4 kg PE bags in cartons on 450 kg pallets for direct dosage in the gussasphalt boiler

On request SASOBIT® can also be supplied in flakes or powdered form.

THE SUCCESS FORMULA FOR BETTER ASPHALT

SASOBIT
modified



2. SASOBIT[®]-Modified Bitumens (SmB)

2.1. Manufacture of SmB

SASOBIT[®] can be blended into hot bitumen at the asphalt blending plant using a simple stirrer. A high shear mixer is not required. The resultant bitumen-SASOBIT[®] blends are completely stable during hot storage and exhibit no tendency for phase separation.

ATS (The Fayat Group) and LT Linnhoff have developed a system which enables in-line blending of the molten SASOBIT[®] with the bitumen stream at the asphalt plant.

The companies G&P, VAM and ANA have also developed a system for direct dosage of SASOBIT[®] pastilles in the bitumen stream.

Direct blending of solid SASOBIT[®] at the asphalt plant for hot rolled asphalt is not recommended for quality reasons since it cannot be relied upon to give a homogeneous distribution of SASOBIT[®] in the asphalt.

In all cases so far evaluated, the optimal addition of SASOBIT[®] has been found to be 3 %, taking the additive's effectiveness and the overall economics into account.

2.2. Physical Properties of SmB Blends Compared to Basic Bitumen

	B 30/45	SmB 25	B 50/70	SmB 35	B 70/100	SmB 45
Base Bitumen		30 /45		50 /70		70/100
Bitumen content (% W)	100	97	100	97	100	97
SASOBIT [®] content (% wt)	-	3	-	3	-	3
Softening point R&B (°C)	53 – 59	80 – 90	48 – 54	75 – 85	43 – 49	70 – 80
Penetration at 25°C (1/10 mm)	30 – 45	20 – 30	50 – 70	30 – 50	70 – 100	35 – 55
Fraass break point (°C, max)	-5	-5	-8	-8	-10	-10

2.3. SASOBIT[®]-modified PmB

The advantageous properties of SASOBIT[®]-modified bitumens, as described above, may be combined synergistically with the elastic properties of polymer-modified bitumens. This is especially beneficial when a highly modified bitumen or stiff PmB is required for selected applications. BP Olexobit NV 25 and BP Olexobit BP 25 have been used successfully for such applications. The combination of SASOBIT[®] and elastic polymers can also improve stability during hot storage. The addition of SASOBIT[®] to rubber bitumens drastically reduces the emission of blue smoke during processing owing to the lower temperatures that may be employed.

3. SASOBIT®-Modified Asphalts

SASOBIT®-modified asphalts have been successfully used since **1997** in a wide range of applications.

Mix types: stone mastic asphalt (SMA) 0/5 – 0/8 – 0/11
 asphalt binder 0/16 – 0/22
 guss asphalt (mastic asphalt).
 asphaltic concrete

In addition SASOBIT® has proved itself in the following special applications:
 asphalt thin layer coatings, asphalts used in waste containment systems, surfacing of container storage areas, other highly loaded asphalt surfacings

3.1. Manufacture of Mixes, their Application and Compaction

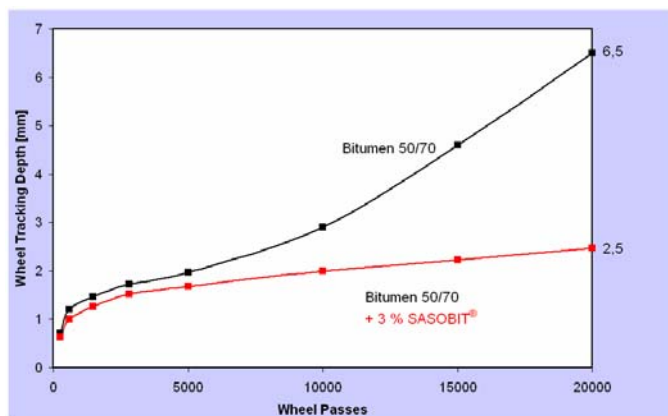
The reduction in viscosity produced by the addition of SASOBIT®, as referred to above, leads to an improvement in the handling and compaction of the resultant asphalts.

The resistance to compaction is reduced.

SASOBIT® content (% wt)	Compaction Resistance D
0	41,6
2	39,7
3	36,3
4,5	33,0

3.2. Deformation Resistance of SASOBIT[®]-Modified Asphalts

At service temperature, SASOBIT[®]-modified asphalts display an increased resistance to permanent deformation. This effect is clearly illustrated by the results of the wheel tracking test.



Rutting Depth Tested
in Hamburg Wheel Tracking Tester:
SMA 0/11 S in a water bath at 50°C

3.3. Low Temperature Behaviour of SASOBIT[®]-Modified Asphalts

The low temperature behaviour of SASOBIT[®]-modified asphalts is determined by the nature of the base bitumen that is used. SASOBIT[®] does not significantly affect this property. This is demonstrated by the results of a series of Arand cooling tests simulating service conditions in which rigidly-mounted asphalt test samples were subjected to cooling at the rate of 10°C/h. The tensions created by thermal shrinkage and the break temperatures were measured.

	Max Thermally Induced Tension (N/mm ²)	Break Temperature (°C)
SMA 0/11 S; B 50/70	4,4	-25,0
SMA 0/11 S; B 50/70 + 3 % SASOBIT [®]	4,5	-24,5
Gussasphalt 0/11; B 30/45	6,0	-26,5
Gussasphalt 0/11; B 30/45 + 3% SASOBIT [®]	5,9	-25,5
Gussasphalt 0/11; PmB 45	6,8	-30,0
Gussasphalt 0/11; PmB 45 + 3% SASOBIT [®]	7,0	-30,0

4. Laboratory Tips

Softening Point R&B

In accordance with DIN-EN 1427 the R&B softening point above 78°C must be determined using glycerol in water bath.

Extraction

If SASOBIT®-modified binder is to be recovered from asphalt by the extraction method, we recommend cold extraction with the use of ethylene trichloride. We further recommend pre-soaking the sample. The extraction process must be continued for 70 minutes plus a further drying time of 20 minutes. This ensures that the colourless SASOBIT® is fully recovered despite its low solubility. Deviating from other regulations we also recommend ethylene trichloride as a solvent for the arbitration analysis

Checking the Presence of SASOBIT® in Bitumen

The high softening points of SASOBIT®-modified bitumens may be used as an indicator of the presence of SASOBIT®. Precise checks, as well as a quantitative determination, may be carried out by DSC (differential scanning calorimetry). Details of the test method are obtainable from Sasol Wax on request.

The softening point of the original binding agent must also be taken into account when evaluating the R&B softening point increase in order to avoid an incorrect assessment as otherwise the impression could be caused that the binding agent and/or mixed components are thermally overburdened.

5. Research Reports and Independent Assessments

Several well-known Research Institutes, Universities and asphalt test laboratories have investigated extensively the mechanisms by which SASOBIT® functions to achieve significant improvements in asphalt quality.

These studies have been accompanied by road construction research work and the observation of road trials that have confirmed the laboratory results under practical conditions.

The following institutions participated in the researches:

Germany:

Asphaltlabor, Wahlstedt
Asphalta, Berlin
Hansa-Bau-Labor, Hamburg
Institut für Erdöl-und Erdgasforschung, Clausthal
IFM, Rottweil
IFM, Leipheim
IFTA, Essen
LGA, Nürnberg
Dr. Löffler Baustoffprüfung, Hannover
Nordlabor, Pinneberg
Sbt, Trier
TU, Darmstadt

International:

Technical University Vienna, Austria
MAPAG, Gumpoldskirchen, Austria
PRI Asphalt Technologies, Tampa, USA
NIEVELT-Laboratory, Prague, Czech Republic
University of Putra, Malaysia
Xian University, China
Tongji University, Shanghai, China
RTA, Australia
MASZ Budapest, Hungary
Road & Bridge Research Institute, Warsaw, Poland

6. References

SASOBIT® has been used in numerous construction projects with great success. The following list represents a few of the important references.

Germany:

Boehringer AG:	Waste containment lining
Hamburg Neuhof:	Waste covering / container storage area
Motorway A1, Maschen-Harburg:	Thin layer asphalt
Hamburg Port:	Container storage area, road access spur
Motorway A1, Euskirchen:	Surface coating (SMA)
Motorway A111, Berlin:	Binder course
Hamburg Airport:	Runway
Motorway A8 Steel Bridge Friedrichsthal:	SMA 0/8S with BP Olexobit NV 45
Motorway A 8 Munich - Karlsruhe:	Asphalt binder 0/16S + SMA 0/11 S with BP Olexobit NV 45
Car park + side street, Passau:	BP NV 70/100
Bypass, Niederhöft:	BP NV 70/100
AUDI factory driveway, Ingolstadt:	BP NV 50/70
Motorway A1 Euskirchen:	Top layer Gussasphalt (BAST trial road)
Motorway A7 Rader High Bridge:	Gussasphalt 0/11 S with BP Olexobit NV 45
Motorway A3 Danube Bridge, Passau:	Gussasphalt 0/8 S with BP Olexobit NV 45 + 3% SASOBIT®
Munich Airport:	Top layer AB 0/11 S with BP Olexobit NV 45
Motorway A25 Hamburg:	Binder Course 0/16 S with PmB 25 RC + 1,5% SASOBIT®
	SMA 0/8 S with PmB 45 + 1,5% SASOBIT®
Fraport, Runway North Frankfurt:	ATS CS 0/32 30/40 + 4% SASOBIT®
	Asphalt binder 0/22 S Caribit 25 + 4% SASOBIT®
	SMA 0/11 S Caribit 45 + 4% SASOBIT®
Recklinghausen, K5 Haltern:	AiF Research AB 0/11 NT
	Nytemp 30/45
Freiheit, Berlin	Asphalt binder 0/16 S PmB 25 + 3% SASOBIT®
	SMA 0/11 S PmB 25 + 3% SASOBIT®
OD Hohn, Schleswig-Holstein	AB 0/11 S NT SmB 35

International:

China:	Motorway
Denmark:	Trunk road
France, Paris:	City roads
Hungary:	Trial Road Szekesfehervar
Italy:	Piemont, national road
Malaysia, Kuala Lumpur:	Highway No. 1
Malaysia, Sengalor	Kajang Ring Road
Norway	Motorway Oslo-Drammen
Russia, Moscow	City Motorway
Sweden (Near Arctic Circle)	Military Airport
Switzerland:	Stallikon, national road
South Africa, Johannesburg:	Ben Schoemann Highway
South Africa, Johannesburg:	Christian de Wet Road
United Kingdom:	Cambridge Airport
United Kingdom:	Cardiff Docks
United States of America:	Trial roads

7. Literature and Patents

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- U. Oberthür: *Einfluss der Paraffinkonzentration und -struktur auf rheologische Eigenschaften von Bitumen, (Influence of paraffin concentration and paraffin structure on the rheologic properties of bitumen)*, Dissertation Technical University, Clausthal 1998
- I. Rahimian, I Sachs: *Ersatz des Paraffingehalts als optimales Anforderungskriterium im Rahmen der europäischen Normung, (Substitute of the paraffin content as optimal requirement criteria within the framework of the European standardization)*, Finishing Report of the research FE 07.169 G 95 of the BAST 1998
- T. Butz, I. Rahimian, G. Hildebrandt: *Modifikation von Straßenbaubitumen mit Fischer-Tropsch Paraffin, (Modification of road construction bitumens with Fischer-Tropsch waxes)*, Bitumen 2000, P. 91-96
- I. Rahimian, T. Butz: *Eignung von FT-Zusatz als Bindemittel für den Straßenbau, (Suitability of the addition of Fischer-Tropsch waxes as a binding agent for road construction)*, IfE Finishing report, 1998
- T. Butz, G. Hildebrandt, F. Richter, G. Riebesehl: *Drei Jahre SASOBIT® - ein Erfahrungsbericht, (Three Years of SASOBIT® - an experience report)*, asphalt 5/2000
- F. Richter, H. Gregori: *Synthetic Paraffins enhance Bitumen stability*, Erdöl Erdgas Kohle 2000, P. 509-512
- F. Richter: *Paraffin in Bitumen*, Bitumen 2001, P. 104-108
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SASOBIT® has been patented in many countries. For further information please contact our product management.

Asphalt Flow Improvers As 'Intelligent Fillers' For Hot Asphalts – A New Chapter In Asphalt Technology –

Klaus-Werner Damm, Jörg Abraham, Thorsten Butz, Günter Hildebrand and Gerhard Riebesehl*

Summary

Asphalt flow improvers in the form of Fischer-Tropsch wax and Romontan wax (ozokerite) have emerged successfully from an extensive program of laboratory testing and road trials to assess their suitability as modifiers for rolled asphalts and gussasphalt. They produce flow improvement effects in hot asphalt mixes that enable mixing temperatures to be reduced by 20 – 40°C.

Below the temperatures used in laying and compaction, these materials produce a strong increase in asphalt viscosity and stiffness. This results in a significant improvement in the stability (resistance to deformation) of the asphalt under operational conditions of high ambient temperatures and heavy traffic. The data gathered so far show that low temperature properties are not adversely affected. The higher density that is achieved on compaction greatly improves the life span of asphalts in service.

Although these benefits can be realised by using flow improvers alone as bitumen additives, they are also suitable as co-modifiers for PMB 45 and PMB 25 grades since they significantly improve handling and compactibility. As is well known, PMBs (polymer-modified bitumens) have a higher cohesion energy than straight bitumens, which in terms of performance leads to a higher resistance to fatigue cracking. However, they have the disadvantage that they are more difficult to lay and compact. This can be overcome through the use of flow improvers. The combination of PMBs and asphalt flow improvers creates important technical advantages.

Based on current experience, the recommended level of additivition with asphalt flow improvers is 3 % wt. of the binder quantity. Nearly all the data from road trials presented in this paper relate essentially to works-mixed binders derived from a single crude oil. The results from trials using base bitumens from other sources indicate that similar positive results can be achieved.

1 Introduction

The principal objectives when modifying bitumen for road applications are to produce a lasting improvement in the service properties of the asphalt pavement, and/or a corresponding increase in service life, at a cost that is economically justifiable. The most important properties in this regard relate to the durability of the road surfacing, the grip it affords, and its resistance to deformation under load.

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The functional performance of asphalt pavements depends to a large degree on the grade and quantity of the binder used and on the compaction achieved. Binders must exhibit several important features:- good adhesion towards the aggregate, satisfactory stiffness in the upper range of operating temperatures, satisfactory resistance to cracking caused both by low operating temperatures and material fatigue under traffic loads, and satisfactory resistance to ageing. In addition they must give the resulting asphalts good workability during application.

The elastomer-modified bitumens employed in Germany fulfil all these requirements with the exception of the handling properties and compactibility of the manufactured asphalts. Harder grades of PMB, and bitumen with high polymer content, require as a rule a high compaction force or a higher handling temperature. These can have a deleterious impact on the technical properties of the binder and the asphalt when laying times are prolonged.

In our opinion, asphalt flow improvers produce a technical advance that cannot be over-estimated and is perhaps best compared with the major innovative impetus brought about in the cement industry some 20 or 30 years ago by the introduction of flow improvers and high performance flow improvers. The potential for the asphalt construction industry is not confined to the improvements conferred to the building material. It extends to energy savings and reduced emissions to the environment (the latter being currently of particular concern) that may also be realised; the emissions can be halved or reduced even further. The new land of asphalt flow improvers has been discovered and many areas have already been visited. Following its discovery, we now need carefully to explore further and to undertake scientific and experimental trials in order to avoid unnecessary risks and failures. This paper is aimed at that objective.

In the following illustrations of viscosity-reducing additives, we shall seek to support the major claims by reference to comprehensive laboratory testing and practical trials.

Asphalt flow improvers enable not only a higher degree of compaction to be achieved, even at lower compaction temperatures, they also produce a greater stiffness of the binder that leads to a greater structural stability under hot service conditions. Moreover, all this is accomplished without any adverse effect on low temperature properties. Because the asphalt attains a more compacted state, resulting in an increase in internal frictional forces within the aggregate mix, both the resistance to deformation under hot service conditions and durability are improved. Furthermore, a reduction in asphalt mixing temperatures of 20 – 40°C can be expected, even with a usefully longer compaction time.

Asphalt flow improvers are substances that, on heating, change from the solid to the liquid state at temperatures above ca. 80°C and thereby significantly reduce bitumen viscosity beyond this temperature. When the bitumen cools, the flow improver changes to a finely divided, crystalline, solid form and thereby imparts a stiffening effect to the binder. Asphalt flow improvers may therefore be seen as 'intelligent fillers', which, by using their crystalline structure, imbue the binder with a form of defence against the effects of temperature.

It must however be emphasised that the road trial experiences of the authors with Fischer-Tropsch wax relate principally to bitumen-flow improver systems that are based on works-prepared blends derived from the same base bitumen, i.e. from the same crude oil source. It cannot be excluded that other base bitumens may require some adjustment to the additivation level of flow improver.

2 Structure and Modification of Bitumens

The physical properties of bitumens that enable them to be used as binders in asphalt result from their complex colloidal structure. According to current knowledge, the components of bitumen may be ascribed to the three fractions: asphaltenes, resins and dispersion material (oils); the latter two fractions are often jointly called maltenes. The individual molecules of the asphaltene fraction associate to form small, sub-microscopic colloids due to the effects of their attractive forces. This material may be considered as a solid state. The resins create a layer on the surface of the colloids and form a transition to the dispersion phase. At low temperatures the volume of the colloidal structures is very large so that they contact one another and become a continuous phase that occludes the remaining dispersion medium. Through this process, bitumen gradually approaches a gel state and becomes first elastic and then, at very low temperatures, a hard brittle substance. In contrast, as temperatures rise, molecules release themselves from the colloid structure so that the dispersion phase content increases and the volume of asphaltene colloids shrinks (sol condition). The bitumen thereby gradually changes in its visco-elastic condition and at very high temperatures tends towards the rheological behaviour of an oil. Softening starts to occur at a certain temperature range that depends on the concentration of associate-building asphaltenes and resins as well as the viscosity and solvent properties of the dispersion phase. This process is reversible, giving bitumen the characteristics of a thermoplastic material and imparting in turn excellent recycling properties to both bitumen and asphalt.

Bitumens have for decades been modified with polymeric materials, one reason being to increase the temperature range between embrittlement at low temperatures and softening at high temperatures, the so-called plasticity range. In the ideal case the polymers build an interlinked network through chemical bonding or physical interactive forces. The network has elastic properties that can improve low temperature properties of the bitumen and its stiffness at summer temperatures. Polymer-modified bitumens may also be clearly distinguished from their unmodified counterparts by an increased cohesive energy and ability to regain their shape in tensile strength tests. A side effect of modification with polymers is normally an increase in viscosity in the temperature range at which asphalts are mixed and handled. Road construction engineers know that asphalts made with, for example, PMB 45, not to mention PMB 25, are difficult to lay and compact.

The working principles of the asphalt flow improvers described in this paper lead to an increase in stiffness at summer temperatures, but on the other hand to a viscosity reduction in the temperature ranges used during asphalt manufacture and handling.

If one wishes to modify bitumen, the existing colloid system that we have been considering should not be destroyed by any added colloids, which as a rule are of larger size. Since asphalt flow improvers are distributed as fine crystals in the bitumen at normal service temperatures, it is obvious that the quantity of those crystals should be matched to the type of bitumen used. Therefore the quantity of asphalt flow improver added must be adjusted according to the various bitumen grades and sources so that defined binder properties can be achieved without margin of error.

By the use of suitable test methods it is possible to determine the optimum quantity of flow improver that must be added to the base bitumen.

3 Asphalt Flow Improvers

Tests were conducted on two asphalt flow improvers that produced a significant improvement in the mixing and handling properties of asphalts due to their viscosity-reducing effect. One was a Fischer-Tropsch wax, the other Romontan wax (a type of mountain wax or ozokerite) and its derivatives. The lower viscosity resulting from use of the additives facilitates wetting of the aggregate by the bitumen, while at the same time reducing mixing and laying temperatures by 20 to 40°C. That means not only considerably lower energy costs but also a large reduction in the emissions of bitumen vapours and aerosols.

Accompanying these flow improvement effects, the addition of bitumen with both FT-wax and Romonta wax (see 3.2) produces other improvements in the binder's properties that lead to parallel improvements in the quality properties of the asphalt, such as its structural stability in hot service conditions. These aspects are covered in detail in section 4.

3.1 FT-Wax

The statement that a high content of paraffin wax adversely affects the quality of bitumen is an over-generalisation that cannot be substantiated. The effect depends on the structure of the waxes, as Duriez [1] amongst others advised in 1961. Krenkler [2] noted that a high wax content does impair certain properties of bitumen, namely ductility, the service temperature range, the Fraass breaking point and the adhesive strength. De Bats [3] concluded from research into 8 year-old asphalt coatings that bitumens with a high wax content of up to 12 % wt. have performances as good as those of standard bitumens whose wax contents are limited to 2% wt.. Oberthür [4] came to the conclusion that the setting of a generally applicable limit value on the concentration of waxes in bitumen needs to be re-examined.

The decisive factor in any adverse effect of waxes is their crystal structure. The bitumen matrix exerts an important influence on the formation of wax crystals. Bitumens with a high microcrystalline wax content exhibit a very low Fraass breaking point, giving a wide service temperature range. The favourable effect of microcrystalline waxes may be attributed to a 'lubrication' effect stemming from the ease of alignment of the small wax crystals that allows them to slip past one another and their plastic deformation behaviour. Macrocrystalline waxes on the other hand have an adverse effect on the Fraass breaking point if the bitumen matrix is not capable of dissolving them.

The effects of the waxes that occur naturally in bitumens (bituminous waxes) on the service properties of the end-product asphalts is an area of dispute. They may reduce the quality of the bitumen at the higher concentrations. Therefore the content of bituminous wax is an optional requirement in the harmonised European Standard for bitumen and bituminous binders, EN 12591, and has been adopted by certain countries, amongst them Germany, at the limit level of 2.2% wt. or 4.5%, dependent on the test method used¹⁾. It is therefore necessary at this point to compare the essential differences between bituminous waxes and FT-waxes in terms of their structure and physical properties and their relationship to the application-orientated properties of bitumens.

¹⁾ The limit of 2.2% wt. applies when using method EN 12606-1 (a destructive distillation technique), while the limit of 4.5% applies using method EN 12606-2 (a simulated deasphalting/dewaxing procedure).

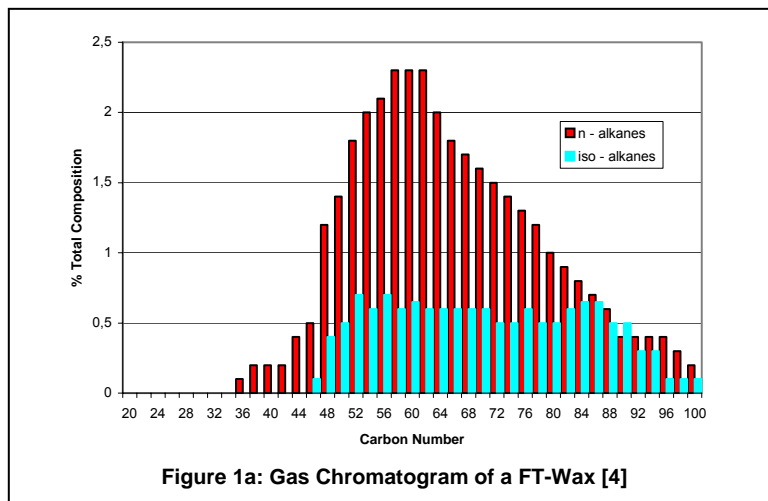
The effect of bituminous waxes and FT-waxes on the properties of bitumens has been the subject of extensive research projects undertaken by the German Petroleum Institute, Clausthal-Zellerfeld [5 - 9].

The work revealed that the waxes do not always have an adverse effect on bitumen properties and, in certain areas, may indeed be beneficial. The effect is critically dependent on the chemical structure of the waxes, which encompass a broad range as follows:-

- plastic microcrystalline waxes and
 - highly crystalline macrocrystalline waxes
 - fine crystalline FT-waxes
- } bituminous waxes

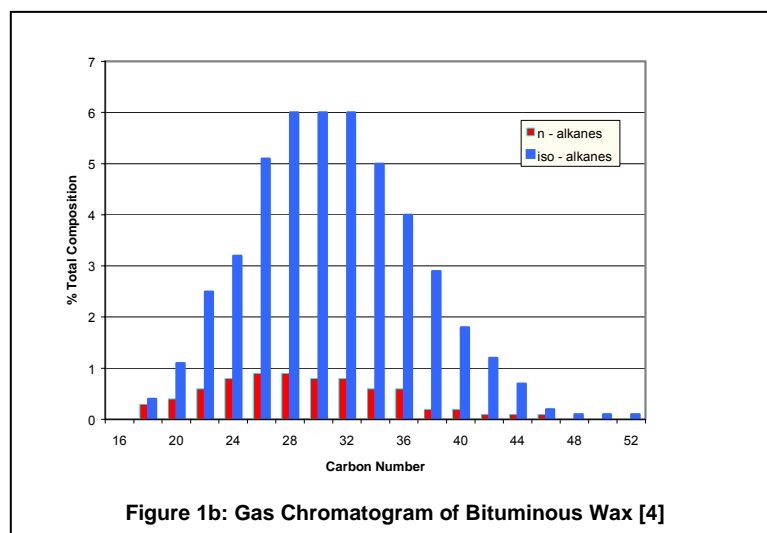
While the microcrystalline waxes have a plasticising effect at low temperatures, resulting in a reduction in the breaking point, the macrocrystalline waxes cause embrittlement at low temperatures and an accompanying increase in breaking point. When the wax content rises above saturation point, which is dependent on the types of wax and bitumen present but lies in the region of 2% wt., crystalline bituminous waxes appear that create a stiffening effect. However, this effect reverses at temperatures above the wax melting point due to a reduction in viscosity. Bituminous waxes melt in the range 20 to 70°C [10] so they lead to additional softening of bitumen in the upper range of service temperatures. The cause of the low melting point of these waxes is their relatively low chain length of 22 to 45 carbon atoms.

The FT-wax used as asphalt flow improver comprises a mixture of long-chain aliphatic hydrocarbons that are produced from coal using the Fischer-Tropsch process. In this process, discovered in 1926, carbon monoxide is converted by catalytic hydrogenation into a mixture of hydrocarbons having chain lengths of C₁ to C₁₀₀ and greater.



The starting point for the process is synthesis gas (CO + H₂), which is produced by gasification of coal. The liquid products are separated by fractionation and the FT-waxes are contained in the highest boiling fraction.

The predominant chain length of the hydrocarbons in FT-waxes is 40 – 100 carbon atoms. A gas chromatogram of the material is shown in figure 1a, while a bituminous wax is shown for comparison in figure 1b.



The congealing point of the FT-wax is about 100°C and it has a melting range from about 70°C to 120°C, a factor which is used as a descriptor for the grades that are marketed. The melting range of FT-waxes can be measured by differential scanning calorimetry. Details of the method are given in [3] and [10].

FT-waxes have physical properties that are quite different from those of bituminous waxes. The difference arises from their much longer chain lengths and the fine crystalline structure of FT-waxes.

3.2 Romontan Waxes

The working principles of the Romontan family of asphalt flow improvers from a German manufacturer are representative of mountain waxes (ozokerite) in general. The material is a fossil hard wax originating from sub-tropical vegetation that flourished in the Tertiary Period. Because of its high biological stability and insolubility in water, the wax has survived over long geological time periods.

Romontan wax is a multi-component mixture with a complex composition [11]. Under carbonisation conditions during its formation, the plant waxes underwent a small compositional change. Condensation reactions between mono- and multi-functional groups, especially oxy-acids, led to the formation of high molecular weight substances. Waxy acids comprise 20 to 50% wt. of the total content and waxy alcohols 20 to 25%. The predominant species are the even-numbered homologues in the range C24 to C32, peaking at C28. Because these components are mostly in the form of esters, Romontan wax may be denoted as an esterified wax. The material offers the possibility of modifying the properties of bitumens and asphalts, especially those involving viscosity, softening behaviour and adhesion to the surfaces of minerals. Romonta waxes have long been used for such purposes, especially for modifying gussasphalt [12].

Building on the extensive experience gained from using these products in asphalts, a new generation of application-optimised additives was developed. This work covered not only the use of the known properties of the Romontan wax known as Romonta Normal. In addition, targeted application properties were achieved by selecting efficacious components from the base structure of the Romontan wax, by using chemical reactions with the active carboxyl groups present, and by the use of other high molecular weight hydrocarbons. This affects the viscosity of the additivated bitumen and leads to an increase in softening point (ring and ball). By making use of organic compounds with bipolar character, the adhesion of the additivated bitumen to minerals is improved.

4 Improvement of Bitumen Properties by Additivation with Flow Improvers

4.1 Bitumens Modified with FT-Wax

The FT-wax used for modifying bitumens has the trade name Sasobit. Sasobit-modified bitumens (SMB) are available on the German market under the grade names SMB 25, SMB 35 and SMB 45. Asphalt experts are well aware that the temperature dependency of asphalts is primarily dictated by the type and quantity of binder used. However, it is surprising how often this simple fact is forgotten in practice. As far back as 1954, Van der Poel [13] was able to demonstrate that through knowledge of the asphalt composition and the bitumen properties, the stiffness of the asphalt can be 100 times greater than that of the binder. Nomograms that took account of the properties of the binder and of the asphalt mix were developed for determining the dynamic stiffnesses of bitumen and asphalt.

The properties used to define the stiffness of a binder according to conventional test methods are the Ring and Ball softening point and the penetration. More recent test methods, such as the dynamic shear rheometer for example, enable stiffness to be defined in terms of physical parameters, namely the complex modulus G^* and the phase angle δ . For a description of this procedure, reference should be made to Litzka [14].

Bitumens of different provenance or grades may well have different temperature susceptibilities. Therefore one cannot draw conclusions about their properties at normal or low operating temperatures from properties at elevated operating temperatures unless further data are available to define fully the behaviour with respect to temperature. In terms of conventional test methods, the additional data required are penetration, ductility with possibly elastic recovery, the Fraass breaking point and ageing (hardening) after thermal treatment. All these procedures are empirical test methods whose results can only be assessed on the basis of practical experience gained in the past. The newer test methods – one has already been mentioned above – deliver physically-based property data which may in future be used as inputs for calculations concerning structural overlay design and deformation behaviour. These test methods are therefore called performance-related test methods. In Germany, methods used to define the properties of binders are force-ductility at normal ambient temperatures, and the bending beam rheometer at low temperatures.

Viscosity is used to describe the binder's properties in its liquid condition, which is important for handling bitumen and mixing it with aggregates. Table 1 contains data on the binder properties of a base 70/100 bitumen with varying levels of treatment with flow improver, in this case FT-wax [15]. The following conclusions can be drawn from the binders' characteristic data:

Table 1 Conventional Test Data for 70/100 Bitumen with/without FT-Wax Flow Improver

Test Method		FT-Wax (% wt.)				Limits in DIN EN 12591
		0.0	1.5	3.0	4.5	
Softening point (R&B)	[°C]	48	52	76	96	—
Penetration/25°C	[mm/10]	71	48	42	37	—
Fraass point	[°C]	-7.5	-7.5	-6.5	-7.5	—
Ductility at 25°C	[cm]	>100	100	95	100	—
Density at 25°C	[g/cm ³]	1.0228	1.0233	1.0214	1.0216	—
Ash	[% wt.]	0.18	0.16	0.15	0.19	≤ 0.5
Penetration index		-0.76	-0.81	+2.98	+5.8	
Properties after thermal ageing						
– weight change	[%]	-0.05	0.05	0.1	0.2	≤ 0.8
– soft. point (R&B)	[°C]	51.5	61.5	81.5	95.5	—
– Increase in SP	[°C]	3.5	9.5	5.5	-0.5	≤ 6.5
– penetration/25°C	[mm/10]	53.0	36.2	33.0	31.0	—
– decrease in penetration	[%]	25.4	24.6	21.4	16.2	≤ 40
– ductility at 25°C	[cm]	—	100	90	100	

- R&B softening point is increased only slightly by the addition of 1.5% FT-wax; it then increases noticeably with further additive dosage at a rate of about 14.5°C/1% wt.
- Penetration falls sharply with addition of 1.5% FT-wax and then reaches a plateau of about 40 mm/10.
- At a FT-wax content of 3%, the modified bitumen corresponds to a 10/20 grade with respect to softening point, and to a 30/45 grade in terms of penetration.
- The Fraass breaking point remains practically unchanged with the quantity of FT-wax added.
- The ductility at 25°C (test temperature for a 30/45 bitumen) is practically unchanged up to the maximum content (4.5%) of additive used.
- After subjecting the bitumen to thermal ageing (hardening) in a rotating flask, all the requirements in DIN EN 12591 for a 30/45 grade are met.

Table 2 and figure 2 present the effect of FT-wax in the temperature range at which bitumens are handled.

Table 2: Dynamic Viscosity by Ball Draw Viscometer

Dynamic viscosity (mPa·s) at:	FT-Wax Content (% wt.)			
	0.0	1.5	3.0	4.5
110°C	1410	2119	1713	1593
130°C	521	510	505	462
140°C	292	250	220	202
150°C	204	181	169	155
180°C	88	72	68	65

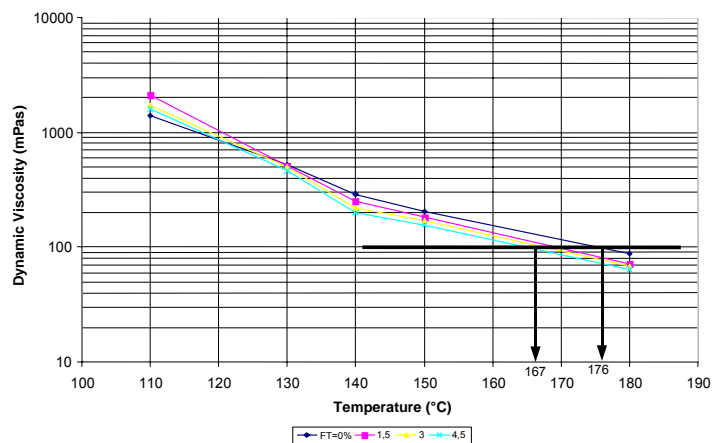


Figure 2: Dynamic Viscosity (Ball Draw Viscometer) of a 70/100 Bitumen Containing FT-Wax

From the data and the shape of the viscosity graphs it can be deduced that:

- At temperatures below 110°C the dynamic viscosity of the blends is greater than that of the parent bitumen.
- Above 130°C the viscosity falls noticeably as the FT-wax content increases.
- Binders are capable of being blended and sprayed at what is termed the equiviscous temperature, EVT_{100} , which is the temperature at which the binder has a dynamic viscosity of 100 mPa·s. This means that the bitumen modified with 3% FT-wax is capable of being handled at a temperature about 10°C lower than needed for the base bitumen. However, this is not to say that an asphalt mix can be compacted at a correspondingly lower temperature. Besides the viscosity of the binder, the compactibility of the asphalt depends on the asphalt composition to a not inconsiderable degree. The trials conducted with Sasobit have shown that the compaction temperature can be reduced by up to 40°C (see section 6), which is more than can be attributed just to the reduction in binder viscosity. It is assumed that lubricating effects are produced in the region of the crystallisation point by release of the heat of crystallisation, thus enabling compaction to be achieved in this lower temperature range.

The experiments described so far were conducted using a 70/100 bitumen as the base grade. This raises the question of what effect FT-wax would have on harder standard grades. Figures 3 to 5 show the effect of FT-wax on the R&B softening point, penetration at 25°C and on Fraass breaking point [16]. This work involved use of bitumens derived from a different crude oil.

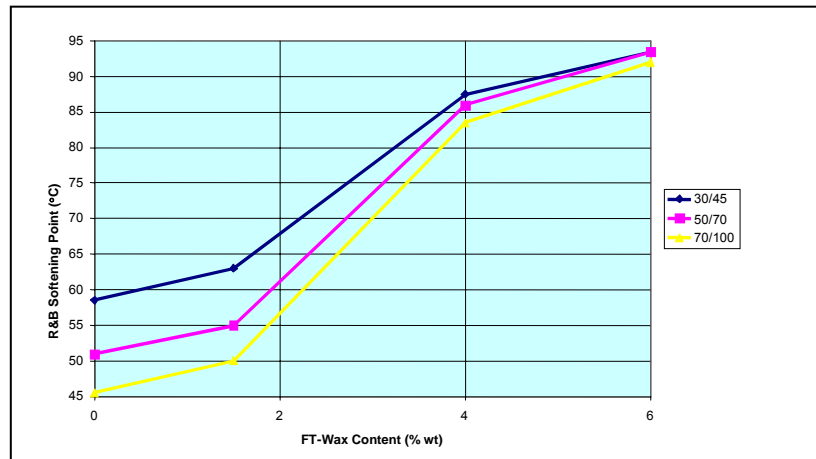


Figure 3 Effect of FT-Wax Content on Ring & Ball Softening Point [16]

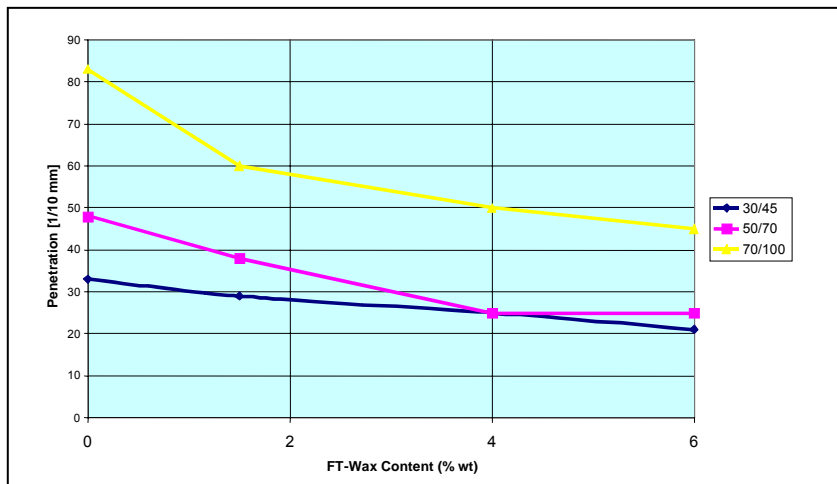


Figure 4 Effect of FT-Wax Content on Penetration at 25°C [16]

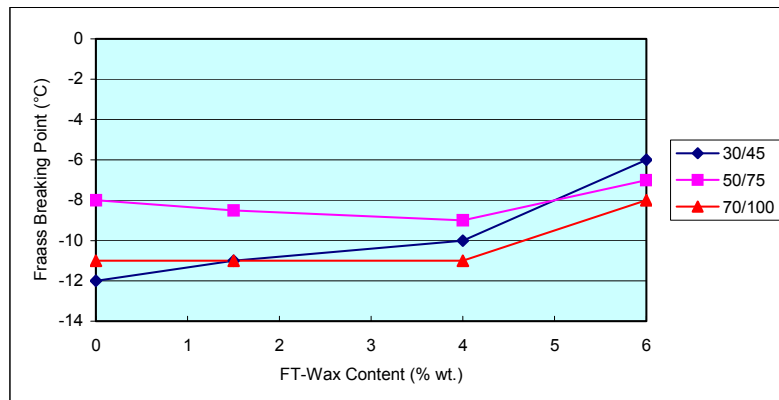


Figure 5 Effect of FT-Wax Content on Fraass Breaking Point [16]

The figures show that up to a FT-wax content of 1.5% the R&B softening point has risen only slightly, while a drop in penetration is clear to see. At concentrations above 1.5% these two binder characteristics change significantly. In comparison the Fraass breaking point does not worsen until a concentration of 4% has been reached in all three binders.

The effect of FT-wax on softening point and penetration becomes less pronounced as the hardness of the binder increases. In contrast the effect on Fraass breaking point is more pronounced. The R&B softening point eventually reaches a common final value of about 90 – 95°C, which may be explained by the melting point of 100°C for FT-wax.

Using a dynamic shear rheometer (DSR), Butz [7] investigated how the phase angle δ and the complex shear modulus, or its elastic component – expressed in terms of the storage modulus $G'' = G^* \times \cos \delta$ – changes for fundamentally various base bitumens, using an oscillation frequency of 0.2 Hz over a range of temperatures and with varying concentrations of FT-wax. The smaller the phase angle δ , the greater the elastic component of the mechanical reaction of the binder to the applied strain. The larger the storage modulus, the larger the elastic component of the binder stiffness.

This work involved a waxy base bitumen from Russia and a Middle East bitumen (see figures 6 and 7).

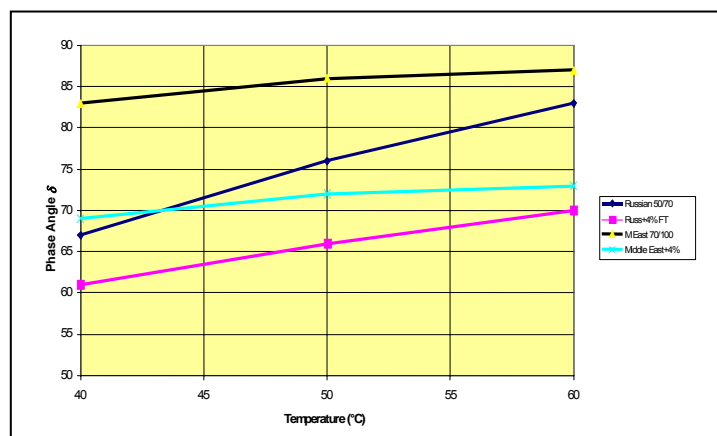


Figure 6 Variation of Phase Angle δ with Bitumen Source, Temperature and FT-Wax Content at 0.2 Hz

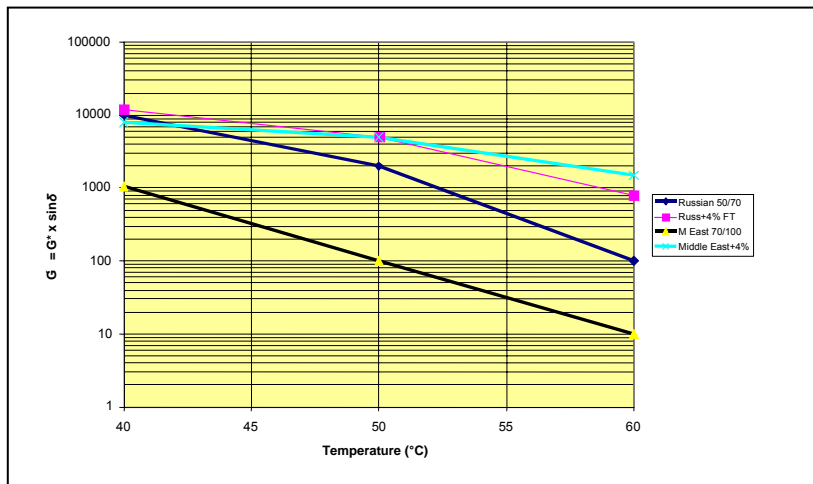


Figure 7 Variation of Storage Modulus G'' with Bitumen Source, Temperature and FT-Wax Content at 0.2 Hz

As the FT-wax content is raised, the structural elasticity and stiffness of the binder increase. The different sources of bitumen vary in their response to FT-wax, especially in terms of the storage modulus $G^* \times \cos \delta$. These findings are equally valid at the oscillation frequency of 1.59 Hz that is normally used today.

4.2 Bitumens Modified with Romontan Waxes

Romontan waxes are recovered from brown coal having a high wax content. They are marketed under the trade names Romonta N, Asphaltan A and Asphaltan B. Their congealing points are about 78°C, 125°C and 100°C respectively. Romontan waxes and their derivatives have a similar effect to FT-waxes as bitumen flow improvers.

The products Romonta N and Asphaltan A are normally applied in gussasphalt mixes while Asphaltan B is aimed at rolled asphalt or Asphaltan-modified bitumen (AMB). Table 3 gives an illustrative overview of their effect on the properties of 50/70 bitumen when 3% wt. is added.

Table 3: Properties of 50/70 Bitumen Blended with 3 % wt. Romonta Waxes

	Base Bitumen	Romonta N	Asphaltan A	Asphaltan B
Softening point R&B [°C]	53.0	55.0	63.0	76.0
Penetration [mm/10]	55.0	48.0	45.0	40.0
Dynamic viscosity [mPa·s]				
at 120°C	1200	1002	850	890
at 140°C	445	390	370	375
at 160°C	182	168	145	148
Fraass point [°C]	-9.5	-10.0	-10.5	-9.5
Ductility [cm]	14.6 (13°C)	100 (25°C)	> 100 (25°C)	> 100 (25°C)

Asphaltan B has the greatest effect in increasing the R&B softening point, although this is somewhat less than that of FT-wax, possibly due to the difference in molecular size and chain length of these waxes.

The products have little or no effect on Fraass breaking point or ductility.

The viscosity-reducing potential of the three products is of interest when trying to find ways of achieving desirable reductions in the temperatures used in the manufacture and laying of asphalt. Similar reductions in viscosity are observed for other types of bitumen, including polymer-modified bitumens.

Figure 8 shows the drop in dynamic viscosity for a 50/70 bitumen modified with Asphaltan B. The effects of Asphaltan A on gussasphalt are similar to those of Romonta N. Comparing the properties of the neat binder and those with added flow improver, the significantly lower viscosity produced by the additives gives the potential for a considerably lower handling temperature for gussasphalt.

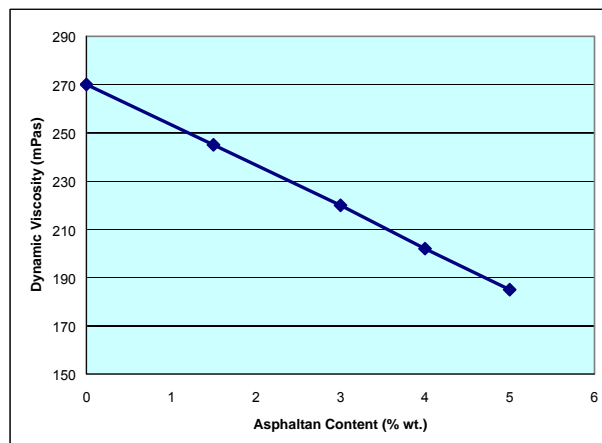


Figure 8 Dynamic Viscosity at 150°C of 50/70 Bitumen with Varying Asphaltan B Content

5 Asphalt Trials

5.1. Asphalts Modified with FT-Wax

Following the results achieved with flow improvers in bitumen as described in section 4, asphalt tests were arranged using a model stone mastic asphalt 0/11S that was difficult to compact. The trials covered treatment levels with FT-wax of 0%, 2.0% and 4.5% wt. calculated on the quantity of 50/70 bitumen used. The resultant mixes correspond to a 20/30 bitumen in terms of softening point, and a 30/45 grade in terms of penetration. The trials were also aimed at examining the effect of water on the asphalts' properties, so aggregates were selected having adhesion-critical properties:

- ground quartz
- quarried quartz-diorite sand
- quartz-diorite gravel

The quality property data of the binders indicate that a viscosity-reducing effect at temperatures above 100°C can affect the properties of asphalt as follows:

- higher absolute level of compaction;
- thereby giving a lower optimum binder content (subject to approval testing);
- greater compactibility;
- reduced absolute compaction temperature.

In the region of the service temperatures on the road, i.e. under about 60°C, effects on the following properties are to be expected:

- structural stability under hot conditions (rutting-resistance);
- low temperature properties;
- adhesion to the aggregate.

5.1.1. Approval Testing

Approval testing of the mixes gave test values that are shown in Table 4

Table 4 Data from Approval Testing of SMA 0/11S Grades Containing 0% to 4.5% FT-Wax in Binder

Mix		Zero	A	B
Base bitumen grade		50/70		
FT-Flow improver content	[% wt.]	0	2	4.5
Optimal binder content	[% wt.]	6.5	6.2	6.1
Softening point	[°C]	50	69	90
Bulk density*	[kg/m ³]	2391	2435	2445
Void content*	[% vol.]	3.5	2.7	2.2
Void content of aggregates mix	[% vol.]	18.6	17.5	17.1
Degree of filling	[%]	80.6	84.6	87.2
Degree of compaction	[%]	100	101.8	102.7

* Marshall test sample

Based on a knowledge of conventional asphalt technology data, it can be deduced that the viscosity-reducing effects of FT-wax strongly influence bulk density, storage density of the mix and thereby the optimum binder content. Despite an equal compactibility in the Marshall test (2 x 50 blows) and lower binder content, the aggregate mix achieves a significantly higher density in storage. At the equal residual void content that is aimed for, a small binder volume still remains. However table 4 also shows that the binder content indicated as optimum for mixes A and B is still 0.3% wt. too high. If it is wished to avoid reducing the binder content due to considerations of the fatigue stability of the asphalt, which is something that is of course desirable, a more open matrix with a higher VMA (voids in the mineral aggregates) level can be chosen.

Table 4 also contains a compaction level at which the bulk density of the zero mix corresponds to 100%. Addition of FT-wax produces a 2% increase in the degree of compaction that, according to Huscek [17], leads to a 30% improvement in structural stability under warm road conditions.

5.1.2 Assessment of Compactibility by the Arand/Renken Procedure

The compactibility of an asphalt can be judged from the compaction resistance D according to Arand/Renken [18]. The compaction equation is:

$$\frac{1}{d} = a - bc^{\frac{S}{D}}$$

where

- d is the height of the Marshall test specimen;
- a, b, c are regression coefficients for the individual mix;
- S is the number of compaction blows;
- D is the compaction resistance by Arand/Renken.

The test procedure involves compacting the mix at $135 \pm 5^\circ\text{C}$. The reduction in size of the test sample is registered electronically on a continuous basis. The compaction resistance D is calculated iteratively from the compaction curve. The greater the compaction resistance D , the more difficult the mix is to compact.

Table 5 gives the D -values for a SMA 0/8 S grade, which was selected for these tests because it can be manufactured homogeneously in the laboratory.

Table 5 Compaction Resistance (Arand) for SMA 0/8

FT-Wax content	[% wt.]	0	2.0	4.5
Compaction resistance	D	41.6	39.7	33.0
Void content				
after 100 blows	[% vol.]	6.8	4.77	4.4
after 200 blows	[% vol.]	3.5	1.7	1.9

Although the D -value declines noticeably with increasing FT-wax content and, according to Renken, falls in the range of easily/moderately compactable stone mastic asphalts, the void content declines only slightly beyond 2% additive content.

Lawrence [19] has investigated the influence of FT-wax on the compactibility and resistance to deformation of rolled asphalt using the Marshall procedure. As an example, figures 9 and 10 illustrate the influence of the compaction work on the bulk density of Marshall test specimens for a 0/16 S asphalt binder with a varying FT-wax content.

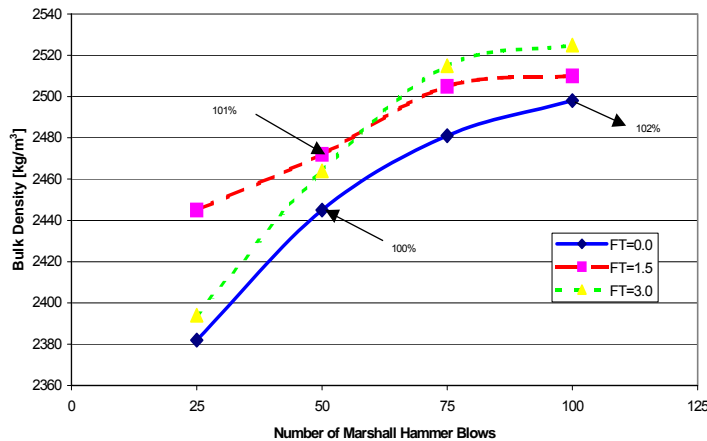


Figure 9 Effect of FT-Wax Content on Compaction of 0/16 S Asphalt Binder (50/70 Bitumen, Content 4.2%, Compaction Temperature 135°C)

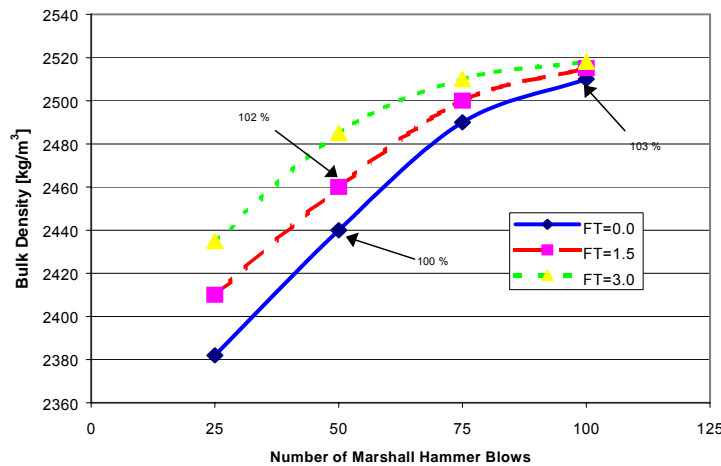


Figure 10 Effect of FT-Wax Content on Compaction of 0/16 S Asphalt Binder (50/70 Bitumen, Content 4.7% wt., Compaction Temperature 135°C)

The results emerging from this work show that:

- for asphalts that are intrinsically easily compactable, for example owing to their mix composition and/or a high binder content, asphalt flow improvers have little effect on compactibility;
- for asphalts that are difficult to compact, FT-wax is effective at contents of 1.5% wt. and above, increasing the degree of compaction by 2 – 3%;
- a FT-wax content of 3% wt. ‘replaces’ a 50% higher compaction work load;
- the Marshall stability increases with increasing FT-wax content by up to 20%. If the surface course is required to have good resistance to deformation under hot ambient conditions, a FT-wax content of 3% wt. is recommended.

5.1.3 Resistance to Deformation Under Hot Service Conditions

As previously mentioned, the flow improvers crystallise at temperatures below ca. 100°C. The exact range of crystallisation temperature is dependant on the distribution of carbon-chain length of the product. Long-chain molecules crystallise at higher, and short chain molecules at lower temperatures. Heat is released by crystallisation and can be measured by differential scanning calorimetry (DSC).

FT-wax exists in a microscopically finely-divided form in the binder at service temperatures and creates a stiffening elastic structure. The wax formations are easily recognized as light-coloured lines in electron microscope slides (figure 11).

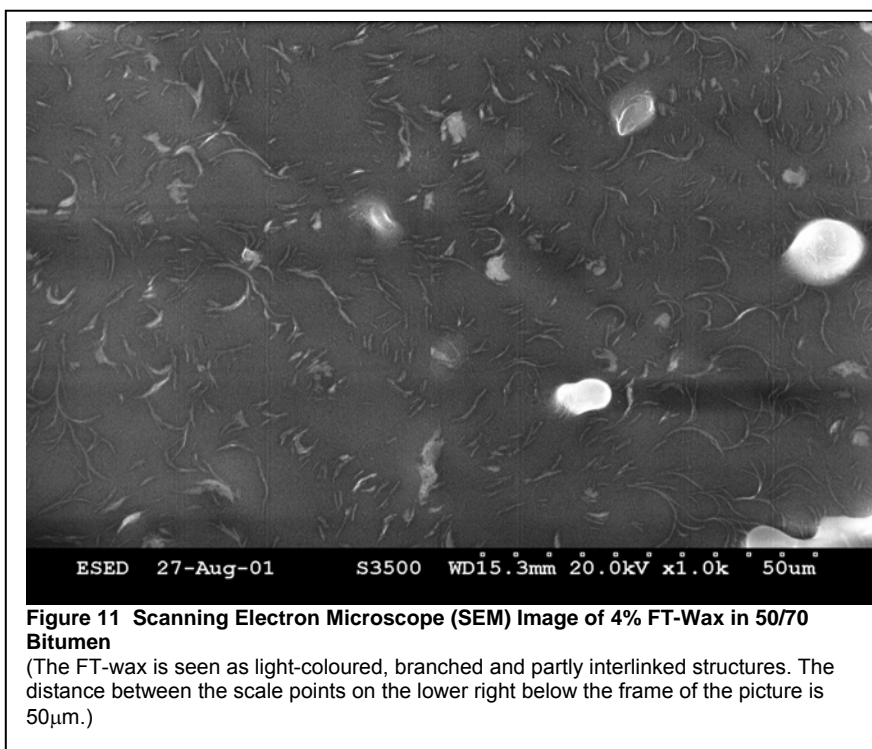


Table 6 gives the rut depths for various asphalt mix types as determined in the A-Stb Rutting Test, carried out in a water bath at 50°C and using a steel wheel with 20,000 roller passes.

Table 6 Rut Depths at 50°C for Various Asphalt Grades

Asphalt Grade	Binder Content [% wt.]	Binder Type	Softening Point [°C]	VC [% vol.]	Compaction Degree [%]	Rut Depth 50 °C [mm]
SMA 0/11 S	6.8	PMB 45 + 2 % FT	81.0	2.8	99.5	2.0
Asphalt Binder 0/22	3.9	70/100 + 4 % FT	93.0	3.2	99.6	2.4
SMA 0/8 S	6.4	50/70 + 3 % FT	81.0	3.9	99.7	2.1
SMA 0/8 S	7.0	50/70 + 3 % FT	81.0	3.2	99.9	2.2
SMA 0/8 S	7.4	50/70 + 3 % FT	81.0	2.7	100.1	2.6
SMA 0/8 S**		50/70 + 4 % FT	75.5			1.8
Asphalt Binder 0/16	4.0	160/200 + 3%FT	72.0	} 8 - 9	99.5	3.8
		160/200 + 4%FT	80.0		100.1	4.21
		160/200 + 0%FT	42.5		99.9	14.6*

*) premature failure

**) trial laid on Veddeler Damm, Hamburg

VC = void content in asphalt concrete

From experience gained by the authors and the regulatory limits specified in Hamburg and other German States, the relationship between the depths of ruts found in the rutting test and on the road may be established. Rut depths of <3.5 mm at 50°C with 20,000 roller passes in the rutting test equate in practical terms to rut depths of less than 8 mm after the equivalent of 15 million passes of a 10 ton axle load [20]. It is noteworthy in the results from the rutting test that even a soft base bitumen of 160/220 PEN modified with FT-wax has excellent structural stability under warm conditions, though this has yet to be confirmed in road trials. Binder systems of this type may be expected also to have very good low temperature properties, as discussed in 5.1.4.

Schellenberg [21] has investigated the effect of FT-wax on the warm stability of gussasphalt 0/11 using both static (at 40°C) and dynamic load indentation tests at 50°C (figures 12 and 13). This work also demonstrated the additive’s ability to produce a marked improvement in stability under hot conditions.

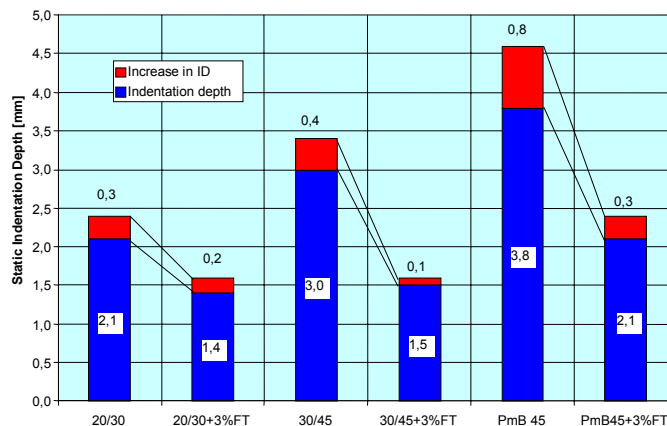


Figure 12 Static Indentation Depth (mm) at 40°C for 0/11 Gussasphalt Produced from Various Binders with/without 3% wt. FT-Wax

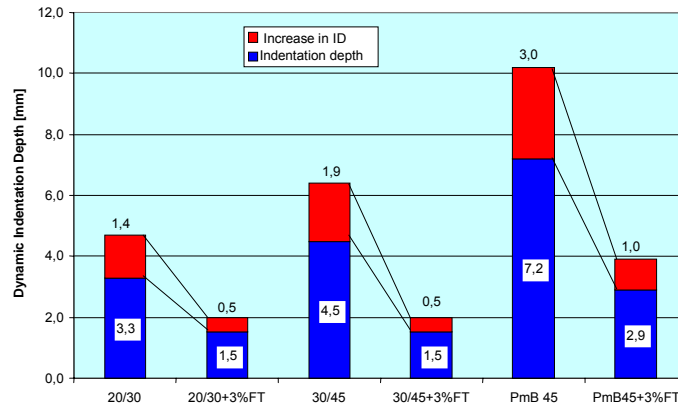


Figure 13 Dynamic Indentation Depth (mm) at 50°C for 0/11 Gussasphalt Produced from Various Binders with/without 3% wt. FT-Wax

5.1.4 Low Temperature Properties

The long-term durability of asphalts is dependent equally on both their low temperature properties and high temperatures properties.

The low temperature properties of asphalts are influenced by

- the type of binder;
- the quantity of binder;
- the particle size distribution of the aggregates.

For example, a gussasphalt despite being produced from standard 30/45 bitumen, or even 20/30, behaves quite differently from a rolled asphalt using the same binder. This is due to the 'film thickness' of the binder film surrounding the aggregate particles, as can be demonstrated in models or, more precisely, to the low temperature properties of the mastic, which comprises binder, filler and fine sand. However, the binder properties dominate in this effect.

In the climatic conditions of central Europe there is absolutely no point in achieving good stability under hot service conditions by using a hard bitumen if the surface suffers contraction cracking or fatigue cracking due to high traffic loads at low temperatures in winter. Crack development in pavements on bridges is particularly dangerous because this allows water penetration that may severely damage the bridge structure, especially when it contains anti-icing salt.

Therefore if one wants to make statements about the low temperature properties of asphalts, it is not sufficient for a basic evaluation, as in the case just described, to consider solely the binder properties. Instead it is essential to carry out cold tests on the asphalt.

Two test methods are available for characterising the low temperature properties of bitumen: the Fraass breaking point and procedures involving the bending beam rheometer.

Table 7 contains laboratory data from research undertaken by Rahiminian and Butz [7]. The data show that when 4% FT-wax is added to the bitumen, the low temperature properties of the binders worsen slightly, although within test repeatability. The FT-wax content should therefore not exceed 4% wt. for this reason and also because of the effect on adhesion, as discussed below in 5.1.5.

Table 7 Binder Properties for Different Bitumen Sources with/without 4% FT-Wax

Bitumen Source	0% FT-Wax			4 % FT-Wax		Asphaltene Content	Wax Content *
	SP [°C]	PEN	Fraass BP [°C]	Fraass BP [°C]	[%]	[%]	
160/220	41	156	-16.5	-12	13	-	
Russia	52	65	-11	-13	20.6	2.8	
Middle East	48	72	-18	-12	19.1	1.8	
Venezuela	47	77	-12	-9	15.5	0.1	
China	49	85	-13	-14	17.9	1.7	

* Bituminous wax

Schellenberg and Damm [15] have carried out cooling tests on asphalts by the Arand method. This involves subjecting a rigidly mounted test specimen to a prescribed rate of cooling until it fractures under the strain. The results (see table 8) show that the cold properties of the asphalt are dominated by the properties of the base bitumen.

Table 8 Break Point and Maximum Thermal Tension Data from Cooling Tests at 10°C/h Conducted on SMA 0/8 S and AC 0/16 S with Various Binders

Asphalt Grade	Binder	Fracture Temperature [°C]	Max. Thermally Induced Tension [N/mm ²]
SMA 0/8	50/70	-25.4	4.273
	70/100 + 2% FT	-24.4	4.287
	70/100 + 3% FT	-24.4	4.235
	160/220 + 2% FT	-30.7	4.186
	160/220 + 3% FT	-30.6	4.265
SMA 0/8	PMB 80 + 2 % FT	-32.2	5.070
	PMB 80 + 3% FT	-32.8	5.069
Asphalt Binder 0/16	70/100 + 2% FT	-25.1	4.848
	70/100 + 3% FT	-24.9	4.692
Asphalt Binder 0/16	PMB 25	-20.3	4.421

In practice, the fracture temperatures shown in this table may be reduced by 10°C before thermally induced cracking is likely to appear.

Schellenberg also investigated the cold temperature behaviour of gussasphalt samples GA 0/11

compounded with the binders 20/30 bitumen, 30/45 bitumen and PMB 45 with and without 3% wt. FT-wax. The results are presented in figure 14.

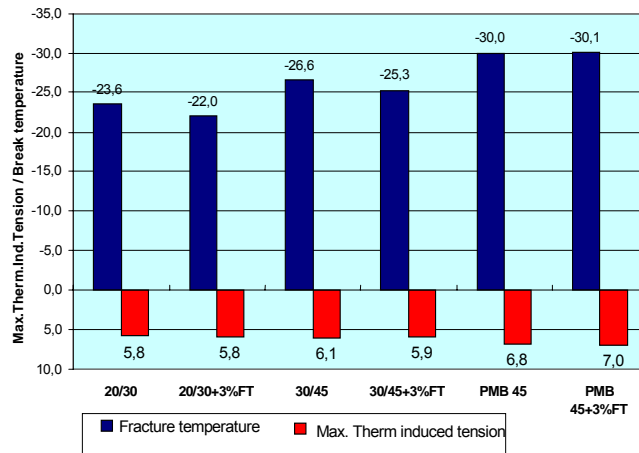


Figure 14 Fracture temperature and max thermally induced tension for 0/11 Gussasphalt with Various Binders in Cooling Tests at 10°C/h

The following conclusions can be drawn from the cooling tests and the accompanying stability testing under hot conditions:

- the base bitumen has a dominant influence on the cold properties;
- this is equally valid for both rolled asphalt and gussasphalt;
- when hard bitumen, e.g. 20/30 grade, is additivated, the stability at high service temperatures and the cold properties have to be balanced against each other; additivation is recommended if low temperatures may be experienced during laying and/or improved handling properties are desired;
- additivation of PMB with flow improver is sensible in view of the improvement in handling properties.

Schellenberg [21] was able to establish that the information acquired in the cooling tests was also corroborated after the gussasphalt samples had been stored over 50 days at -20°C , conditions under which any delayed transformation in the structure of the binder matrix would have had time to take place.

In order to assess these sterical hardening or physical hardening effects for other binders, further experiments are considered necessary.

5.1.5 Adhesion Properties [15]

The effect of water on the strength of asphalt is determined by means of an indirect tension test at $+5^{\circ}\text{C}$ on a sample immersed in water. The cross-sectional expansion is measured and from that the tensile splitting E-modulus calculated [figure 15].

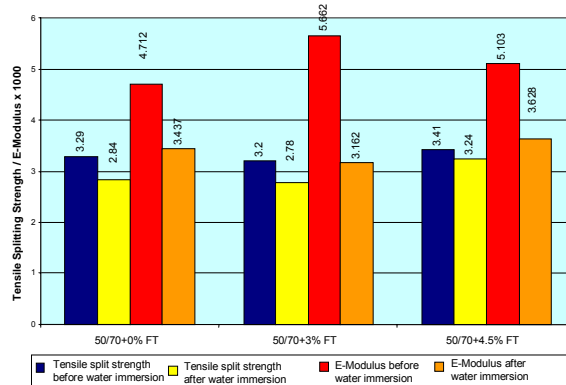


Figure 15 Splitting Tensile Strength and E-Modulus Before and After 96 h Storage Under Water

In order to achieve a satisfactory void content in the Marshall test specimen, a low binder content of 5.7% wt. was chosen. The effect of adding FT-wax is not shown by the decrease in tensile splitting strength, which remains relatively unaffected by water immersion, but rather by the tensile-E-modulus. Therefore, in consideration of adhesion, a FT-wax content of over 3% wt. is not recommended without first testing the adhesive properties of the aggregate employed.

5.2 Asphalts Modified with Romontan Additives

The use of Romonta N in gussasphalt 0/11 S is already widely practised in Germany. At a treatment level of 1.5 to 2.0% wt. based on the binder quantity, the laying temperature, which lies in the range 210°C to 240°C, can be reduced by about 20°C without adverse effect on workability. A similar effect is produced with a gussasphalt cement made from 0/8 mm and hard bitumen. Increasing the Romontan wax content beyond 2% wt. brings little further improvement in properties [22].

The compaction resistance *D* in the Arand test was determined for an asphalt binder 0/22 S that was difficult to compact. This material, comprising 72% wt. of aggregate greater than 2 mm and 4.0% wt. binder (PMB 45), was modified with various levels of wax. In addition to the *D*-value, the average rut depth was determined after 19,200 roller passes at 50°C in the rutting test (steel wheel, water immersion) [23]. The results are given in table 10.

Table 10 Influence of Romonta N Content on the Compaction Resistance and Average Rut Depth of Asphalt Binder 0/22 S Containing PMB 25

Romonta Content [% wt.]	Compaction Resistance <i>D</i>	Average Rut Depth [mm]
0	41.6	3.1
1.5	33.8	2.7
3.0	35.3	2.8
4.5	-	2.2

The compaction resistance falls sharply even when just 1.5% Romonta is used.

Experience has been gained from trials laid with Asphaltan B mixes. Figure 16 shows the development of compaction resistance for an asphalt binder 0/22 S with 50/70 PEN bitumen compared to a binder containing PMB 45 plus varying levels of Asphaltan B [24]. As the additive content increases the asphalt becomes gradually more amenable to compaction.

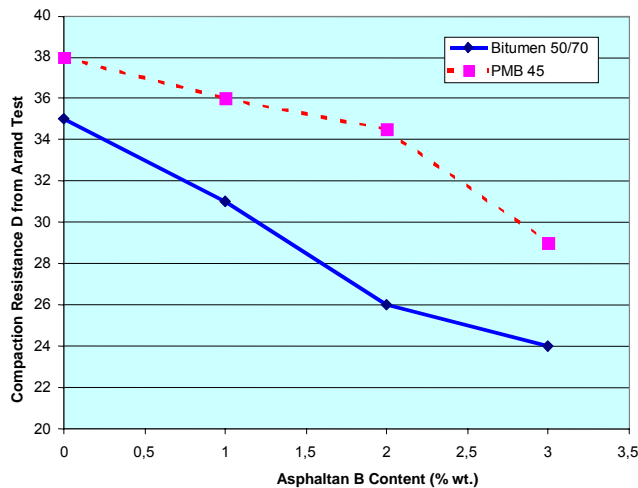


Figure 16 Compaction Resistance by Arand Test for Asphalt Binder 0/22 S with Varying Asphaltan B Content

The compaction resistance of an asphaltic concrete 0/11 S was reduced by addition of only 2% wt. Asphaltan B. Figure 17 shows the increase in structural stability under warm service conditions (50°C) of asphaltic concrete 0/11 S mixed with 50/70 bitumen with and without Asphaltan B [28].

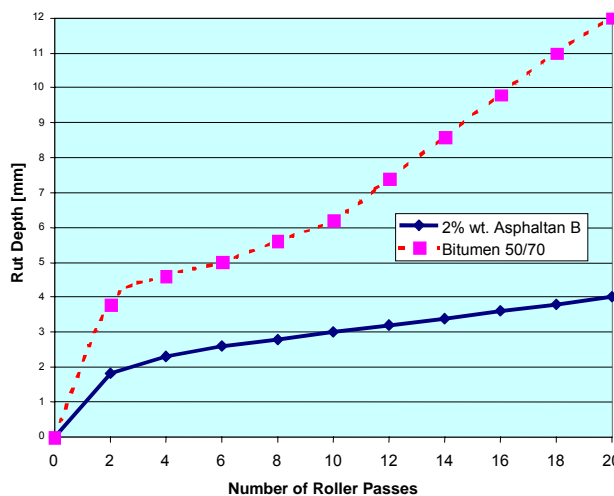


Figure 17 Rutting Test Results at 50°C for Asphaltic Concrete 0/11 S with/without Asphaltan

Comparative investigations of a stone mastic asphalt 0/11 S compounded both with PMB 45 and a standard bitumen with Asphaltan B were carried out by the PEBA Test Institute, Berlin, in connection with the road trial on highway L217 Klosterwalde – Jakobshagen in Germany [24]. The void content, 2.0% volume, of the Asphaltan B mixes corresponded to a compaction rating of 101.2%, while the asphalt top coating compounded with PMB 45 had a void content of 3.2% volume at 100.0% compaction grade. This shows the favourable compactibility produced when Asphaltan is used.

The skid resistance properties of surface courses continue to attract close attention, especially stone mastic surfaces. Grip tests carried out with the SCRIM grip-tester machine 6 weeks after a section was laid with SMA surface course modified with Asphaltan showed a significantly improved level of skid resistance. The limit value for skid resistance according to German road construction standard Stb 94/98 ($\mu_{\text{SCRIM}} = 0.53$ at 60 km/h) was achieved throughout the entire section. This result confirms that, contrary to popular opinion, paraffins and waxes do not adversely affect skid resistance.

6 Practical Experiences with FT-Wax

6.1 Trial Section Laid on Veddeler Damm, Hamburg

The first trial stretch of asphalts produced with binders containing FT-wax was laid in Hamburg on the Veddeler Damm in 1997. This is a heavily loaded highway in the Hamburg Free Port, classified as Construction Class SV (meaning heavy traffic). Before repair, the road section, which comprises two exit lanes on the approach to traffic lights, had developed ruts up to 5 cm deep. In the renewal of the surface, the binder course that was installed comprised an 8.5 cm thick layer of asphalt binder 0/22 S. This was then topped with a 3.5 cm course of stone mastic asphalt 0/8 S. The binder used for both courses was a pre-blended mix of 50/70 PEN bitumen with 4% FT-wax.

The technical data of the asphalts are listed in table 11 [25, 26].

Table 11 Technical data of the asphalts from the quality control tests of the trial stretch "Veddeler Damm"

	Asphalt Binder 0/22 S	SMA 0/8 S
Binder content [Wt. %]	3.6	6.7
Softening point R&B [°C]	91.5	75.5
Fraas break point [°C]	-7.0	-9.5
Void content [Vol. %]	6.0	3.5
Degree of compaction [%]	101.9	99.4
Rut depth at 50°C [mm]	1.9	4.3

The following conclusions can be drawn from the data:

- a high degree of compaction was attained;
- the rut depths in the rutting test at 50°C show that both courses are stable or very stable.

After 4 years in service, the trial section exhibits rut depths from 2 mm to a maximum of 6 mm. Owing to the extremely high traffic loading to which the section is subjected, these results are considered satisfactory. In all other respects, the section is completely undamaged.

6.1.1 Temperature Reduction

During the course of laying the Veddeler Damm trial, density measurements were carried out by Troxler gamma-ray probe on the asphalt binder 0/22. Figure 18 shows the relationship between the measured densities, the temperature of the asphalt mix and the number of roller passes [26].

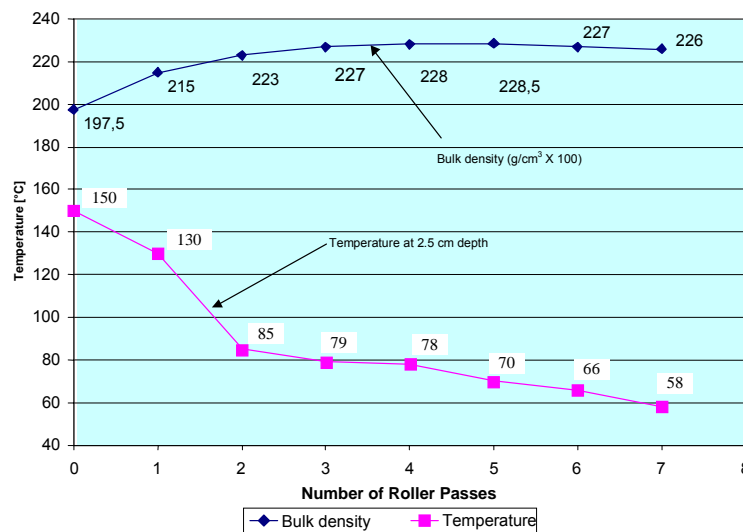


Figure 18 Change of Course Temperature and Bulk Density with Number of Roller Passes

The data show that the asphalt mix behind the laying machine had a temperature of 150°C. Even at a temperature as low as 100°C, an increase in density can clearly be detected by the measurements. This could also be seen from observations:- the mix visibly moved under the finishing machine. Above 8 rollings and at temperatures below ca. 80°C, there is a danger that the structure of the laid course might be destroyed. From the experience gained here, Damm made the following recommendations whose validity has since been confirmed in several other construction works:

- the asphalt mix temperature should not exceed 150°C on delivery;
- the compaction must be completed by about 90°C at the latest;
- rubber-wheeled rollers should not be used since they can result in binder being squeezed to the surface;
- when vibration rollers are used, not more than 2 passes should be given; special care must be taken at high ambient temperatures to avoid over-compaction;
- in approval testing, the greater storage density of the heaped aggregate must be taken into account; either reduce the binder content by 0.3% wt. or select a more 'open' particle size distribution.

6.2 Further Practical Experience

In the meantime, about 2 million square metres of asphalt coatings, equating to 300,000 tons asphalt containing FT-wax flow improver, have been successfully laid. The sections include the highly loaded container depot at Burchard Quay, Hamburg. This contains a lorry loading lane handling about 1000 lorries a day. The bay has been re-surfaced with 10 cm of asphalt binder 0/16 and 4 cm of SMA 0/11 S, using 50/70 PEN bitumen with PMB + 4% FT-wax. The section remains completely free from ruts after 2 years in service. The runways at Hamburg Airport were renewed with asphalt manufactured from 50/70 bitumen containing 3% wt. FT-wax. In this instance, 5,000 m² of asphalt binder 0/16 mm and 45,000 m² of stone mastic asphalt 0/11 S were laid under an extremely tight time schedule at mix temperatures ranging from 140°C to 155°C.

The compaction that was achieved throughout was 98.3% to 99.6%. The rutting tests conducted in the course of quality control testing gave results for both courses of <3.5 mm at 50°C, confirmation that this new technology has matured from its infancy and now opens new perspectives for asphalt construction.

Several other construction projects have been carried out in which the binder was PMB 65A with 3% wt. FT-wax, including the A1-motorway intersection at Hamburg-Maschen (2 cm thin asphalt coating, laid hot). At a waste disposal site at Neuhöferdeich, Hamburg, where containers are stacked, 30/45 bitumen with 3% wt. FT-wax was employed. The construction comprised 8 cm of asphalt binder 0/16 mm, 4 cm stone mastic asphalt 0/11 mm, with void content in the compacted state of less than 3% volume, which is classified as water impermeable. In all cases the compaction grade of the surface exceeded 98%, even under unfavourable weather conditions. Rutting tests showed a very high stability of the asphalts even at 60°C, i.e. 10°C above the standard test temperature. In the case of the high level bridge crossing over the Friedrich Valley on the A8 motorway, stone mastic asphalt 0/8 mm was successfully applied using PMB 45 plus 3% FT-wax.

7 Looking to the Future

Like it or not, the terms 'paraffin' and 'wax' used in the context of bitumen quality tend to create a negative image for many people. Waxes are now used world-wide as asphalt flow improvers and could be termed 'low molecular weight polymers'. Certainly this is a reasonable description of FT-wax and Romontan wax considering their molecular weight and structure. It should be emphasised that the majority of road works laid with these materials involved works-blended SMB 45 (70/100 bitumen + 3% wt. FT-wax) or SMB 35 (50/70 bitumen + 3% wt. FT-wax), using bitumen from a single crude oil source. Further research is required to confirm the success of these applications in products derived from other crude oil sources.

Using asphalt flow improvers it seems possible to achieve the concept of the 'ideal binder' [27], which is represented in figure 19.

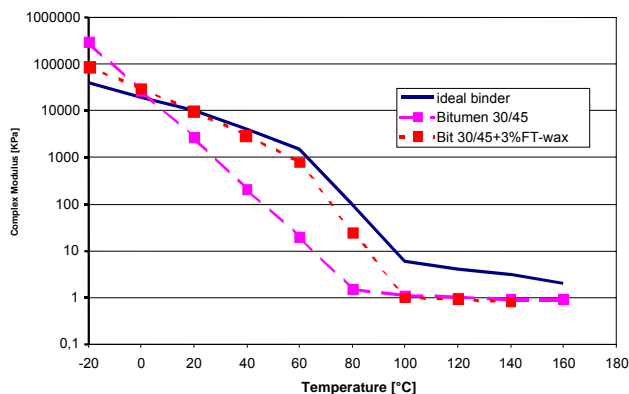


Figure 19 Plots of Temperature-Stiffness Graphs for an Ideal Bitumen [see 27], 30/45 Bitumen and 35/45 + 3% FT-Wax

Asphalt flow improvers offer the opportunity not just of reducing the mixing temperature of asphalts to a significant degree in order to extend the time available for compaction, which in turn reduces the installation risks. They also allow asphalts to be conceived that, especially with reference to their resistance to deformation under warm service conditions, will be able to withstand the increased traffic loadings forecast for the future without rutting, while at the same time resisting low-temperature cracking.

To achieve this goal the asphalt flow improver could be compounded with very hard PMB 25, which can now play a special role due to the ease of laying that the additive provides.

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Recommended Applications for SmB 25

SmB 25 is a ready-to-use bituminous binder with excellent storage stability.

We recommend SmB 25 for the following applications:

THE SUCCESS FORMULA FOR BETTER ASPHALT



Duty	Road Classification	Asphalt Binder 0/16 S + 0/22 S	SMA / AC 0/8 S + 0/11 S	Gussasphalt 0/5, 0/8 S, 0/11 S
Heavy	SV, I + II	SmB 25	SmB 25	SmB 25 *
Special	III	SmB 25	./.	SmB 25 *
Normal	IV und V	./.	./.	SmB 25

* It is technically better to modify B20/30 with SASOBIT® in order to achieve a lower depth of indentation as well as an additional depth of indentation

The choice of binder depends on case specific deformation resistance performance tests and low temperature behaviour performance tests

Technical Specifications for SASOBIT®-modified Bitumen (SmB) for Hot Mix:

Properties	Test Method	SmB 25
Penetration at 25°C (0,1 mm)	EN 1426	20 – 35
Softening Point Ring and Ball (°C)	EN 1427	80 – 90
Fraass Breaking Point Max. (°C)	EN 12593	- 5
Resistance to Hardening	EN 12607-3	
Change in Mass Max. (%)		0.5
Remaining Penetration Min. %		60
Increase of Softening Point Max. (°C)		6.5
Softening Point after Hardening Min. (°C)		80
Flash Point Min. (°C)	EN 22592	240
Stability against Separation Max. (°C)	EN 1427 Appendix A	2
Deformation Resistance DSR at 60° G* min. Pa δ max. °	AASHTO TP 5	12,000 70

Recommended Applications for SmB 35

SmB 35 is a ready-to-use bituminous binder with excellent storage stability.

We recommend SmB 35 for the following applications:

THE SUCCESS FORMULA FOR BETTER ASPHALT



Duty	Road Classification	Asphalt Binder 0/16 S + 0/22 S	SMA / AC 0/8 S + 0/11 S
special	II and III	SmB 35	SmB 35
normal	IV und V	SmB 35	SmB 35

The choice of binder depends on case specific deformation resistance performance tests and low temperature behaviour performance tests

Technical Specifications for SASOBIT®-modified Bitumen (SmB) for Hot Mix:

Properties	Test Method	SmB 35
Penetration at 25°C (0,1 mm)	EN 1426	30 - 50
Softening Point Ring and Ball (°C)	EN 1427	75 – 85
Fraass Breaking Point Max. (°C)	EN 12593	- 8
Resistance to Hardening	EN 12607-3	
Change in Mass Max. (%)		0.5
Remaining Penetration Min. %		60
Increase of Softening Point Max. (°C)		6.5
Softening Point after Hardening Min. (°C)		75
Flash Point Min. (°C)	EN 22592	230
Stability against Separation Max. (°C)	EN 1427 Appendix	2
Deformation Resistance DSR at 60° G* min. Pa δ max. °	AASHTO TP 5	5,000 80

Advice for the Application of SASOBIT[®] in Gussasphalt

Influence of SASOBIT[®] on Gussasphalt:

THE SUCCESS FORMULA FOR BETTER ASPHALT

- Reduction of the working temperature by 20-30°C
- Reduction of the indentation depth

SASOBIT
modified

To achieve these goals successfully the following points must be observed:

- 1.) To achieve an optimal temperature reduction we recommend a SASOBIT[®] content of 3.0 wt.-% of the binder in addition to the normal binder.
- 2.) Because the addition of SASOBIT[®] increases the ring and ball softening point we recommend the addition of 10 wt.-% B30/45 when manufacturing gussasphalt screed with hard bitumen in order to ensure optimal processing also in the low temperature range.
- 3.) For these two principles to be successful, laboratory tests are essential for the preliminary trials. With regard to the bitumen/filler system in gussasphalt there is a tendency for the components to interact which is, however, not specific to SASOBIT[®] and as such cannot be generalised. It is, therefore, necessary to take this aspect into account and to check this from case to case. This is particularly so for mixing plants where the filler is not pre-warmed. Trials have shown that a suitable dosage lies between 2,5 and 3,5 wt.-%.
- 4.) Good results have also been achieved with the addition of SASOBIT[®] to gussasphalt used for road construction produced with PMB 45 and PMB 25, in particular for the construction of bridge surfaces. The resultant reduction in viscosity has a positive effect on the manufacturing and working temperatures. In the preliminary trial stages we further recommend carrying out tests that exceed the usual heat stability and low temperature behaviour requirements.
- 5.) We have also had excellent results when adding SASOBIT[®] to gussasphalt used for road construction produced with B 30/45 and B 20/30. With regard to the indentation depth the gussasphalt produced with B 30/45 + SASOBIT[®] is similar to that of gussasphalt produced with B20/30 + SASOBIT[®].
- 6.) When adding SASOBIT[®] to gussasphalt numerous projects have shown that it is advantageous to use a modern boiler that not only measures the temperature accurately but also determines the pressure the stirrer needs to mix the asphalt. In order to constantly achieve optimal results we recommend using the pressure readings as an orientation before and after the addition of SASOBIT[®]. The amount of pressure is dependant on the boiler construction, the stirrer – vertical or horizontal -, rotational speed, amount of paddles on stirrer as well as the general condition of the boiler.

- 7.) In the case of gussasphalt where, due to the addition of SASOBIT[®], the temperature has been reduced we advise that the boiler has a lead-sealed temperature regulator that only authorised personnel may adjust. Due to the risk of separation it is detrimental for a low temperature gussasphalt with a range of 220-230°C to be heated to a temperature of 250-260°C.

Advice regarding the addition of SASOBIT[®] to gussasphalt

Addition to the boiler:

- 1.) Best results have been achieved by adding SASOBIT[®] directly to the boiler. 20 kg of SASOBIT[®] in a 10 t boiler are required by an average binder content of 6.8 – 7 wt.-%. The slit or opened PE bag of SASOBIT[®] should be added after the third batch of gussasphalt. We do not recommend adding SASOBIT[®] at the end, after the last batch, as in this case a rapid homogenisation cannot be guaranteed with a vertical stirrer.
- 2.) Sasol Wax also offers SASOBIT[®] in 2 kg to 4 kg PE bags for ease of dosage.

Addition to the mixer:

- 3.) Should SASOBIT[®] be added directly to the mixer during the production of gussasphalt it is essential that this takes place *after* the addition of the filler and bitumen. Otherwise the functions of SASOBIT[®] could be impaired due to contact with the extremely hot aggregates.
- 4.) We recommend adding SASOBIT[®] using the melting system developed by ATS (Fayat Group) and the pre-blending system from LT Linnhoff. The company Ingenieur-Gesellschaft G&P have developed a jet mixer to allow inline dosage of SASOBIT[®] pastilles to the bitumen stream.

Our experiences since 1997 have confirmed to us that under compliance of these points gussasphalt will once more gain significance and indeed, we are convinced, experience a renaissance.

Roads and Trials with SASOBIT®

October 2005

Location	Year	Country	AC Binding Course	AC Wearing Course	Project size m2	Binder used
BUNA	2005	DE		SMA 0/11 S	19 000	SmB 35
B 93, Wiesen	2005	DE		SMA 0/11 S	13 200	SmB 35
B 171, Sayda	2005	DE		SMA 0/8 S	30 000	SmB 35
B 92, north. Plauen	2005	DE	Abi 0/16 S	SMA 0/8 S	6 000 37 000	SmB 35
B 282 Syrau	2005	DE	Abi 0/22 S	SMA 0/8 S	26 000 17 000	SmB 35
Container Terminal Eurogate, Hamburg	2005	DE	Abi 0/22 (inkl. 50% Recycling)	AB 0/8 (inkl. 20% Recycling)	50 000	B 50/70 + 4% SASOBIT Nypol 25 HR inkl. SASOBIT
Bridge Road Surface, BAB A9 Talbrücke Lanzendorf	2005	DE	GA 0/11 S SS	GA 0/11 S DS	66 000	PmB 45 + 3% SASOBIT
Bridge Road Surface, BAB A6 Talbrücke Unterrieden	2005	DE	GA 0/11 S SS		9 000	PmB 45 + 3% SASOBIT
Bridge Road Surface, BAB A9 Alpebachtalbrücke	2005	DE	GA 0/11 S SS	GA 0/11 S DS	16 000	PmB 45 + 3% SASOBIT
Uelzen, Fa. Tengemann	2005	DE		SMA 0/8 S	5 000	SmB 35
Stade, EADS Airbus	2005	DE	ATS CS 0/32 Abi 0/16 S	SMA 0/8 S	4 000	SmB 35 PmB + Sasobit
Winsen Luhe, Fa. Feldbinder	2005	DE		TDS 0/16	2 500	SmB 35
Häcklingen, Roundabout	2005	DE	Abi 0/16	SMA 0/8 S	2 000	SmB 35
Airport Linz-Hörsching	2005	AUT	BT 22 HS BT 22	pmAB 16 AB 16	50 000	PmB 50/90S NV 70/100 NV
B37, Gföhl Ost	2005	AUT		pmAB 16	5 000	PmB 50/90S NV
Mündle Satteins	2005	AUT	BT 22		3 600	70/100 NV
ÖBB Train Station Wolfurt, 1.	2005	AUT		pmAB 16	7 000	PmB 50/90S NV
ÖBB Train Station Wolfurt, 2.	2005	AUT		pmAB 16	10 000	PmB 50/90S NV
Dellacher Rampen Wolfurt	2005	AUT	BT 22 HS BT 22		1 200 1 200	PmB 50/90S NV
Mountains Region Ladestrassen Sanierung	2005	AUT		pmAB 11	5 000	PmB 50/90S NV
L 202, Bregenz	2005	AUT		DDH 8	6 700	PmB 50/90S NV
Roundabout City Center Wörgl	2005	AUT		AB 11	2 900	70/100 NV
Works Road Cement Factory Eiberg	2005	AUT	BT 16		1 000	70/100 NV
Works Ground Fa. Pfeiffer	2005	AUT	BT 22 HS BT 32		1 300 2 000	70/100 NV 70/100 NV
Works Ground Fa. Wimpissinger	2005	AUT	BT 32		1 500	70/100 NV
Spodnjibrnik - Moste	2005	SI	BT 0/16 S BT 0/22 S	AB 0/11 S	1 800	50/70 +3% SASOBIT
Laze	2005	SI	Abi 0/22	SMA 0/8	1 000	50/70 + 3% SASOBIT Olexobit 45 +3% SASOBIT
Container Terminal Tollerort (TCT), Hamburg	2004	DE	Abi 0/16 S	SMA 0/16	70 000	PmB 25 RC + 4% SASOBIT
Airport Berlin Schönefeld	2004	DE	Abi 0/16 S	Antiskid overlay	135 000	PmB 45 + 3% SASOBIT
Airbus Terminal Finkenwerder, Hamburg	2004	DE		AB 0/11 S	96 000	PmB 45 +2,5% SASOBIT
Access Road Supermarket, Bamberg	2004	DE		SMA 0/11 S	10 000	SmB 35 (50/70 + SasoCell)
BAB A93, Regensburg - Hof	2004	DE		SMA 0/11 S	10 000	Olexobit 45 NV
Roundabout Fürth	2004	DE	Abi 0/16 S	SMA 0/11 S	6 000 6 000	SmB 35 SmB 35 (50/70 + SasoCell)
B92, Plauen - Ölsnitz	2004	DE		SMA 0/11 S	10 000	SmB 35

Roads and Trials with SASOBIT®

October 2005

Location	Year	Country	AC Binding Course	AC Wearing Course	Project size m2	Binder used
B 92, south. Plauen	2004	DE		SMA 0/8 S	16 500	SmB 35
B 283, OD Klingenthal	2004	DE		SMA 0/8 S	14 000	SmB 35
B 169, OD Stützengrün	2004	DE		SMA 0/8 S	4 800	SmB 35
OD Frauenreuth (Sachsen)	2004	DE	Abi 0/16 S	SMA 0/11 S	3 000	SmB 35
B31, Donaueschingen	2004	DE		SMA 0/11 S	45 000	Olexobit 45 NV
BAB A99, Kirchheim - Ottobrunn	2004	DE		SMA 0/11 S	30 000	Olexobit 45 NV
NL Coca Cola, Landshut	2004	DE		AB 0/11 S	3 000	Olexobit 25 NV
Logistic Center Straubing	2004	DE		AB 0/11 S	8 000	Olexobit 25 NV
Storage Gienger Com. Markt Schwaben	2004	DE		AB 0/11 S	8 500	Olexobit 45 NV
Official Building Schweinfurt	2004	DE		GA 0/8 S GA 0/11 S	2 000	Olexobit 45 NV
Berlin, Wilhelmstraße	2004	DE		AB 0/8 S	3 600	SmB 35
Wustermark, Containerterminal	2004	DE		AB 0/16 S	2 500	PmB 25 + 3% SASOBIT
L17, Warsow - Jagnberge	2004	DE		AB 0/8	10 000	SmB 45
Berlin, Emmentaler Straße	2004	DE	Abi 0/16 S	SMA 0/8 S	2 000	SmB 35 PmB 45 + 3% SASOBIT
Neuseddin, K 6907	2004	DE	Abi 0/16	AB 0/11 S	2 000	SmB 35
Berlin, Messedamm	2004	DE		SMA 0/11	15 000	PmB 45 + 3% SASOBIT
Berlin, Freiheit 2. Bauabschnitt	2004	DE	Abi 0/16 RC	SMA 0/11 S	4 000	PmB 25 + 3% SASOBIT
Bridge Road Surface BAB A9 Rope Bridge Kinding	2004	DE	GA 0/11 S SS	GA 0/11 S DS	24 000	PmB 45 + 3% SASOBIT
Bridge Road Surface BAB A17 Müglitztalbrücke	2004	DE	GA 0/11 S SS	GA 0/11 S DS	14 000	PmB 45 + 3% SASOBIT
Bridge Road Surface BAB A 71 Lauerbachtalbrücke	2004	DE	GA 0/11 S SS	GA 0/11 S DS	14 500	PmB 45 + 3% SASOBIT
Bridge Road Surface BAB A10 Havelbrücke Werde	2004	DE	GA 0/11 S SS	GA 0/11 S DS	20 000	PmB 45 + 3% SASOBIT
Bridge Road Surface BAB A 9 Hienbergbrücke	2004	DE	GA 0/11 S SS		40 000	PmB 45 + 3% SASOBIT
Bridge Road Surface BAB A 81 Rötsteinbrücke	2004	DE	GA 0/11 S SS	GA 0/11 S DS	18 600	PmB 45 + 3% SASOBIT
Bridge Road Surface BAB A 93 Waldnaabbrücke	2004	DE	GA 0/11 S SS	GA 0/11 S DS	8 000	PmB 45 + 3% SASOBIT
Access Way Hamburg KAM	2004	DE		TDS 0/22	5 000	PmB 25 + 2% SASOBIT
Bituminous Surfacing Hamburg KAM	2004	DE	ATS 0/22 RC	TDS 0/16 RC	5 000	SmB 45 B 70/100
Roundabout, Rankweil	2004	AUT		SMA 0/11 S	5 500	50/90 SNV
Busterminus Rankweil	2004	AUT	BT 16		1 900	70/100 NV
Mähr, Feldkirch	2004	AUT	BT 22		1 200	70/100 NV
L188 Gortipohl	2004	AUT		AB 16	9 500	70/100 NV
Vögel, Gais	2004	AUT	BT 16		7 000	70/100 NV
Battloggsstrasse, Schruns	2004	AUT	BT 32		3 000	70/100 NV
L 188, St. Anton	2004	AUT		DDH 8	10 000	PmB 50/90S NV
L 188, St. Anton- Montafon	2004	AUT	BT 16	DSH	12 000 10 000	50/70 NV 50/90 SNV

Roads and Trials with SASOBIT®

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Location	Year	Country	AC Binding Course	AC Wearing Course	Project size m2	Binder used
Forwarding Agent Vögel, Nenzing	2004	AUT	BT16/ BT32 S		14 500 14 500	50/70 NV
L 314 Fernpaßstraße, Tirol	2004	AUT		SMA 0/11 S	10 000	Olexobit 45 NV
Forwarding Agent Grounds Feldkirch	2004	AUT		AB 0/16 S	2 000	50/70 NV
NL Daimler Chrysler, Klagenfurt	2004	AUT		AB 0/16 S	4 000	Olexobit 45 V
Containergate Wolfurt	2004	AUT	Asphalt binder 0/16S	AB 0/16 S	20 000	50/70 NV
Heavy Traffic Road, Perak	2004	MY		SMA	35 000	PmB 45 + 3% Sasobit
NS Expressway	2004	MY		SMA	40 000	SMB 35
Bridge Road Surface Shanghai	2004	CN	GA-SS		6 500	PmB + Sasobit
Trial Road Jiangsu	2004	CN		SMA	30 000	AH 70 + 3% Sasobit
Bridge Road Surface Guangxi	2004	CN		SMA	5 000	PmB + Sasobit
Fujian	2004	CN		Asphalt binder	8 000	AH 70 + 3% SASOBIT
N3 Ashburton	2004	ZA		18 mm DSH	2 500	B 60/70 + 3% Sasobit
P385 Hammersdale	2004	ZA		Med. Cont. Grade	3 500	B 60/70 + 3% Sasobit
N1 Du Toitskloof Pass	2004	ZA		Med. Cont. Grade	4 000	B 60/70 + 3% Sasobit
N4 Witbank	2004	ZA		Med. Cont. Grade	140 000	B 60/70 + 3% Sasobit
South Coast Road	2004	ZA		Med. Cont. Grade	12 000	B 60/70 + 3% Sasobit
M4 Southern Highway	2004	ZA		Med. Cont. Grade	60 000	B 60/70 + 3% Sasobit
K 103 Rigel Road	2004	ZA		Med. Cont. Grade	7 000	B 60/70 + 3% Sasobit
K 69 Hans Strijdom	2004	ZA		Med. Cont. Grade	15 000	B 60/70 + 3% Sasobit
L53 Tangerhütte, Saxony-Anhalt (B-Road)	2003	DE		SMA 0/8 S	55000	SmB 35
Nordzucker, Uelzen	2003	DE	Asphalt binder 0/16 S	SMA 0/8 S	30000	SmB 35
Röhrs, Soltau	2003	DE		SMA 0/8 S	500	SmB 35
Moscow	2003	RU		GA 0/11 S	8000	SmB 35
A25 Hamburg (Motorway)	2003	DE	Asphalt binder 0/16 S	SMA 0/8 S	25000	Caribit 25 RC + 1,5% Sasobit Caribit 45 + 1,5% Sasobit
Fraport Runway North, Frankfurt	2003	DE	ATS CS 0/32 Asphalt binder 0/22 S	SMA 0/11 S	50000 50000	Caribit 25 RC + 4% Sasobit Caribit 25/Caribit 45 + 4% Sasobit
Recklinhausen, K5, Haltern AiF Research Project	2003	DE		AB 0/11 NT	6000	Nytemp 30/45
OD Hohn, Schleswig-Holstein Trial Road	2003	DE		AB 0/11 S NT	14000	SmB 35
Freiheit, Berlin	2003	DE	Asphalt binder 0/16 S	SMA 0/11 S	16000	PmB 25 + 3% Sasobit
Urban Road, Wolfsburg	2003	DE		SMA 0/8	30000	SmB 35
A7, Hamburg Elbe Tunnel (Motorway)	2003	DE		SMA 0/8 S	2000	SmB 35
Hamburg Airport Runway	2003	DE		SMA 0/11 S	100000	SmB 35
Railtrack Foundation, Dresden	2003	DE		GA 0/11 S	5000	PmB 45 + 3% Sasobit
L 1086, Mohlsdorf	2003	DE	Abi 0/16 S	SMA 0/8 S	8 500 5 100	SmB 35
S 317, OD Fraureuth	2003	DE	Abi 0/16 S	SMA 0/11 S	3 500 3 000	SmB 35

Roads and Trials with SASOBIT®

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Location	Year	Country	AC Binding Course	AC Wearing Course	Project size m2	Binder used
S 289 Mißlareuth, Saxony (Dual Carriageway)	2003	DE	Asphalt binder 0/22 S	SMA 0/8 S	32 500 15 100	SmB 35
B4 Berliner Ring, Bamberg (A-Road)	2003	DE		SMA 0/11 S	16 500	SmB 35
Bridge Ramps, Bamberg	2003	DE		SMA 0/11 S	5000	SmB 35
Bridge Road Surface, Bamberg	2003	DE		GA 0/11 S	1000	PmB 45 + 3% Sasobit
B16 Ingolstadt, Bruck, Bayern (A-Road)	2003	DE		SMA 0/8 S	10 000	SmB 35
Aprons, Munich Airport	2003	DE		AB 0/11 S	40000	PmB 45 + 3% Sasobit
A3 Schaldinger Bridge nr. Passau, Bavaria (Motorway)	2003	DE	Gussasphalt 0/11 S	GA 0/11 WC	13500	PmB 45 + 3% Sasobit
A9 Nuremberg (Motorway)	2003	DE		SMA 0/11 S	10000	PmB 45 + 3% Sasobit
A99 Aschheim (Motorway)	2003	DE	Asphalt binder 0/22 S	SMA 0/8 S	10000	PmB 45 + 3% Sasobit
B11 Thouslettin, Munich (A-Road)	2003	DE	Asphalt binder 0/22		8000	PmB 45 + 3% Sasobit
A6 Neckarbrücken (Motorway)	2003	DE	Gussasphalt 0/11	GA 0/11 WC	10000	PmB 45 + 3% Sasobit
Ludwigstraße, Saarbrücken	2003	DE		SMA 0/11 S	7000	PmB 45 + 3% Sasobit
B268 Schmelz, Saarland (A-Road)	2003	DE	Asphalt binder 0/16		5000	PmB 45 + 3% Sasobit
Schmelz, Saarland	2003	DE		SMA 0/11 S	5 000	PmB 45 + 3% Sasobit
Bus Stops, Munich	2003	DE	Asphalt binder 0/22		6000	PmB 45 + 3% Sasobit
Railtrack Foundation, Dresden	2003	DE		GA 0/11 S	4500	PmB 45 + 3% Sasobit
Urban Roads, Brno	2003	CZ		SMA 0/11 S	3000	PmB 45 + 3% Sasobit
B314 Fernpassstraße, Tirol (Trunk Road)	2003	AT		SMA 0/11 S	5000	PmB 45 + 3% Sasobit
Omnibus Station, Feldkirch, Voralberg	2003	DE		SMA 0/11 S	6000	PmB 45 + 3% Sasobit
Kajang Ring Rd, Seri Kembangan, Selangor	2003	MY		ACWC 20	1500	80/100 + 3% Sasobit
Highway, Shandong	2003	CN		AK16	500000	Chun Hai 36-1 + 3% SBS + 1% Sasobit
State Road, Taranaki Region	2003	NZ		AC 0/10	2800	B 80/100 + 3% Sasobit
Car Park, Tarankari Region	2003	NZ		AC 0/10	1 400	B 80/100 + 3% Sasobit
Ermelo	2003	ZA		Med. Cont. Grade	2400	B 60/70 + 3% Sasobit
Devon	2003	ZA		Med. Cont. Grade	7000	B 60/70 + 3% Sasobit
Winburg	2003	ZA		Med. Cont. Grade	3000	B 60/70 + 3% Sasobit
Military Airport, Umea (near Arctic Circle)	2003	SE		ABTS 11	110000	B 120/160 + 3% Sasobit
M30, Rodby, (Motorway) (Heavy traffic side)	2003	DK	ABB		30000	B 40/60 + 2% Sasobit
M11, Holbaek (Motorway) (Heavy traffic side)	2003	DK	ABB		15000	B 40/60 + 2% Sasobit
M70, Alborg South (Motorway)	2003	DK	ABB	SMA 11	30000 51000	B 60 + 1,5% Sasobit (BC) B 60 + 3% Sasobit (WC)
B81 Langenweddingen, Saxony-Anhalt (A-Road)	2002	DE		SMA 0/11 S	44000	SmB 35
FT01 Kuching-Sri Aman, Sarawak	2002	MY		ACWC 20	4700	Shell 80/100 + 3% Sasobit
Urban Road Fushang, Guangdong	2002	CN		AK16	6000	Moaming #70 + 3,5% SBR + 3,2% Sasobit
M23, Oslo-Drammen (Motorway)	2002	NO		SMA 15	100000	B 85 + 3% Sasobit

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Location	Year	Country	AC Binding Course	AC Wearing Course	Project size m2	Binder used
Wolfurt	2002	AUT		pmAB 16	2 400	Olexobit 45 NV
Wolfurt	2002	AUT		pmAB 16	5 600	Olexobit 45 NV
L 193 Nüziders	2002	AUT		AB 11	3 100	Olexobit 45 NV
E18, Drammen-Westfall (Euro Road)	2002	NO		SMA 11 + 15	10000	B 85 + 3% Sasobit
Schiffbeker Weg, Hamburg	2002	DE		SMA 0/8	30000	SmB 35
Legienstr. Hamburg	2002	DE		AB 0/11	10000	SmB 35
Oejendorfer Weg, Hamburg	2002	DE		SMA 0/8	5000	SmB 35
A1 Euskirchen (Motorway)	2002	DE		Gussasphalt 0/11	2500	20/30 Kuwait Petrol + 3% SASOBIT
A3, Danube Bridge, Passau	2002	DE	Gussasphalt 0/8	Gussasphalt 0/8	12000	BP Olexobit NV 45
A7 Hochbrücke (very high bridge), Rendsburg	2002	DE	Gussasphalt 0/11 S	Gussasphalt 0/11 S	16500	Olexobit 45 + 3 % SASOBIT
B173, Bridge, Pirk	2002	DE		SMA 0/8	5000	SmB 35
Bredow Str., Hamburg	2002	DE	Asphalt binder 0/16	SMA 0/8	11500	SmB 35
Bridge, Neumark	2002	DE	Gussasphalt 0/8	Gussasphalt 0/8	1000	B 30/45 + 3% SASOBIT
Bridge, Wurzburg	2002	DE	Gussasphalt 0/8	Gussasphalt 0/8	1000	B 30/45 + 3% SASOBIT
Ellerholz Bridge, Hamburg	2002	DE	Gussasphalt 0/11 S	Gussasphalt 0/11	4000	PmB 25 +4 % SASOBIT
Kolumbus Str.	2002	DE	Asphalt binder 0/16	SMA 0/8	5500	SmB 35
Liebigstr., Hamburg	2002	DE	Asphalt binder 0/16	SMA 0/8	15000	SmB 35
Otto Catalogue works ground	2002	DE	Asphalt binder 0/16	SMA 0/8	4000	SmB 35
Urban roads, Plauen	2002	DE	Asphalt binder 0/22	SMA 0/8	5000	SmB 35
B92, Bad Brambach (A-Road)	2002	DE	Asphalt binder 0/22	SMA 0/11 S	24 500 13 000	SmB 35
Veddeler Damm, Hamburg	2002	DE	Asphalt binder 0/16	SMA 0/8	4500	PmB 45 RC + 3 % SASOBIT
Land Road 514, Tonder/Hojer	2001	DK		GAB 0/16	15000	B 40/60 + 2% Sasobit
A111, Airport Tegel, Berlin (Motorway)	2001	DE		SMA 0/11	3000	B 50/70 + 3 % SASOBIT
A 8, Munich - Karlsruhe	2001	DE	Asphalt binder 0/16	SMA 0/11	10000	BP Olexobit NV 45
AUDI Factory Driveway, Ingolstadt	2001	DE	Asphalt binder 0/16	SMA 0/11	5000	B 50/70 + 3 % SASOBIT
B 71 OD Kakerbeck (A-Road)	2001	DE		SMA 0/11	7300	SmB 45 (Direct comparison to PmB)
Bosch Factory, Bad Homborg	2001	DE	Asphalt binder 0/16	SMA 0/11	5000	Nypol 45 + 3 % SASOBIT
Braunschweiger Straße, Magdeburg	2001	DE		SMA 0/8	3500	Genicel (Fibre + SASOBIT)
First grade road, Shi-Jia Zhuang, Hebel	2001	CN		AK-131	5000	AH 90 + 4.5% SASOBIT
Bus stops, Dresden	2001	DE		SMA 0/8	500	PmB 45 + 3 % SASOBIT
Cambridge Airport, Cambridge	2001	UK		Asphalt binder 0/ 16	3000	BP NV 50/70
Cardiff Docks, Cardiff	2001	UK		Asphalt binder 0/16	3000	BP NV 50/70
Heggenstaller Factory, Uelzen	2001	DE		Asphalt binder 0/11	3000	SmB 35
Hohe Schaarstr., Hamburg	2001	DE		Asphalt binder 0/8 S	4000	SmB 35

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October 2005

Location	Year	Country	AC Binding Course	AC Wearing Course	Project size m ²	Binder used
Misc. factory grounds, Dresden	2001	DE	Asphalt binder 0/22	SMA 0/8	1000	SmB 35
L 1086, Greiz (B-Road)	2001	DE	Asphalt binder 0/16	SMA 0/8	5000	B 50/70 + 3 % SASOBIT
Dual Carriageway, Nuthe	2001	DE		SMA 0/11	3000	SMB 35
Bypass, Niederhöft	2001	DE		SMA 0/11	5000	BP NV 50/70
Car park and side street, Passau	2001	DE	Asphalt binder 0/16	SMA 0/11 S	5000	BP NV 70/100
A Road, Piemont, Turin	2001	IT		Asphalt binder 0/16	4000	B 50/70 + 3 % SASOBIT
Urban Road, Wuxi Jiangsu Province	2001	CN		AK-131	4500	AH 70 + 3.5% SASOBIT
Stahnsdorf, Brandenburg	2001	DE	Asphalt binder 0/16	SMA 0/11	7000	SmB 35
Coloured asphalt, Brussels and Liege	2001	BE		Gussasphalt 0/5	5000	Mexphalt C 20/30 + 3 % SASOBIT
Szekesfehervar	2001	HU		SMA 0/11	3000	B 50/70 + 3 % SASOBIT
Thalkirchener Bridge, Munich	2001	DE		Gussasphalt 0/8	800	Mexphalt C 20/30 red + 3 % SASOBIT
Berlin Zoo Tunnel, Berlin	2001	DE		SMA 0/8	500	SmB 35
Runway 05/23, Hamburg Airport	2001	DE		SMA 0/11	60000	B 50/70 + 3 % SASOBIT
Eurogate container terminal, Hamburg	2000	DE	Asphalt binder 0/22	SMA 0/11	15000	Caribit 25 + 3 % SASOBIT
Ringroad, Vienna	2000	AT		Gussasphalt 0/11	2000	B 20/30 + SASOBIT
A 1, AD Erfthal - Euskirchen (Motorway)	2000	DE		SMA 0/8	1500	B 50/70 + 3 % SASOBIT (Genicel)
A1, Maschen - Harburg (Motorway)	2000	DE		SMA 0/5	25000	Caribit 45 + 3 % SASOBIT
A 111, AD Oranienburg - Berlin (Motorway)	2000	DE	Asphalt binder 0/22	SMA 0/11	3000	Olexobit 25 NV + 3 % SASOBIT B 50/70 + Genicel
Friedrichsthaler Steel Bridge, (A 8) (Motorway)	2000	DE		SMA 0/8	6000	BP Olexobit NV 45
Docking station Schoitema, Woerden	2000	NL		Gussasphalt 3-layered	15000	B 20/30 + 2,6 % SASOBIT
Highway entrance, Guangdong Province	2000	CN	AC-251	AK-16A	4500	AH 70 + 3% SASOBIT + 1.5% SBR
B 6 n, Abbenrode - Stapelburg (A-Road)	2000	DE	Asphalt binder 0/16	SMA 0/11 S	16000	SmB 35 / SmB 45
B 83, Bad Eilsen (A-Road)	2000	DE		SMA 0/5	25000	Caribit 45 + 3 % SASOBIT
B 92, Gera (A-Road)	2000	DE		SMA 0/11	1000	B 50/70 + 3 % SASOBIT
Burchard Quay container terminal, Hamburg	2000	DE	Asphalt binder 0/22	Asphalt binder 0/16	1000	Caribit 25 + 3 % SASOBIT
Burchard Quay, van carrier lane, Hamburg	2000	DE	Asphalt binder 0/22	SMA 0/11	5000	Caribit 25 + 3 % SASOBIT
Bus stops, Leipzig	2000	DE		Gussasphalt 0/11	1000	B 30/45 + 3 % SASOBIT
Waste disposal site, Neuhofer Straße, Hamburg	2000	DE	Asphalt binder 0/16	SMA 0/11	80000	B 50/70 + 4 % SASOBIT
Misc. streets in Paris	2000	FR		Gussasphalt	20000	B 30/50 + 3 % SASOBIT
Ceramic Works Factory, Boizenburg	2000	DE		Asphalt binder 0/11	12000	SmB 35
Frankenschellweg, Nuremberg	2000	DE	Asphalt binder 0/22	SMA 0/11	5000	B 30/45 + 3 % SASOBIT
Roundabout, Merchweiler	2000	DE		SMA 0/11	5000	B 30/45 + 3 % SASOBIT
Moorfleeter Straße, Hamburg	2000	DE	Asphalt binder 0/22	SMA 0/11	1500	B 50/70 + 3 % SASOBIT
Müggenburger Straße, Hamburg	2000	DE	Asphalt binder 0/16		1200	S 90 Plus + 3 % SASOBIT

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Location	Year	Country	AC Binding Course	AC Wearing Course	Project size m2	Binder used
Salzgitter AG Grounds, Salzgitter	2000	DE		SMA 0/8 S	7000	SmB 35
A-Road, Stallikon	2000	CH	Asphalt binder 0/22	SMA 0/11	10000	BP Olexobit NV 45
Urban Road, Guangdong Province	2000	CN		AK-131	20000	AH 70 + 3% SASOBIT + 1.5% SBR
Urban roads, Wolfsburg	2000	DE	Asphalt binder 0/11	SMA 08/ + 0/11	25000	SmB 35
Bypass, Aarhus	2000	DK		SMA 0/8	22000	B 50/70 + 3 % SASOBIT
An der Trave, Lübeck	1999	DE		Gussasphalt 0/5	1500	Hard bitumen + 3 % SASOBIT
Highway 1, Seremban, Negei Sembilan	1999	MY		ACWC 20	8500	Esso 80/100 + 4% SASOBIT
B 190, Ritzleben - Pritzier (A-Road)	1999	DE	Asphalt binder 0/22	SMA 0/11	35000	SmB 45
B 209, Amelinghausen (A-Road)	1999	DE		SMA 0/11	1500	B 70/100 + 3 % SASOBIT
B 242, Güntersberge - Stiege (A-Road)	1999	DE	Asphalt binder 0/22	SMA 0/11	5000	SmB 35
Central Flower Market, Berlin Centre	1999	DE		SMA 0/5	10000	SmB 35
BMW works grounds, Berlin - Spandau	1999	DE		SMA 0/8	1500	SmB 35
Waste disposal site, Altwarmbüchen	1999	DE	Waste containment lining (tip asphalt)	Asphalt binder 0/8	6500	SmB 45
Waste disposal Site, Böhringer	1999	DE	Waste containment lining (tip asphalt)	Asphalt binder 0/11	10000	PmB 45 + 3% SASOBIT
Falkenseer Platz, Berlin Spandau	1999	DE	Asphalt binder 0/22	SMA 0/11	5000	SmB 35
Hohenzollerndamm, Berlin	1999	DE	Asphalt binder 0/16	SMA 0/8	3000	SmB 35
Holmpassage (Shopping Centre), Flensburg	1999	DE		Gussasphalt 0/5	1400	Hard bitumen + 3 % SASOBIT
Kaltenmoor, Lüneburg	1999	DE		Gussasphalt 0/5	7800	Hard bitumen + 3 % SASOBIT
Pichelswerder Str., Berlin - Spandau	1999	DE	Asphalt binder 0/16	SMA 0/11	2000	SMB 35
Maritime High Court, Hamburg	1999	DE		Gussasphalt 0/8	3000	Hard bitumen + 3 % SASOBIT
Sophie-Charlotte-Str., Berlin	1999	DE		Gussasphalt 0/11	5500	SmB 35
Stralauer Straße, Berlin Centre	1999	DE	Asphalt binder 0/16	SMA 0/11	3000	SmB 35
AOL Arena, Hamburg	1998	DE		Gussasphalt 0/8	1000	SmB 35
Car park Buxtehuder Straße, Hamburg	1998	DE		Gussasphalt 0/8	400	SmB 35
Pinkertweg, Hamburg	1998	DE		Asphalt binder 0/11	1500	SmB 45
Veddeler Damm, Hamburg	1998	DE	Asphalt binder 0/16	SMA 0/8	5000	B 50/70 + 3 % SASOBIT
Sugar Factory, Könnern	1998	DE		Asphalt binder 0/8	2500	SmB 45
Jean Avenue	1997	ZA		SMA	2700	B 80/100 + 3% Sasobit
Andreas-Meyer-Straße, Hamburg	1997	DE	ATS 0/32		11000	PmB 45 + SASOBIT as a compaction aid
Veddeler Damm, Hamburg	1997	DE	Asphalt binder 0/22	SMA 0/11	3000	B 70/100 + 3 % SASOBIT
Worthdamm, Hamburg	1997	DE		Asphalt binder 0/11	500	B 70/100 + 3 % SASOBIT



PRODUCT DATA SHEET

SASOBIT®

Date: 28.08.2006

Revision: 15.05.2003

TEST METHOD	UNITS	SPECIFICATION	TYPICAL VALUES
<i>Congealing Point ASTM D938</i>	°C	100 min	100
<i>Needle Penetration at 25°C ASTM D1321</i>	0.1 mm	1 max	<1
<i>Needle Penetration at 65°C ASTM D1321</i>	0.1 mm	11 max	9
<i>Brookfield Viscosity at 135°C Sasol Wax 011</i>	cP	10-14	12

Compliance

F&DA: This product complies with the requirements of 21 Code of Federal Regulations: Parts 175.105 (Adhesives), 177.1390 (Laminate Structures)

NOTICE: This product information is indicative and does not include any guarantee

Sasol Wax GmbH

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EEC-Safety data sheet SYNTHETIC HYDROCARBON

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Revision: 2003.01.17

1. Identification of the substance and company

SASOBIT

Manufacturer/supplier:

Sasol Wax GmbH

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Tel.: +49-40-7 81 15 -0, Fax: +49-40-7 81 15 - 444

Emergency telephone:

Safety engineer, Tel.: +49-40-7 81 15 254 (24-hr-Service)

2. Composition/information on ingredients

Chemical characterisation:

synthetic long chain hydrocarbons C_nH_{2n+2}

Synonyms: polymethylene

CAS number: 8002-74-2

Hazardous ingredients: None

3. Hazards identification

EEC-labelling: None

Potential health effects and main symptoms:

Skin contact: Solid - None. When molten results in heat burns. Not readily absorbed.

Eye contact:

Solid - none. Molten material results in burns.

Prill – irritation

Inhalation: Inhalation of synthetic long chain hydrocarbons vapours or powder particles may cause respiratory tract irritation.

Ingestion: Liquid – the high temperature may cause burns on contact with mouth/oesophagus/stomach

4. First-aid measures

Ingestion: May cause damage only in liquid (hot) state. Same actions as in case of burns.

Skin contact/absorption: Liquid – immerse the area in water to assist cooling. Apply sterile cover. Seek medical attention. Solid – do not remove solidified product from skin. It will peel off with the dead skin as the burn heals.

Eye contact: Liquid – flush eyes with cold water. Seek medical attention.

5. Fire-fighting measures

Suitable extinguishing media:

Foam, carbon dioxide, sand

Extinguishing media that must not be used for safety reasons:

Water

Special protective equipment for firefighting:

Use breathing apparatus independent of the ambient air.

Specific hazards:

Incomplete combustion produces fumes, flue gases, carbon monoxide

Additional information:

Apply cold water in order to cool containers exposed to danger.

6. Accidental release measures

Personal precautions:

Eye/face/body: A self-contained breathing apparatus or a face shield and protective clothing (overall) should be worn when working with molten product.

Hands: Use leather gloves as they provide heat insulation and do not absorb molten product.

Environmental precautions:

Keep away from drains and surface water

Methods for cleaning up:

Solid: Remove mechanically. Liquid – suck off the fluid or allow synthetic long chain hydrocarbons to cool and remove mechanically

Additional instructions:

Inform authorities in case of large amount leakage.

7. Handling and storage

Handling

Technical measures/precautions:

Liquid – prevent aerosol generation during pumping. Containers and discharge pipes should be earthen. Prevent ignition source.

Powder – danger (of explosion) adopt measure to prevent dust-explosion.

Fire class as prescribed by DIN EN 2: B

Safe handling advice:

Solid – usual handling of solid transport goods

Liquid - usual precautions for handling hot fluids. Consider common hygiene measures for handling chemical substance.

Storage

Requirements for storage rooms and containers:

Slabs: Store under cool, dry and light protected conditions

Liquid: Store in heatable tanks/containers.

Product is not allowed to contain water at temperatures above 100°C (delay in boiling).

Additional information:

VCI storage class: 11

8. Exposure controls / personal protection

1. Germany/Switzerland/Austria:

There is no MAK-value for synthetic long chain hydrocarbons

2. Germany:

For aerosols and fine dust MAK-value of 6 mg/m³ has to be adhered to.

3. USA

TLV-value for synthetic long chain hydrocarbon vapours: 2 mg/m³

Engineering measures:

General ventilation should be provided to maintain ambient concentration below nuisance levels. Synthetic long chain hydrocarbons should not be exposed to water, as it causes violent steam explosions on molten product.

Personal protective equipment:

Skin – to avoid any contact with skin, wear protective clothing such as heavy rubber gloves, leather safety boots, acrylic or polycarbonate face shields, and impervious cotton or cotton blend overalls.

Eye/face – face shields should be worn to protect eyes and face against hot paraffin wax splashes.

Avoid contact with hot fluid.



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9. Physical and chemical properties

Physical state: solid
Colour: White/whitish
Odour: Practically odourless
pH-value: Aqueous extract: Neutral
Congealing range (DIN-ISO 2207): $\leq 99^{\circ}\text{C}$
Lower explosion limit:
 Dust/powder: $> 15 \text{ g/m}^3$
Upper explosion limit:
 Dust/powder: $> 1000 \text{ g/m}^3$
Vapour pressure at 20°C: $< 0,01 \text{ hPa}$
Density at 20°C (DIN 51 757): About 940 kg/m^3
Solubility at 20°C
 - in water: Insoluble
 - Soluble in warm methyl-iso-butylketon
Viscosity at 120°C (DIN 51 562): $> 11 \text{ mm}^2/\text{s}$

10. Stability / reactivity

Conditions to avoid:
 Under normal conditions no hazardous reactions likely
Material to avoid: Strong oxidising agents
Decomposition products:
 In case of incomplete combustion and/or thermal decomposition carbon monoxide, carbon dioxide and smoke may be formed.
Thermal decomposition: Approx. 300°C

11. Toxicological information

Acute oral toxicity/Rat Non-toxic
Irritant effect on rabbits' skin: Non-irritant
Irritant effect on rabbits' eye: Non-irritant
Sensitization: Non-sensitizing

12. Ecological information

The product is a water-insoluble, solid aliphatic hydrocarbon mixture which, under environmental conditions has no detrimental effects on plants, animals or micro-organisms. It can be removed mechanically in a purification plant.

13. Disposal considerations

Product: After re-conditioning the product may be used again

GERMANY:

Can be disposed off after consultation with the responsible authorities according to the following waste disposal codes (European Waste Catalogue):

EWC-Code	Description
05 01 06	Sludges from plant, equipment and maintenance operations
07 01 99	Wastes not otherwise specified
12 01 12	Spent waxes and fats

Packaging:

Pallets: Can be returned to supplier via the haulier/forwarding agent
Cartons: Cartons with the "Resy" symbol may be returned to the associated used paper collecting point
Paper bags: Paper bags containing the "Repa-Sack"-symbol and "Chemical Classification 4" may be returned to the associated used paper collecting point
Big-Bags: Re-usable packaging can be returned to supplier

14. Transport information

(ADR/RID; BinSchV/ADNR/ADN; IMDG/GGVSee; ICAO-TI und IATA-DGR):
 Products like this one are not hazardous goods at temperatures $< 100^{\circ}\text{C}$.
 In case of transport of liquids with temperatures of $\geq 100^{\circ}\text{C}$ hazardous goods class 9, number 20c
UN: 99/3257 applies
IMDG-Code: 9027-1

15. Regulatory information

The product does not require a hazard warning label in accordance with the EEC directives

National regulations

Classification according to VbF: Not applicable

TA Luft:

Threshold limit value TA Luft 150 mg/m^3
 Mass flow 3 kg/h or more
 Substance class III, amendment E

Water hazard class (WGK): Not water endangering substance according to Annex I VwVwS

StörfallVO: Not applicable for synthetic long chain hydrocarbons

16. Other information

Literature:

- Ullmann's Encyclopedia of Industrial Chemistry
 Chapter "Waxes", 5th Edition 1996, VCH Weinheim
 - Römpp, Chemie-Lexikon

This safety data sheet describes a product group. It contains only safety related information. For specific data see product data sheet.

Although the information contained herein is presented in good faith and to the best of Sasol Wax's knowledge and experience, it is made without any warranty or guarantee whatsoever.

In case any questions should arise please call the number given in point 1.

Sasol Wax GmbH

Preparation and basic evaluation of bitumen emulsions containing Sasobit[®] BE 88

Introduction

THE SUCCESS FORMULA FOR BETTER ASPHALT

SASOBIT
modified

The aim of this work has been to investigate, if the beneficial modification of bitumen properties by Sasobit[®] can be applied for bitumen emulsions. The production of bitumen emulsions is generally limited to 70/100 pen grade or softer bitumen. For many applications it would be advantageous to have emulsions with harder bitumen grades. The basic idea of this work is to use a 70/100 bitumen, which can be emulsified easily, and blend Sasobit[®] BE 88 with the bitumen before emulsification. This should result in low viscosity bitumen during emulsification and in stiff modified bitumen after breaking of the emulsion.

Experimental work and results

The company Goldschmidt (emulsifier producer) prepared a storage stable anionic bitumen emulsion containing 60% bitumen and 4 wt.% Sasobit[®] BE 88 and a fast breaking cationic emulsion (U60K) with 2 % Sasobit[®] BE 88.

In order to analyse the influence of the Sasobit[®] BE 88 on the bitumen properties, the emulsions were broken according method DIN 52041. The resulting bitumen phases were collected and analysed in comparison to bitumen from a similar emulsion without Sasobit[®] BE 88.

Bitumen samples from broken emulsions	Needle penetration @ 25°C [1/10 mm]	Softening point R&B [°C]
B 70/100	81.5	45.1
B 70/100 + 2% Sasobit [®] BE 88 (cationic)	40.5	76.5
B 70/100 + 4% Sasobit [®] BE 88 (anionic)	33.5	96.1

The cationic emulsion is storage stable for approx. 3 weeks.

Conclusions

This investigation has proven the possibility to produce anionic and cationic bitumen emulsions containing Sasobit[®] BE 88. The addition of 2 or 4 wt.% Sasobit[®] BE 88, i.e. 3.3 % or 6.7 % in the bitumen phase, results in a modified bitumen with a two grades lower penetration and a significantly increased softening point. The cationic emulsion should be optimised in order to extend the storage stability.

Note: Sasobit[®] BE 88 is a long chain FischerTropsch hydrocarbon

Anionic bitumen emulsions with Sasobit[®] BE 88

A trial anionic bitumen emulsion with Sasobit[®] BE 88 has been formulated by Goldschmidt AG:

DIE ERFOLGS-FORMEL FÜR BESSEREN ASPHALT



Bitumen B 70/100 (Nynas)	60.0 %
Water	33.7 %
NaOH	0.2 %
TEGO Antifoam AS10	0.1 %
TEGO Addibit DF	2.0 %
Sasobit [®] BE 88	4.0 %

This emulsion was produced without problems. The storage stability is very good. Because of the slow setting behaviour anionic emulsions are not useful for road applications, but for waterproofing (structural sealants, protecting paints etc.).

Technical consulting and experimental support regarding other bitumen types or special applications is available at:

Goldschmidt AG
Technical Service Bitumen/Asphalt
Juergen Ballandies
Goldschmidtstrasse 100
45127 ESSEN
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Phone: +49-201-173-2617

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Juergen.Ballandies@de.goldschmidt.com

Cationic bitumen emulsions with Sasobit[®] BE 88

Example for preparation of a Sasobit[®] BE 88 modified cationic bitumen emulsion

THE SUCCESS FORMULA FOR BETTER ASPHALT



Formulation

Bitumen B 70/100 E (Nynas)	60.0 %
HCl (36.5 %)	Adjust mixture to pH 2.5
H ₂ O	36.7 %
CaCl ₂	0.2 %
Tego Antifoam AS 10 (Goldschmidt)	0.1 %
Sasobit [®] BE 88	2.0 %
Tego Addibit F4HB SZ10 (Goldschmidt)	0.5 %
Tego Addibit L200 (Goldschmidt)	0.5 %

Preparation

1 Preparation of emulsifier solution

Add the required amounts of emulsifiers to the water and dissolve the emulsifiers at 50-55 °C. Adjust the pH to 2.5 with HCl. Then add CaCl₂ and the defoamer.

2 Preparation of bitumen phase

Heat the bitumen to 125-130°C, add Sasobit[®] BE 88 and homogenise by stirring (approx. 15 min). Store in an oven at 125-130°C for some minutes until the air bubbles escape the mixture.

3 Preparation of emulsion

Fill the emulsifier solution (50-55°C) into a high shear mixer (colloid mill or ultraturrax), start the mixer and add the bitumen phase (125-130°C) gradually and continuously. Continue the mixing until complete emulsification is obtained.

Remarks

The formulation has to be adjusted/optimised if other bitumen types are used.

Frankfurt Takes Off From Asphalt

Low Temperature Asphalt makes Reconstruction of the Airport Possible

The northern airstrip of Frankfurt Airport carries the burden of 200,000 annual flight movements.

The concrete surface, some of it more than 35 years old, has started to show signs of damage and cracks. In some parts this damage goes as deep as the sub-grade. The extensive reconstruction work which started in the night from 22.-23. April 2003 is unique - world-wide - and has been made possible only by using low temperature asphalt. As the work takes place at night, the air traffic is not even constricted.

The work cannot be carried out in high summer, winter or during periods of heavy rainfall. The first two construction phases have already been completed. In total, five phases have been planned comprising a total of 300 nights for the work on this 4,000 m long and 60 m wide airstrip. The project is scheduled to be completed by mid 2005.

Before the start

A comprehensive study of the airstrip was undertaken in May 2001. After which several plans for the reconstruction work were drawn up and carefully examined. As the air traffic could not be restricted, it was only possible to work at night and the airstrip had to be divided into small sections. Asphalt was the only building material that came into question. During the past 15 years experience has been gathered with several smaller nightly reconstruction works. The former "white" airport Frankfurt/Main is slowly becoming a "black" one.

The size of this undertaking was, however, new. The Fraport AG issued a Europe-wide tender. Only 9 companies submitted an offer, 8 of them from Germany. The civil engineering works was awarded to Kirchhoff-Heine Straßenbau GmbH and F. Kirchhoff Straßenbau GmbH & Co. KG. The quality assurance to the Asphaltlabor Steinmetz.

The work will be carried out as a full depth asphalt construction. Consequentially, the traffic burden puts very little strain on the existing sub-grade. The 4 km long airstrip was divided into diagonal strips, each 15 m long. This ensured that only one middle line of light beacons and maximum 2 short girders of the touch down zone light beacons would fall out for a maximum period of 16.5 hours. Thus, 90% of the light beacons would remain functional in accordance with the ICAO requirements.

Closing off the northern runway is only possible between 22:30 h - 06:00 h. All work sequences were planned with military precision in 15 minute tact. 1.5 hours were allotted for the demolition and excavation work, 4.5 hours for the paving and the remaining 1.5 hours for marking and cleaning up. The nightly completed strips are interlocked with each other to avoid cracking. The work is carried out in two phases: In the first phase the first two asphalt base courses, both 24 cm are laid. On top of that the 12 cm thick a/c binder course is laid and used temporarily as the wearing course.

The second phase takes place once 500 m length and the total 60 m width of the strip has been thus completed; 4 cm of this binder course (temporary wearing course) is milled off 100 m/per night and replaced by the permanent stone mastic asphalt wearing course. It goes without saying that during every phase, teamwork and logistics must be 100% synchronized.

Only new equipment with sufficient power reserve is used. For safety reasons the vehicles involved are only allowed to use pre-determined routes. 3 m long ramps were excavated and filled with asphalt either side of the airstrip to enable the equipment/machines to shunt optimally. Possible suction or blowing away of material due to planes starting and landing during the daytime is thus avoided. The ramps will be removed at a later date and replaced with grass grids (grass grid stones).

Not only are the technology and the logistics of this project high-tech, the asphalt used is also a high-tech product. In every course, low-temperature asphalt has been used. The building contract stipulated a paving temperature of 125°C. In order for the asphalt to remain workable at this temperature, *Sasobit*[®], a hard wax, was added to the bitumen. Apart from the temperature, 50°C cooler, the paver and roller drivers could tell no difference to normal asphalt.

The low temperature asphalt is 100°C after paving and compacting. A further 1.5 hours remain for the asphalt to cool down by a further 15°C so that an aeroplane - 330 tonnes - can take off and land without causing damage. The asphalt is expected to last 20 years. The accomplishment of a project such as Frankfurt Airport has been made possible by the “market maturity” of low temperature asphalts.

Night in Night out

Every day at 14:45 h the weather forecast is studied before the decision is made whether to go ahead with the next segment. If the decision is positive then the 3 mixing plants of Johannes Nickel GmbH & Co KG get a phone call that asphalt is needed. Approx. 1,500 t asphalt is delivered and stored in asphalt silos before the shift begins. No risk is taken that a mixing plant cannot deliver.

At 22:30 h the meticulously planned “game” begins for the 65 man team. Eight 44 t excavators each fitted with 2-3 t chisels break up the old airstrip. The resulting 1,400 t rubble is loaded onto 26 lorries which is then transported to nearby depots. The first asphalt sub-base layer (24 cm) is poured onto the area and distributed and compacted with bucket excavators and bulldozers. The use of pavers was not possible in this course, as the hollow pipes (225 mm) for the light beacons had to be laid here.

Two Vögele Type Super 2100 pavers each 7.5 m wide were used for the second asphalt layer (also 24 cm). The 125-135°C asphalt is laid “hot on hot” at a speed of 2 m/min.

Two Vögele Typ Super 1900 pavers were at the ready in case of emergencies. The pavers are fitted with Nivel levelling instruments and Niveltronic technology. The paver responsible for the left hand surface (as seen from travel direction) determines the actual value on the left hand longitude with a 1.2 m ski. The old concrete surface is used as a reference line.

The diagonal level is adjusted with the help of a high precision pendulum. The paver for the right hand side determines the actual value of both sides with a 1.2 m ski sensing device. The old concrete surface on the left and the binder layer on the right, as laid the previous night, act as reference lines.

The A/C binder course (12 cm) is laid in the same way. Due to the thickness of the layers a screed device fitted with compactors and two press rods is used. The compression ratio measured 86%. Four Hamm DV-8 tandem rollers fitted with oscillation and vibration were then able to carry out the concluding compaction, problem-free. The requirements for evenness and profile accuracy are analogue to those of normal road construction. The more level the surface the less vibration is diverted to the plane.

The excavators have a 5 night break once a sufficiently large area has been thus completed - approx every 7 weeks. The building site team is then reduced to 55 men. Four Wirtgen W 2000 milling machines then mill off 4 cm of the binder course and replace it with an equally thick layer of stone mastic asphalt. Here too, the Vögele pavers are used, this time all four. The paving speed of the first top course was 5 m/min. The compaction also needed more power. For this, seven rollers were used.

Future Prospects

This re-construction method has proved to be a success: The test records of the first two construction phases display excellent results. For example; the unevenness of the new surface is in the millimetre range and thus far below the stipulated value. The low temperature asphalt was 52-79°C at the time the first plane landed. The maximum upper limit is 85°C. Control tests confirmed that the compression factor of the low temperature asphalt was around 100%. Neither technology, logistics, manpower nor materials had to be changed for the second construction phase. The Fraport AG is particularly proud of the fact that do date not one accident has been reported. A project of this size where heavy equipment is used in such a constricted creates a potential hazard, so that it was necessary to have a health and safety protection coordinator.

The cost for this reconstruction work is approx. 38 Mio EURO. This successful premiere is sure to find world-wide emulation. The reconstruction work of the northern airstrip at Frankfurt/Main has attracted a great deal of interest in the airport branch. Technical advisors from other airports who are faced with similar reconstruction work as well as road builders confronted with rebuilding concrete roads as well as members of universities are showing great interest in this project and are informing themselves on the site.