# ASPHALT FLOW IMPROVERS – A NEW TECHNOLOGY FOR REDUCING MIXING TEMPERATURE OF ASPHALT CONCRETE MIXES WITH HIGH RESTISTANCE AGAINST PERMANENT DEFORMATION

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## ABSTRACT

Asphalt flow improvers in the form of Fischer-Tropsch wax and Romontan wax 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 stepwise 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 especially suitable as co-modifiers for polymer modified Bitumen PMB 45 and PMB 25 grades since they significantly improve handling and compactibility. Based on current experience, the recommended level of additivation with asphalt flow improvers is 3 % wt. of the binder quantity. Till the end of 2002 about 3 million m² of asphalt pavements would be laid successfully in Germany.

**KEYWORDS**
Pavement / Polymer / Materials

## 1 INTRODUCTION

The principal objectives when modifying bitumen for road applications are the improvement of the durability of the road surfacing, the skid resistance and the resistance to permanent deformation under load.

Asphalt flow improvers - also called asphalt liquefier - enable not only an improvement of compactibility and 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. Furthermore, a reduction in asphalt mixing temperatures of 20 – 40°C can be expected, even with a usefully longer compaction time.

## 2 STRUCTURE AND MODIFICATION OF BITUMENS

The physical properties of bitumens result from their complex colloidal structure. If one wishes to modify a bitumen, the existing complicate colloid system 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.

## 3 ASPHALT FLOW IMPROVERS

Asphalt flow improvers are substances that, on heating, change from the solid to the liquid state at temperatures above ca. 85°C to 105°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. The softening point ring and ball can be raise up till 80 - 90°C without hardly effecting the deep temperature behaviour. 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

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 paraffin, hereafter termed FT-Wax, the other Romontan wax (fossil hard wax from sub-tropical vegetation) and its derivatives. In the following will be discussed only FT-Waxes.

The statement that a high content of paraffin wax adversely affects the quality of bitumen is an over-generalisation that cannot be substantiated [Krenkler 1950, Duriez 1961, De Bats 1975, Oberthür 1998]. It is therefore necessary 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. The effect of bituminous waxes and FT-waxes on the properties of bitumens has been the subject of extensive research projects undertaken by the Institute for Crude Oil and Natural Gas Research, Clausthal-Zellerfeld, in Germany [Rahimian 1998, Rahimian 1998, Butz 2000]. While the microcrystalline waxes (FT-waxes) have a plasticising effect at low temperatures, resulting in a lower breaking point, the macrocrystalline waxes (bituminous waxes) cause embrittlement at low temperatures and therefore a higher breaking point. Bituminous waxes melt in the range 20 to 70°C [Rahimian 1998] 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-waxes used as asphalt flow improvers comprise a mixture of long-chain aliphatic hydrocarbons [Figure 1] that are produced from coal using the Fischer-Tropsch process.

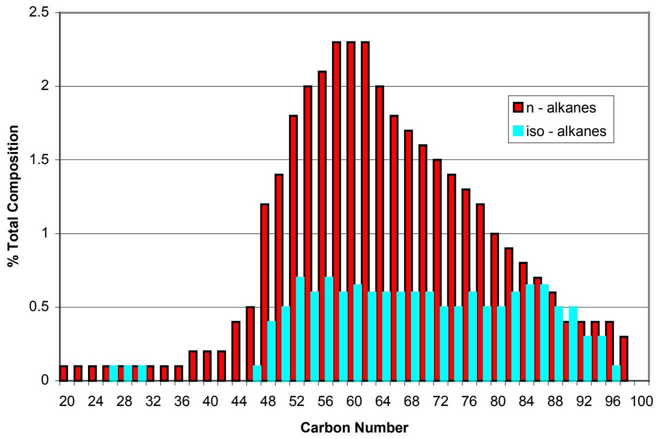


Figure 1: Gas chromatogram of a FT-Wax

The congealing point of the FT-waxes is about 105°C . The melting range of FT-waxes can be measured by DSC,Differential Scanning Calorimetry. [Claudy 1991,Rahimian 1998].

## 4 IMPROVEMENT OF BITUMEN PROPERTIES

The FT-wax used for modifying bitumens has the trade name Sasobit.
Table 1 shows the improvement of the modified bitumen properties.

| **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 content | [% 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 | |

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

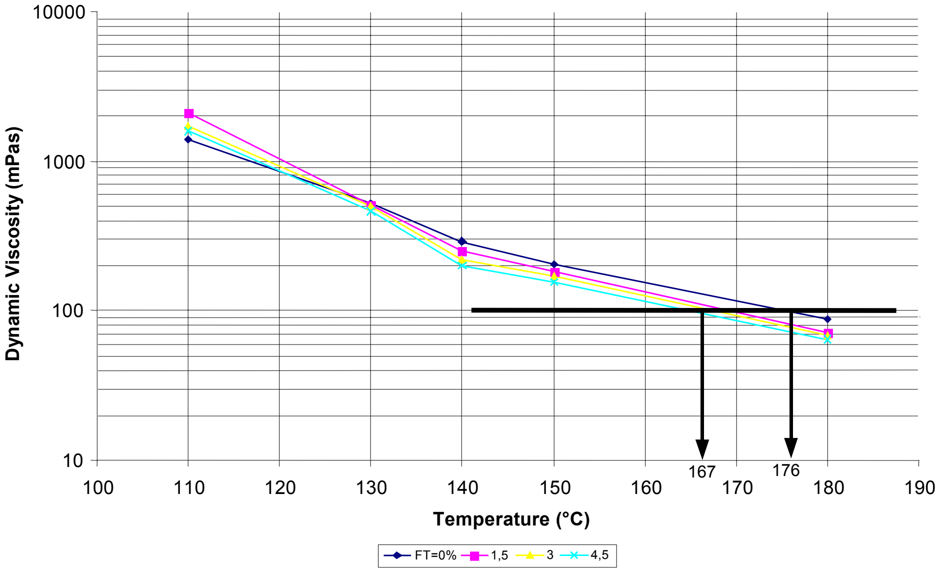


Figure 2 - Dynamic viscosity against temperature, bitumen 50/70 with 0% , 1,5 % , 2 % and 4,5% FT-wax

Figure 2 present the effect of FT-wax on the viscosity in the temperature range at which bitumens are handled.
From 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.
Fig. 3 shows the results of DSR-measurements [Rahimian 1998] using an oscillation frequency of 0.2 Hz over a range of temperatures and with varying concentrations of FT-wax.

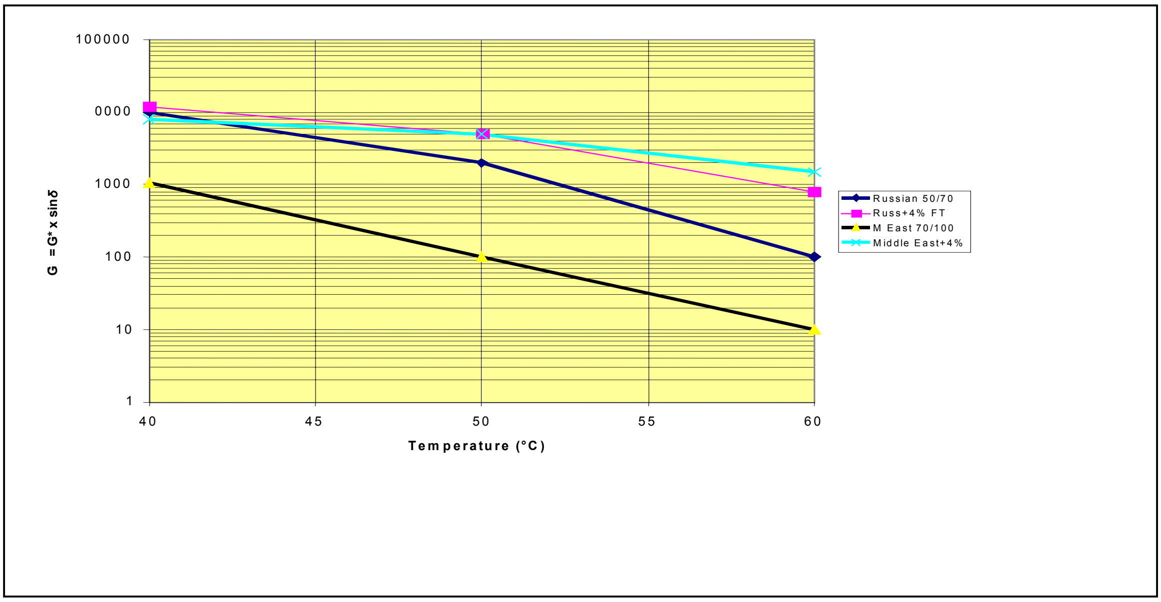


Figure 3- Variation of Loss Modulus G' with Bitumen source, Temperature and FT-Wax Content at 0.2 Hz

The different sources of bitumen vary in their response to FT-wax, especially in terms of the loss modulus G* x sin *δ*. As the FT-wax content is raised, the stiffness of the binder increase considerable.

## 5 ASPHALT TRIALS

Asphalt trials were arranged using a stone mastic asphalt SMA 0/11S ( S= high resistance against permanent deformation) that was difficult to compact.
It can be deduced that the viscosity-reducing effects of FT-waxes strongly

| Mix | Dimension | 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 |
| Air Void content* | [% vol.] | 3.5 | 2.7 | 2.2 |
| VMA Voids in mineral aggregate | [% vol.] | 18.6 | 17.5 | 17.1 |
| VFA voids filled with asphalt | [%] | 80.6 | 84.6 | 87.2 |
| Degree of compaction | [%] | 100 | 101.8 | 102,7 |

* Marshall test sample

Tabel 3 – Data from Approval Testing of SMA 0/11S Grades containing 0% to 4.5% FT-Wax in the Binder

influence bulk density, VMA and VFA and thereby the binder demand. Despite an equal compactability in the Marshall test (2 x 50 blows) and lower binder content, the aggregates achieves a significantly higher density in storage.

### 5.1 RESISTANCE TO PERMANENT DEFORMATION

The resistance against permanent deformation was tested by the Wheel tracking Test, carried out in a water bath at 50°C and using a steel wheel with 20,000 roller passes[Damm 1998, Damm 1997,Damm 1998,Butz 2000].
From experience gained by the author 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 15 million passes of equal - 10 ton -axle loads [Damm 1998].
Wheel tracking tests with SMA 0/8S and 0/11S and a binder 50/70 + 3% FT-wax shows rut depths of 1,8 to 2,4mm, which is comparable to SMA 0/11S with a binder PmB 45 or 25 .The problem with rutting seams to be solved !

### 5.2 LOW TEMPERATURE PROPERTIES

Direct Tension tests by cooling the specimens (gussasphalt samples GA 0/11 compounded with the binders 20/30 bitumen, 30/45 + 3 % wt. FT-wax and PMB 45 + 3% wt. FT-wax ), at a rate of 10 °C/h shows figure 4. The conclusions are:

- the base bitumen has a dominant influence on the deep temperature properties;

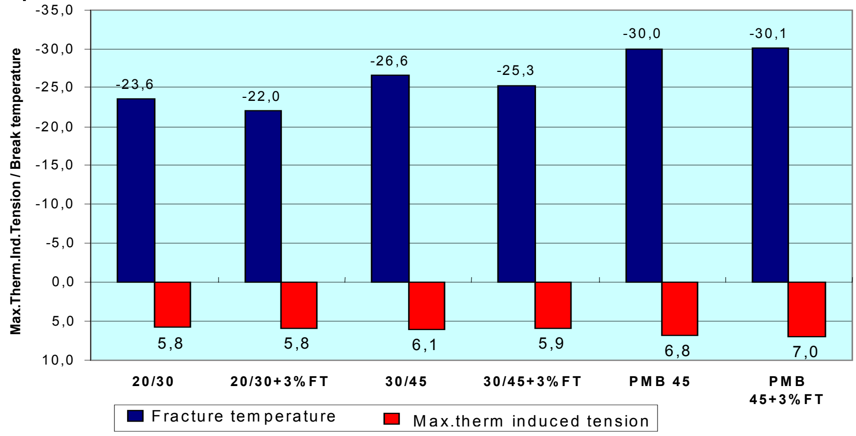


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Figure 4 - Tension tests at a cooling rate of 10°C/ h , gussasphalt 0/11

- this is equally valid for both rolled asphalt and gussasphalt;
- additivation of PMB with flow improver is sensible in view of the improvement in handling properties.

## 6 REDUCTION OF MIXING TEMPERATURE

The first test road of asphalts produced with binders containing FT-waxes was laid in Hamburg in 1997 [Damm 1997, Damm 1998]. In the renewal of the surface, a 8,5 cm thick binder course 0/22 was installed, followed by a 3.5 cm wearing 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.

During compacting the binder course 0/22 density measurements were carried out by Troxler gamma-ray method. Figure 5 shows the relationship between the measured densities, the temperature of the

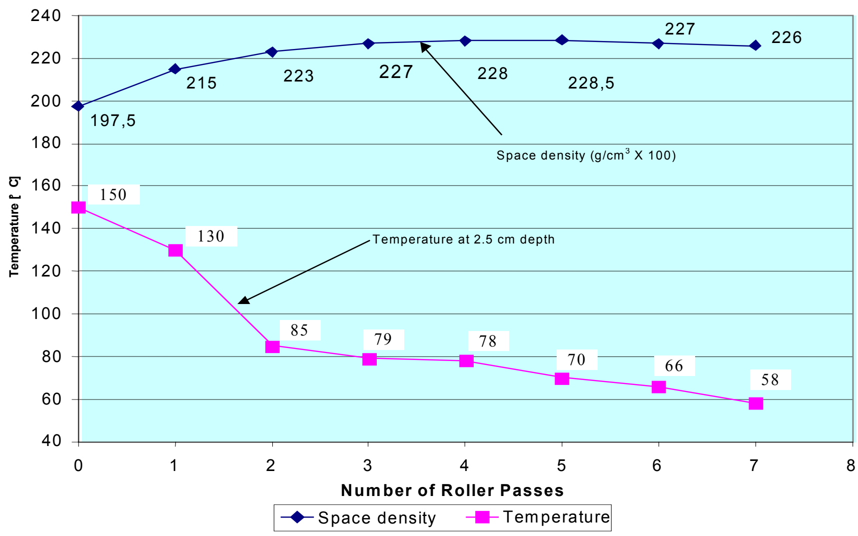


Figure 5 - Change of Course Temperature and Bulk Density with Number of Roller Passes

The data show that the asphalt mix behind the laying machine had a temperature of 140°C. Even at a temperature as low as 85 - 100°C, an increase in density can clearly be detected by the measurements.

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