PROGRESS REPORT 2006

The German

BITUMEN FORUM

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This report introduces the German BITUMEN Forum, explains its aims, provides an overview of past work and summarises current knowledge on the subject of bitumen. The various applications for bitumen and their associated exposure risks are also given.

Special attention has been given to pointing out that tar and bitumen, despite their shared colour, have totally different toxicological properties, with tar no longer being used – either for hot-laid asphalt surfaces or for roofing.

This report is intended as the basis for a factual presentation of the uses of bitumen and bituminous products, and of the associated hazards. The laying of bitumen at lower temperatures is highlighted. This method reduces the risk to workers and the environment.

The report gives an insight into bitumen's various applications, techniques and possible exposure risks, as well as the extensive research carried out by the Forum. For more details, please refer to the BITUMEN Forum website at: www.gisbau.de/bitumen.html. It contains up-to-date figures and comprehensive reports on the different studies which have been carried out.

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The German BITUMEN Forum

The BITUMEN Forum identifies possible hazards and necessary protective measures when working with bitumen and bituminous products. The Forum contains representatives of all institutions and organisations which are themselves or through associated companies responsible for handling bitumen and bituminous products (see last page for addresses and contacts). This guarantees thorough investigation of the topic and makes the BITUMEN Forum the expert contacts as regards questions of industrial safety when handling bitumen and bituminous products.

The BITUMEN Forum was founded in 1997 at the suggestion of the Federal Ministry for Work and Social Services. It initiates and coordinates comprehensive research into exposure, possible hazards caused by bitumen or vapour and aerosols of bitumen, and necessary protective measures. This present report contains details of the results of the work of the Forum and facts about bitumen usually known only to experts and made available to interested members of the public.

Work in progress is also described, as are forthcoming projects.

The BITUMEN Forum is recognised both nationally and internationally. In 2003, the European Agency for Industrial Health and Safety awarded the Forum a Good Practice Commendation.

European Week for Safety and Health at Work
2003
'Dangerous substances - handle with care'
Good Practice Commendation
This certificate acknowledges the positive contribution that
Gesprächskreis BITUMEN
GERMANY
has made to preventing risks from dangerous substances at work in Europe.

Bitumen – what is it?

Bitumen occurs in nature as a component of asphalt (on the island of Trinidad, for example, where it occurs as a natural raw material in the form of an asphalt lake on the earth's surface) and asphalt rocks, formed over long geological periods by the evaporation of the low-boiling point component of crude oil. For this reason, bitumen consists mainly of carbon and hydrogen.

By far the greatest amount of bitumen used industrially is derived from mineral oil refining. It is the fraction of the crude oil remaining after distillation of the evaporated components. The manufacturing process results in distilled bitumen, high-vacuum bitumen, oxidation bitumen or polymer-modified bitumen. Small amounts of natural asphalt are also used in road construction.

Bitumen should not be confused with tar, which is a pyrolytic product (carbonisation product) produced during the heat treatment of hard or brown coal at 700 to 1,200 °C.

Bitumen types

The different types of bitumen and the major bituminous products are defined, with their terminology, in DIN EN 12 597. Most bitumen is used in road construction. In Germany, five grades of distillation bitumen (according to DIN EN 12 591) are used (table 1).

The figures give the bitumen hardness values. They indicate that the penetration of a bitumen type must lie between set limits, e.g. 160 and 220. The penetration is the entry depth in 1/10 mm into a bitumen sample by a nail after 5 seconds at 25 °C.

Distillation bitumen comes from distilling crude oil under low pressure at approximately 360 °C. High vacuum and hard bitumen are obtained from the further treatment of distillation bitumen. They are harder than distillation bitumen. Oxidation bitumens are produced by blowing in air at approximately 250 °C. They are described by two figures, the first being the average softening point (ring and ball method in accordance with DIN EN 1427), and the second the average penetration (DIN EN 1426) within set limits. For example: oxidation bitumen 85/25: softening point 80 to 90 °C, penetration 20 to 30 1/10 mm.

DIN EN 12 591
160/220
70/100
50/70
30/45
20/30

Table 1:
Bitumen grades according to DIN EN 12591

Polymer-modified bitumen (PmB) is obtained from chemical cross-linking of distillation bitumen with polymers.

In machine laid mastic asphalt some of the bitumen can be replaced by natural asphalt.The most popular form of natural asphalt in Germany, Trinidad asphalt, is recovered by open-cut mining from the "Pitch Lake" in Trinidad. Trinidad Epuré, which consists of about 55 % of bitumen and other minerals, is shipped in and used for asphalt work in form of ready for use granulate. Up to 2 % of this granulate may be added to mastic asphalt.

Bitumen and tar

The terms "bitumen" and "tar" are often used interchangeably, with little or no difference being seen between the two materials (Glet, 1996). Everything that is black is termed tar or, if the material is in liquid form, pitch. It is not appropriate to use these terms interchangebly whenn potential health effects from their use are under consideration. This tendency to use the terms interchangeably has resulted and continues to result in bitumen being associated with dangers which only occur with coal tar derivatives. This applies especially to polycyclic aromatic hydrocarbon content and accompanying benzo[a]pyrene (BaP).

The term "bitumen" has been strictly separated from "tar" since 1983. DIN EN 12 597 describes only bitumen and bituminous products.

Table 2 lists the (visual) similarities as well as the major differences between tar and bitumen.

	Tar, pitch	Bitumen
Colour	Black	Black
Origin	Coal	Crude oil
Manufacture	Pyrolysis	Distillation (non-pyrolytic)
BaP content	approx. 5,000 mg/kg (according to IARC up to 1.4 %!)	max. 5 mg/kg
Phototoxicity Reactions	Tar can cause skin damage and discolouration in association with sunlight	Not known for bitumen
Skin cancer	Tar-caused skin cancers are recognised as an occupational illness	Not known for bitumen

Table 2:
Tar and bitumen compared


Laying rolled asphalt – paver

The BaP concentrations during excavation of coal tars (50 to well over 100 µg/m³) and bitumen-bound mastic asphalt (0.099 µg/m³) show the differences between tar and bitumen quite clearly.

Uses of bitumen

Bitumen is a very ancient material. Even the Sumerians, Babylonians and Assyrians used it mixed with sand for a variety of purposes. The industrial use of bitumen began in the 19th century with the increase in motorised traffic. The uses of bitumen fall into two main categories: hot and cold processing. In cold processing, the bitumen is dissolved in solvent or used as an emulsion.

In the case of hot processing – e.g. manufacturing bitumen membranes – bitumen heated in stationary facilities is poured over a carrier material. These sheets can be processed at construction sites by torching using a torch, for example, or by insertion into hot bitumen. Hot liquid bitumen-based materials are also used for filling joints or gluing insulating materials.

Most bitumen, however, is used in asphalt road construction (Table 3). Rolled asphalt contains approximately 5 % bitumen as a binder and 95 % mineral materials. Aside from rolled asphalt, mastic asphalt is also used, for example, as a part of waterproofings, as a wearing course in road and bridge construction or as a screed in house and industrial construction. Mastic asphalt has a higher bitumen content (6.5-8 %).

Rolled asphalt should not be confused with mechanical laying of mastic (gussasphalt) such as that sometimes used in road construction. Typically the rolled asphalt application is accomplished at temperatures of approx. 160 °C (320 °F) while mechanical laying of mastic is accomplished at temperatures of approx. 250 °C (482 °F).

Some of the bitumen can also be replaced by Trinidad asphalt in machine laid mastic asphalt.

	1998		2005	
Rolled asphalt	2,500,000 to	74.5 %	2,387,000 to	79.2 %
Bitumen membrane	700,000 to	20.9 %	429,000 to	14.2 %
Cold bitumen	100,000 to	3.0 %	98,000 to	3.3 %
Mastic asphalt, manual application	32,000 to	1.0 %	18,000 to	0.6 %
Mastic asphalt, mechanical application	17,000 to	0.5 %	16,000 to	0.5 %
Hot bitumen	4,000 to	0.1 %	–	–
Other industrial applications			66.000 to	2.2 %
Total	3,353,000 to	100.0 %	3,040,000 to	100.0 %

Table 3:
Bitumen usage in Germany (tonnes per year and percent)

2-ring systems
Naphthaline
Acenaphthene
Acenaphthylene
1-Benzothiophene*

3-ring systems
Anthracene
Dibenzothiophene*
Fluorene
Phenanthrene

4-ring systems
Benz[a]anthracene
Benzo[b]naphtho-[2,1-d]-thiophene*
Fluoranthene
Chrysene

5-ring systems
Benzo[a]pyrene (BaP)
Benzo[e]pyrene
Benzo[b + k]fluoranthene
Dibenz[a,h]anthracene
Pyrene

6-ring systems
Benzo[g, h, i]perylene
Indo[1, 2, 3-cd]pyrene

Figure 1:
PAH and S-PAH in bitumen and Trinidad Epuré*

Asphalt mixing plant

Emissions of bitumen

Bitumen consists of several hundred materials, a mixture of higher hydrocarbons and heterocyclic compounds (hydrocarbons with other atoms such as sulphur, nitrogen or oxygen). As a result, sulphur (up to 8 mass %), nitrogen (some 0.5 mass %) and oxygen (1-2 mass %) are also components of bitumen, in addition to carbon and hydrogen.

The subject most discussed is the amount of polycyclic aromatic hydrocarbons (PAH; Fig. 1). That is why the Bitumen forum initiated a study into the PAH component and that of some sulphurous or nitrogenous PAHs (S-PAH and N-PAH) in the bitumen used in Germany and in Trinidad Epuré.

The PAHs investigated were the same as those chosen by the US environmental authority EPA, and are regarded worldwide as carrier substances for this group (EPA PAH).

Table 3 shows the usual content of PAHs and some S-PAHs in the bitumen varieties used in Germany. The nitrogenous N-PAHs acridine, benzo[h]chinoline and 2-naphthyl-

Bitumen type	Content (mg/kg)		Emissions (at 180 °C)		
	EPA-PAH	BaP	Total (mg/h)	EPA-PAH (µg/h)	BaP (µg/h)
H 90/100	30.0	1.2	6.6	26.9	0.1
30/45	29.8	2.1	13.0	22.7	0.1
50/70	26.7	1.7	2.2	3.7	nn
70/100	25.6	1.4	3.5	17.0	nn
160/220	32.1	1.8	7.0	25.1	nn
85/25	52.2	1.7	25.1	52.9	0.2
95/35	93.5	2.7	37.2	79.0	0.3
Trinidad Epuré	33.8	2.0	42.6	10.3	0.1

Table 4:
Content and emissions (180 °C) of PAHs and S-PAHs from Fig. 1 in different bitumen types and Trinidad Epuré in laboratory tests on a 100 g sample (nn: not detected)

amine were not detected in any test.

At temperatures below 80 °C (176 °F), there are virtually no emissions of bitumen; even at 150 °C (302 °F), emissions are only about 1 mg/h. Significant emissions were recorded at 180 °C (356 °F). Emission rates for PAHs and S-PAHs at 180 °C (356 °F) from a 100 g sample are also given in Table 2. Higher emissions occurred at 250 °C (482 °F) (laying temperature of mastic asphalt). The research reports can be found on the Forum's website www.gisbau.de/bitumen.html.

Bituminous damping pads

Bituminous damping pads (20-30 % bitumen; car body sound deadening systems) are used in motor vehicles to dampen body vibrations. Emissions from these pads have been investigated at realistic temperatures.

PAH air measurements were made under standardised conditions in an enclosed, 3.64 m^3 recirculating air cabinet at oven temperatures of 60, 80, 100 and 120 °C (140, 176, 212, and 248 °F) for 4 hours. A complete 12.02 kg set of damping pads as used in the passenger compartment of a car was used at each temperature stage. The measured PAH concentrations in most pads were around or slightly above the detection limit. Benzo[a]pyrene (BaP) of 0.05-0.09 µg/m^3 were recorded at 80-120 °C (176-248 °F) oven temperature. Dibenzo[a,h]anthracene, the component with the highest cancer-causing potential, could only be detected at a temperature of 120 °C (248 °F) in the aerosol phase in the test threshold range. In the case of naphthaline, the highest concentration of 16.5 µg/m^3 was measured at 120 °C (248 °F).

The report of the study commissioned by CWW Gerko-Akustik GmbH can be found on the Forum website www.gisbau.de/bitumen.html.

In another test, the emission ratios from hot mastic bitumen cast pads were simulated in a dry oven under the above conditions. The temperatures and time periods used in the car manufacturer's plant formed the basis of the test series. The maximum temperature during a sampling period of 240 mins was 190 °C (374 °F).

The test showed PAHs are emitted above 125 °C (257 °F). Tempering times of 25 to 100 mins had no significant effect on concentration levels. Significantly increased PAH emissions were recorded at 240 mins, mainly easily volatilised PAHs, especially naphthaline. Less easily volatilised PAHs such as BaP were recorded not at all or only at the test limit.

As expected, increasing the temperature from 125 °C (257 °F) to 190 °C (374 °F) during a tempering time of just 25 mins increased PAH emissions significantly. There was,

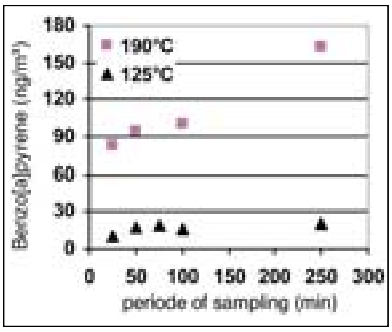


Figure 2: BaP emissions from bituminous damping pads

for example, a concentration increase of some 170 % for all PAHs recorded.

Measurements taken during the testing of time-dependent emissions at a constant temperature of 125 °C (257 °F) show a linear dependence (Fig. 2) in the case of total PAH or naphthalene emissions. Benzo[a]pyrene emissions do not exhibit this linearity because at the above temperature, the tendency for these components to evaporate is insignificant. Concentrations lie in the region of the test threshold and were subject to wide variations.

Tests carried out at a constant max. 190 °C (374 °F) showed comparable linearity, but with considerably higher emissions. A linearity of emitted PAH components in relation to tempering times was also established during these tests, and in this case included benzo[a]pyrene (Fig. 2). Over a sampling time of 240 mins, the naphthalene concentration was approximately 54 µg/m^3, and the benzo[a]pyrene concentration 164 ng/m^3.

The full report of this study financed by Daimler Chrysler AG can be found on the Forum's website www.gisbau.de/bitumen.html.

Exposure during bitumen application

Exposure to vapour and aerosols of bitumen during the processing of bitumen or bituminous products depends on the end-use application and especially upon the temperature of application.

As no measurable emissions occur below 80 °C (176 °F), no vapour and aerosols of bitumen come into the equation during cold pro-

Process	N	95%-value
Production of bitumen	17	2.6 mg/m^3
Production of asphalt		
Control centre	8	0.8 mg/m^3
External area	6	0.7 mg/m^3
Inside the asphalt plant	52	30.7 mg/m^3
Transport of asphalt	14	4.3 mg/m^3
Using rolled asphalt in road building		
Paver operator	115	6.5 mg/m^3
Screed operator	141	10.4 mg/m^3
Roller driver	42	2.6 mg/m^3
Working with joint fillers	40	4.1 mg/m^3
Manual work with mastic asphalt		
Charger on the mixer, outdoors	50	14.6 mg/m^3
Charger on the mixer, indoors	49	24.1 mg/m^3
Transporting in a barrow, indoors	73	49.6 mg/m^3
Transporting in a bucket, indoors	75	7.7 mg/m^3
Smoothing, indoors	227	34.0 mg/m^3
Smoothing, outdoors	20	8.1 mg/m^3
Mechanical laying of mastic asphalt		
Charger on the mixer, outdoors	64	57.8 mg/m^3
Charger on the mixer, indoors	9	22.9 mg/m^3
Screed operator, outdoors	90	38.2 mg/m^3
Screed operator, indoors	22	40.2 mg/m^3
Gritter, outdoors	6	3.9 mg/m^3
Smoother, outdoors	46	10.0 mg/m^3
Smoother, indoors	17	6.5 mg/m^3
Production of bituminous damping pads	10	5.4 mg/m^3
Production of bitumen sheeting	37	4.3 mg/m^3
Roofing work		
Torching of bitumen sheeting	80	8.8 mg/m^3
Pouring of hot bitumen (outdoors)	102	9.8 mg/m^3

Table 5:
Exposure to vapour and aerosols of bitumen (95-percentile-value and number of measurements)

cessing. There is only the possibility of soiling the skin through direct contact with bitumen dissolved in solvents or dispersed in water. During hot processing, the bitumen is heated, so vapour and aerosols are released. The level of emissions depends on the working temperature which, in the case of rolled asphalt, up to 180 °C (356 °F) as compared to mastic asphalt, up to 250 °C (482 °F).

The exposures given in Table 5 were taken from more than 1,000 measurements in the workplace. Measurements were made using the GGP system. At a flow rate of 3.5 L/min, the aerosols were adsorbed in a 37 mm fibreglass filter, and the vapour in 3 g Amberlite™ XAD-2. The filter and XAD-2 were leached with tetrachlorethylene and analysed using IR.

The exposures in the table should be regarded as maximum values because the test method also covered other hydrocarbons (e.g. from road traffic).

Tests carried out into exposure to polycyclic aromatic hydrocarbons yielded values of max. 0.5 $\mu g/m^3$ benzo[a]pyrene.

The amount and the nature of exposures can be reduced significantly in rolled asphalt and mastic asphalt work, if lower temperatures are used (see "Lowering the working temperature of asphalt").

Thresholds for vapour and aerosols of bitumen

Autumn 1996 saw the first thresholds for airborne vapour and aerosols of bitumen laid down for hot processing in Germany: the levels for processing in enclosed areas were 20 mg/m^3 and 15 mg/m^3 for all other work.

As the database used to establish the thresholds was created in a hurry and was lacking data in some areas, the BITUMEN Forum coordinated workplace testing to form the basis of a comprehensive picture of exposure to vapour and aerosols of bitumen during hot processing.

The test results are recorded in 11 exposure reports (Table 6).

The relationships in the reports show that the division of thresholds into inside and outside work is not justified. It is clear that exposure below 10 mg/m^3 occurs in almost all bitumen workplaces except during mastic asphalt work (Table 5).

The test results were used by the German Committee for Hazardous Substances, at the suggestion of the Bitumen Forum, to set new thresholds in May 2000 for vapour and aerosols of bitumen during hot processing at 10 mg/m^3. The explanation of threshold values is as follows:

Paver with driver and bar guide

Manufacturing bituminous damping pads
Gap-filling with hot bitumen
Hot working of bitumen in pouring work
Torching of bitumen membrane
Manufacturing and transporting bitumen
Manufacturing and transporting asphalt
Working with rolled asphalt in road construction
Working with mastic asphalt by hand in domestic and industrial construction
Mechanical processing of mastic asphalt
Manufacturing bituminous roof and sealing sheets

Table 6:
Description of exposure to vapour and aerosols of bitumen (available on Forum website www.gisbau.de/bitumen.html)

"The airborne thresholds for mastic asphalt work are only provisional. There was a discussion of these thresholds again in autumn 2002. New test results for mastic asphalt work were to be received in June 2002. Paver drivers and gang foremen engaged in road construction experience concentrations up to as much as 12 mg/m^3 (state of the art) because of wide variations in weather conditions. The regulatory authorities are recommended in these cases to tolerate test results for paver drivers and gang foremen up to 12 mg/m^3."

The German Committee for Hazardous Substances recognised that lower levels of exposure during laying of mastic asphalt work were not achievable.

The main reasons for the German Committee for Hazardous Substances tolerating relatively high exposure levels was the undertaking to monitor these workers closely (see "Occupational medical care of mastic asphalt workers" and "Human bitumen study") and the expectation that significantly lower exposure levels could soon be expected during this kind of work by mastic asphalt at lower temperatures (see "Lowering the laying temperature of asphalt").

At the request of the Forum, the 2002 Committee for Hazardous Substances agreed to delay implementation of the threshold until 2007. From 2008, exposure levels to vapour and aerosols of bitumen, including during mastic asphalt work, must be the same as the other values applying to work with hot bitumen.

These thresholds for airborne vapour and aerosols of bitumen during hot processing were based on the technology, that is, on the current state of the art. The Minimisation Law applies to such substances as it is not clear whether maintaining such thresholds might not still result in health problems for affected workers.

The new German Hazardous Substances Decree meant that from 1 January 2005, all technology-based thresholds were set out, including the thresholds for vapour and aerosols of bitumen during hot processing.

The Bitumen Forum has also matched all exposure descriptions to the new legislation. The main point was that (except for mastic asphalt work), work can continue without the need for further protective measures. The exposure reports for mastic asphalt work state that exposure levels are too high and that the material should be processed at lower temperatures.

The exposure reports are available in German and English on the Forum's website. These reports enable the employer to carry out a risk assessment without the need for more tests.

Dr. Rainer Arndt from the Federal Institute for Occupational Health and Safety has expressly welcomed this procedure: "It is gratifying to see that the BITUMEN Forum has grasped the intention of the new Hazardous substances decree so rapidly. The exposure reports address exposure to substances without thresholds as well as protective measures. Help is at

Laying rolled asphalt – roller

hand for employers in reducing the damage to their employees' health at work. It is also a positive sign that attention is being given to using low-temperature asphalts."

Manufacturing and transporting bitumen

Bitumen is manufactured at 9 refineries in Germany. Manufacture takes place in closed plants, with loading also occurring in a closed facility right up to the material's exit from the filling pipe. Exposure is only possible when taking samples (about three samples per shift) and when opening the tanker or other vehicle and introducing the filler pipe.

Bitumen is fed into road tanks via a closed system and transported at temperatures (about 200 °C, 392 °F) below the flash point. During processing, the bitumen is also pumped into the storage tank along closed piping systems.

Manufacturing and transporting asphalt

Asphalt is mainly produced in stationary asphalt mixing plants (in Germany, there are about 700 such plants, usually medium-size operations).

The mineral materials – except the filler – are dried in drums and heated to slightly above the processing temperature of the mix being manufactured (190 to 300 °C, 374 to 572 °F). The heated mineral materials are sieved by size, stored temporarily in silos above the mixer, then fed into the mixer to suit the required composition for individual charges. The temperature of the mineral materials must be higher than the processing temperature because the filler is added cold – prewarmed in some cases to 80 - 100 °C, 176 to 212 °F. The different types of bitumen are stored as hot liquids (at temperatures below 200 °C, 392 °F) in tanks and are then fed into the mixer.

Rolled asphalts are transported to the construction site hot, either in closed heated vehicles or in trucks covered by tarpaulins.

Mastic asphalt is transferred into heated mixers directly after manufacture and taken to the construction site. The mixers have thermostatically-controlled heaters. The drivers have to ensure that the temperature of the mastic asphalt does not exceed the optimal processing temperature. This depends on the bitumen used and the hardness class for mastic asphalt required by the application. Optimal temperatures lie between 230 °C (474 °F) for mastic asphalt with bitumen 30/45 (for road construction or general use outdoors) and 250 °C (482 °F) for mastic asphalts with hard bitumen (for use as screed).

Laying rolled asphalt

Rolled asphalt – the classic road material – is produced in Germany by about 3,000 mainly medium-sized companies. Rolled asphalts (working temperature up to 180 °C, 356 °F) are used mainly out of doors, and are usually laid by pavers for roads, paths, parking lots and runways, and also as coastal protection, damns and reservoirs, and to seal waste disposal sites. Rolled asphalt is also used occasionally in large halls. The asphalt is poured directly from the truck into the paver's bucket.

The asphalt is spread on the road surface and pre-compacted by the paver with the aid of a heated screed. After laying, the asphalt surface is compacted by rollers.

The paver is controlled by the driver (also called operator) from an open, raised platform above the screed. The exposure level of the paver driver depends mainly on wind strength and direction, and is subject to a wide range of variations. Efforts in Germany to protect the driver from vapour and aerosols of bitumen by cabins or other measures have not proven successful. As the paver movement needs to be checked continuously, the driver needs sufficient freedom of movement and a clear view. A cabin cannot provide this unless it is extended out over the paver. The driver's freedom of movement would then be very limited. In addition, the windows would become dirty very quickly, leaving the driver with no view of the bar, etc. Furthermore installing cabins would only be possible after an appropriate development time, and then only for new pavers. The existing 4,000 or so pavers could not be retrofitted, so any cabins would only protect a fraction of drivers.

Concentrations of vapour and aerosols of bitumen when working with rolled asphalt are very dependent on weather conditions; wind direction and strength are especially important when it comes to worker exposure. Paver drivers and gang foremen are exposed most. Exposure by the roller driver is far less (below 3 mg/m^3), because the asphalt has already cooled by the time it is compacted.

Laying mastic asphalt

Mastic asphalt screeds are used as flooring in production halls, parking decks and in homes. The work is carried out by around 100 mainly SMEs. The mastic asphalt is transported from the mixing plant to the site in heated mixers.

Where it is laid by hand, the asphalt is transported from the mixer to the location in wooden buckets, heated dumpers (small diesel-driven transporters) or using barrows. The buckets are taken to the location and emptied there. The dumpers usually drive up close to the location, where the asphalt is transported the rest of the way in barrows. The asphalt is distributed by hand and smoothed using a smoothing board.

When laid mechanically, the mastic asphalt is distributed from the mixer directly in front of the paver. Heated screeds are used.

Because of the higher laying temperature of approximately 250 °C (482 °F), concentrations of vapour and aerosols of bitumen are higher with mastic asphalt than with rolled asphalt. Exposure levels are 10 mg/m^3 when emptying the mixer for manual laying and when transporting in buckets.

The emptying of dumpers in enclosed areas (approximately 30 mg/m^3) is, like transport in barrows (more than 50 mg/m^3), associated with considerably higher levels of exposure.

During smoothing in enclosed areas, the exposure level is about 35 mg/m^3, as opposed to below 10 mg/m^3 in the open air. Aside

Smoothing the mastic asphalt

from the amount of ventilation, the working temperature and the effects of the separating agent also play an important role during manual laying of mastic asphalt.

Where machinery is used, the relatively large amount of mastic asphalt and the high laying temperature result in even greater exposure to vapour and aerosols of bitumen (up to 60 mg/m^3).

Joint pouring with hot bitumen

Joints between concrete areas are filled with hot bitumen. Bitumen is transported by a hose line from the bitumen kettle to a spray valve. The worker is spraying the bitumen directly into the joints.

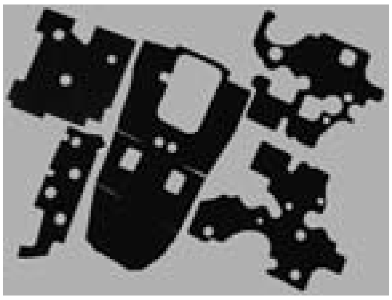
Bitumen temperature is between 160 and 170 °C (320 to 338 °F). Worker exposure using these processes is very low (approximately 4 mg/m^3).

Manufacturing bituminous damping pads

Bituminous damping pads are used in vehicles to dampen bodywork vibrations. The pads are manufactured in partially enclosed, ventilated production lines.

The bitumen is mixed with additives at about 160 °C (320 °F), and the mixture hot-rolled as pads at about 130 °C (266 °F) , fitted with adhesive and varnished, then stamped. Worker exposure using these processes is very low (approximately 5 mg/m^3).

Torching of bitumen membrane



Bituminous pads for cars

Manufacturing bitumen membrane

The manufacture of bituminous and polymer-modified bituminous roofing membranes and waterproofing sheets (referred to below as bitumen membranes) represents the second-largest application for bitumen, following road construction. Bitumen membraneing is manufactured in some 25 medium-sized companies in partially enclosed, ventilated production lines.

The bitumen is mixed with additives at about 160 °C (320 °F), and the mix transferred to the carrier layer at about 180 - 190 °C (356 - 374 °F). The finished sheeting is cooled in a cooling room and packaged. Worker exposure using these processes is very low (approximately 4 mg/m^3).

Roofing

Bitumen membranes are used mainly by roofing contractors (there are about 13,000 roofing companies, most of them with fewer than 10 employees). These days, the membranes are jointed by torching or using peel and stick or pour and roll techniques.

Torching of bitumen membrane

The torching method involves the sheeting being melted using a propane burner (hand burner or mechanical welder, working temperature about 200 °C, 392 °F), then glued to the base. The exposure level is about 9 mg/m^3.

No heating is involved using the peel and stick method or mechanical fastening such as with nails; no vapour and aerosols of bitumen are released.

Use of hot bitumen with pouring method

In the pouring method, bitumen at a temperature of about 200 °C (392 °F) is poured onto the surface to be protected. The sheeting is laid on top of the hot mass.

Pouring of hot bitumen

Insulating materials such as expanded glass are glued using hot, liquid bitumen in the same way as with cast bitumen (approximately 4,000 t bitumen per year). The hot bitumen is poured from cans and the expanded glass blocks laid in the liquid mass.

Measurements taken for bitumen membrane and insulating materials indicate that the pouring method using cans in the open air results in exposure of about 10 mg/m^3. Here, the aerosol component is considerably higher than with torching.

The earlier method of painting hot bitumen on as a roof seal is no longer used.

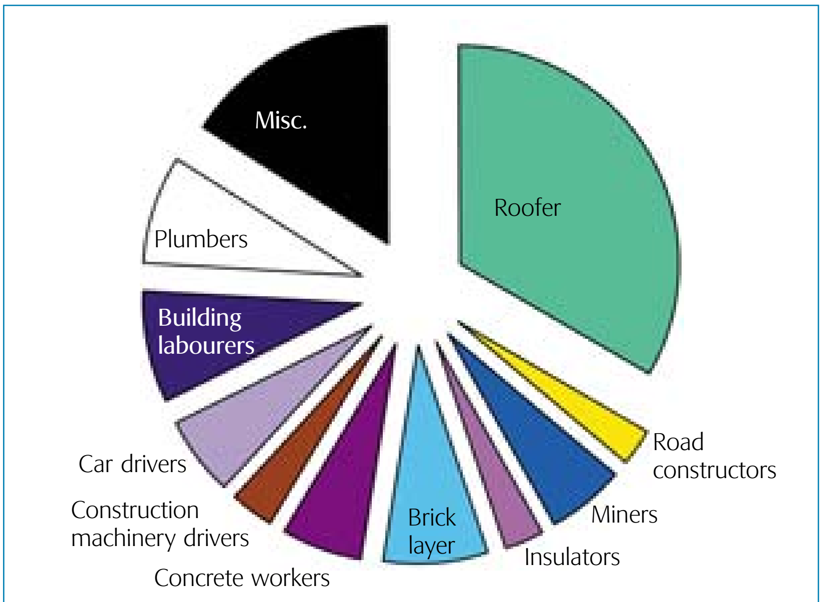


Figure 3:
Burns from bitumen per profession

Burns from hot bitumen

Bitumen is one of the few materials to be processed when hot. It is, of course, known that one can be burnt at the kettle as well as by hot bitumen. Nevertheless, the latter is increasingly common. Fig. 3 provides a summary of bitumen burns for the years 2000 and 2001 (total of 386 cases). Most burns of this kind involve roofers.

Roofers use open gas burners for torching bitumen membraneing, or use hot bitumen. The liquid bitumen is transported from the heater to the usage point in cans or buckets.

The graph only shows burns which resulted in at least three days off work. The many burns caused daily by hot bitumen are not included in the statistics.

Appendix I

Lowering asphalt laying temperature

The laying of asphalt at lower temperatures is the result of developments in the material used as road and bridge surfaces, and as a screed. A small admixture makes it possible to use the material at temperatures of 20 to 40 °C (68 to 104 °F) lower than with traditional rolled or mastic asphalt. This reduction in temperature translates into energy savings and a subsequent reduction in CO_2 production, less wear on mixing equipment and less ageing of the bitumen, not to mention a more important reduction in worker exposure when laying asphalt.

The laying temperature of asphalt can be lowered in a number of ways. For example, the laying temperature of rolled asphalt can be lowered by the addition of a zeolite. This zeolite is used in great quantities as a phosphate substitute in detergents. Zeolites give off water vapour between 100 °C (212 °F) and 200 °C (392 °F) . This has a foaming effect which improves the malleability of the coated material. This makes it possible to lay asphalt at temperatures considerably lower than usual (approximately 30 °C, 86 °F).

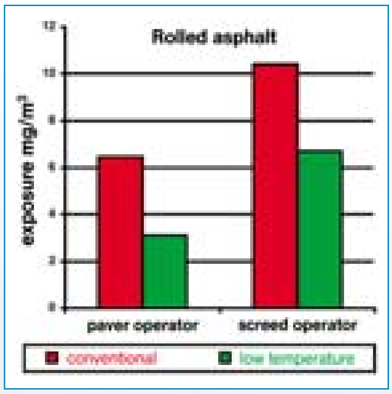
Other methods for lowering the laying temperature result from the addition of organics such as amide waxes or paraffins. This method can be used not only with rolled asphalt, but also with mastic asphalt, which can then be worked at temperatures below 210 °C (410 °F).

Where low-temperature asphalts (in the US "warm mix asphalt") are used, there is significantly less "blue smoke" at the site, yet the asphalts remain easy to work.

Advantages of laying at reduced temperatures

The BITUMEN Forum considers that its most important task is the promotion of the development and use of asphalt at reduced temperatures. The asphalt industry expects this development to result in:

- fewer vapours and aerosols;
- lower emissions at the mixing plant;
- lower energy consumption;
- lower equipment wear;
- reduced CO_2 production;
- minimal ageing of binders during production and laying
- improved usage characteristics for asphalt.



Thus, the use of asphalt at reduced temperatures is not only the ideal way towards work safety, but an innovation for the use of asphalt.

In spring 2006, the German Research Organisation for Road and Traffic e.V. (www.fgsv.de) published a leaflet on reducing the temperature of asphalt. This leaflet gave the authorities (e.g. road construction officials) the opportunity to invite tenders for these asphalts. The leaflet is described in the appendix V.

Significantly lower risk to workers

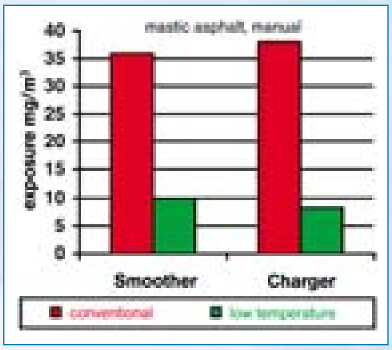
Rolled asphalts can be laid at approximately 130 °C (266 °F) (instead of 160 °C, 320 °F) and mastic asphalts below 210 °C (410 °F) (instead of 250 °C, 482 °F). These temperatures result in significantly reduced exposure of workers (the diagrams show this with 95-percentile values for many measurements). In the case of rolled asphalt, existing exposure levels of less than 10 mg/m^3 are reduced even more.

In the case of mastic asphalt, the improvements are outstanding, achieving levels which would have been unthinkable just a few years ago. The German Committee for Hazardous Substances had set out the thresholds for this kind of work, as neither extractors nor personal protective equipment such as breathing apparatus or ventilated helmets could be used effectively. Exposure levels below 10 mg/m^3 are achievable at lowered temperatures.

From a work-safety perspective, low-temperature asphalts are an ideal means of protecting workers handling hot asphalt. The Federal Ministry for Economics and Labour (BMWA) agrees and honoured the companies Mitteldeutsche Hartstein Industrie AG and Wilh. Schütz GmbH & Co. KG in autumn 2002 with the German Hazardous Substances Prize for their developments in the area of low-temperature asphalts.

Less wear

Bitumen is the final fraction obtained from crude oil distillation. This distillation process is carried out carefully so that the bitumen is not altered (cracked). The bitumen should not be heated too much during asphalt manufacture, either, so it does not "age" and so its characteristics remain unchanged. This is guaranteed with asphalt laid at reduced temperatures. And obviously, there is less wear on asphalt mixing facilities if the mixing temperatures are lower.



Energy saving and fewer exhaust gases

The energy required when lowering the mixing temperature by 30 to 35 °C (86 to 95 °F) is reduced by 0.8 litres heating oil/tonne asphalt. Given the 60 million tonnes of asphalt manufactured in Germany, this means potential energy savings of almost 50 million litres per year.

There is also an enormous potential for reducing CO_2 production. The 60 million tonnes of asphalt produced in Germany per year produce 1.5 million tonnes of CO_2. Low-temperature asphalt would mean some 125,000 tonnes less CO_2 per year in Germany.

Improving usage characteristics

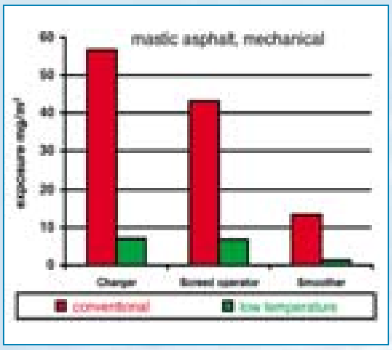
Happily, low-temperature asphalts have improved usage characteristics. Aside from high compressibility during laying, these asphalts also exhibit greater resistance to deformation and, in the case of mastic asphalt, the load stability is far greater.

Divisional Manager Dr Cornelia Fischer (BMWA) conferring the German Hazardous Substances prize on Walter Barthel (MHI) and Ottmar W. Schütz (Schütz).

Disadvantages of reduced temperatures?

Asphalts laid at reduced temperatures cost about 50 % more than conventional asphalts. When one takes the energy savings into account, the conservation of equipment and the improved usage characteristics, these additional costs should be compensated for to some extent.

The greatly reduced exposure of workers as a result of lower emissions is reflected more in greater "work satisfaction" than in financial ways.



Examples of laying asphalt

The following construction sites demonstrate the possibilities offered by laying asphalt at reduced temperatures. Contact people and further information can be found on the Forum's website.

Asphalt stands up to containers

Container storage spaces have to withstand enormous static loads, especially where containers are stacked on top of each other. Asphalt laid at reduced temperatures has higher resistance to deformation in addition to its other positive characteristics.

This is why, in 1997, asphalt for the container area in the Hoechst industrial park near Frankfurt was laid at reduced temperatures. Nine years later, the asphalt was still standing up to the enormous demands on it quite satisfactorily.

Asphalt stands up to containers

Bridge surfaces are conserved by reduced temperatures

Reduced temperatures conserve bridge surface coatings

In August 2001, the A4 motorway was upgraded at the Rodenkirchen bridge near Cologne. As the bridge has a temperature-sensitive surface coating, laying temperatures for the road surface had to be as low as possible. This was achieved with a mastic asphalt which could be laid at 220-230 °C (428-446 °F). Workplace measurements taken during laying showed that workers were subjected to exposure levels below 10 mg/m^3. These values are considerably lower than those taken when standard mastic asphalt is used (in excess of 50 mg/m^3).

The upgrading of the Rodenkirchen bridge was based on experiences from 1997, when mastic asphalt was laid at reduced temperature at the Gruenewald bridge on the A59, also because of a temperature-sensitive surface coatings.

Laying temperature of mastic asphalt at 205 °C (401 °F)!

Low-temperature mastic asphalt works also at smaller construction sites.

Near Frankfurt in November 2001 mastic asphalt was laid at 205 °C (401 °F) at minor repairs.

at reduced temperatures

Despite this low temperature the mastic asphalt could be laid without any problems. The exposures were always below 2.7 mg/m^3.

For the future, laying temperatures below 200 °C (392 °F) seem to be possible for mastic asphalt.

Reduced-temperature asphalts in France

Reduced-temperature asphalt is not only used in Germany – the technique is also employed abroad. Asphalt was laid at Orly near Paris at normal (160 °C, 320 °F) and reduced temperatures.

Despite rain and an outside temperature of 11 °C (52 °F), there were no problems laying the asphalt at 140 °C (284 °F). Exposure levels were significantly lower at the lower temperature.

Road-laying at reduced temperatures in France

Danish countrymen lay mastic asphalt at reduced temperatures

Acid-resistant mastic asphalt laid at reduced temperatures has been used for eight years in Denmark as an industrial screed at stables and milking sheds. The mastic asphalt is produced in Hamburg and transported in heated vessels more than 100 kilometres to sites in Denmark, including Danish islands such as Fanø.

The rheological characteristics of the binder in asphalt change very little despite the hours of transport, and the asphalt can be worked without problems.

The higher material costs for these mastic asphalts are compensated for to a large extent by energy savings and less wear on the transport vessels.

Road-laying at reduced temperatures at Fernpass

Fernpass upgraded with low-temperature asphalt

The road construction section of the Tirol regional government called for tenders in 2004 for low-temperature bitumen to upgrade parts of the Fernpass. The asphalt was supplied to Austria by a Bavarian asphalt mixing plant.

The sections to be upgraded were at a height of more than 1,800 me-

Examples of laying asphalt

Frankfurt runway upgraded at reduced temperature

tres. The surface was laid at temperatures of 128-135 °C (263-275 °F). The new stretches could be opened to road traffic just 20 minutes after laying.

Runways upgraded only with low-temperature material

Frankfurt Airport decided to renew its, in part, 35-year-old northern takeoff and landing runway. The four kilometre long, 60 metre wide runway has to withstand some 200,000 takeoffs and landings each year. Aircraft use the runway each morning from 6 am. At that time, the new asphalt surface had to have cooled to at least 80 °C (176 °F). This could only be achieved with low temperatures (120 to 130 °C, 248 to 266 °F).

The runway was replaced in about 300 individual sections, with an asphalt surface thickness of 60 centimetres. Work started at the site at 22:30 and ended at 06:00 the next morning. Normal takeoffs and landings continued.

The new technique has since been adopted by other airports. In 2004, the Airbus takeoff and landing runway at Hamburg's Finkenwerder Airport was upgraded using 135 °C (275 °F). Work took place during the first weekend in October, with five mixing plants supplying the asphalt.

Reduced temperature keeps the peace

Workers at a Bonn underground parking station complained to other unionists about the vapour and aerosols released during mastic asphalt work. So the manufacturing of the mastic asphalt had to be stopped in April 2003.

The problem was resolved by laying mastic asphalt at reduced temperatures. No-one complained. Even though the temperature was only reduced slightly (240 instead of 250 °C, 464 instead of 482 °F), exposure levels were all below 13 mg/m^3.

Warm Asphalt Mix (WAM) in the USA

A delegation from the National Asphalt Paving Association (NAPA)

Fewer emissions through reduced temperatures

at reduced temperatures

and the National Institute of Occupational Safety and Health in the USA held discussions in August 2002 with representatives of the German Asphalt Federation and the BITUMEN Forum on the use of asphalt at reduced temperatures.

At the 48th meeting of the American Asphalt Federation in January 2003, several German delegates reported on "Warm Asphalt Mix" (WAM). This is the name given in the US to asphalt laid at reduced temperatures, as opposed to normal hot-mix asphalts.

The US Federal Highway Administration reports on WAM on their website (www.fhwa.dot.gov/pavement/wma.htm).

Even the trade press in the USA took up the subject. This led to "Will North America Love Warm Mix?" in Better Roads (www.betterroads.com/articles/jun04e.htm) and in Southeast Construction, "Warm-mix asphalt heats up" (http://southeast.construction.com/features/archive/0507_feature5.asp)

Slovenia also goes for low

Normal and low-temperature rolled asphalts were laid in October 2005 in Slovenia. When conventional asphalt (168 °C, 334 °F) was laid, the paver driver was exposed to 3.8 mg/m^3 and the bar

Low-temperature asphalt in Slovenia

guide to 9.4 and 2.7 mg/m^3. With 143 °C (289 °F) asphalt, exposures were 2.8 and 5.1 or 2.7 mg/m^3.

BASt promotes laying at reduced temperatures

In May and September 2004, test stretches of the A 7 and B 106 were laid with rolled asphalt at reduced temperatures. The Federal Institute for Roads (BASt) and the Forum promoted this use.

Exposure levels on the A 7 were below 2 mg/m^3, and on the B 106 at max. 5 mg/m^3. The rolled asphalt was laid at temperatures below 140 °C (284 °F).

Laying at reduced temperatures on the A 7

Appendix II

Cold-processed bituminous products

Cold bituminous adhesives

In addition to their use in road construction, cold-processed bituminous products are used for sealing and protecting of buildings. They can be laid by smoothing, coating, rolling or spraying, out of doors or in enclosed spaces.

The products involved are liquid bituminous emulsions, some with hydraulic powder components, or solvent-containing bituminous products. Some 100,000 m^3 of cold-processed bituminous products were used in Germany in 1997, mostly solvent-free bituminous emulsions (about 85 %).

One example of the use of cold-processed bituminous products is for sealing external cellar walls with bituminous coatings – mostly during house construction. Bitumen is often applied for better adhesion before bitumen membrane are installed. Cold bituminous adhesives are used for gluing roofing sheeting, damping pads and the like.

Exposure to vapour and aerosols of bitumen plays no role in the cold-processing of bituminous products, although solvent exposure is a factor with solvent-containing products.

BBP 10	Bituminous emulsions
BBP 20	Bituminous compounds, low in aromatics, containing solvents
BBP 30	Bituminous compounds, low in aromatics, high in solvents
BBP 40	Bituminous compounds, low in aromatics, harmful to health, containing solvents
BBP 50	Bituminous compounds, low in aromatics, harmful to health, high in solvents
BBP 60	Bituminous compounds, high in aromatics, harmful to health, containing solvents
BBP 70	Bituminous compounds, high in aromatics, harmful to health, high in solvents

Table 7:
GISCODE for cold-processed bituminous products for construction site sealing

GISCODE

A GISCODE subdivides cold-processed products for worksite sealing according to solvent content and aromatic solvents (Table 7). The GISCODE is included on drums, in safety sheets and technical leaflets. WINGIS supplies information on safe handling (www.gisbau.de).

Safety gloves

At the request of the BITUMEN Forum, the Industry Association of German Construction Chemistry has advised on the kinds of safety gloves to be worn when handling solvent-containing bituminous products and bituminous emulsions. In the case of cold-processed, solvent-containing bituminous products, Best Nitri-Solve 730 and KCL Camatril velours 730 gloves are recommended, and for cold-processed bituminous emulsions, Ansell Edmont Sol-Knit 39-222, Best Nitri-Solve 730 and KCL Camatril velours 730. The complete test reports can be found on the Forum's website www.gis-bau.de/bitumen.html.

Solvent explosions

The use of solvent-containing bituminous coatings in enclosed areas followed by attempts to torch bitumen membranes using gas burners has led to serious accidents and even death.

Even laymen should know that flammable products cannot be used in enclosed spaces, especially if subsequent work is to be carried out using naked flames.

Drum with cold bituminous product

Where bituminous products are employed in enclosed spaces, solvent concentrations can remain for some time well above the permitted workplace thresholds. The air can also contain an explosive mix. Tests have shown that an explosive atmosphere can re-establish itself even after an explosion has taken place.

There are safe bituminous emulsions for these applications, which should at least be used in enclosed areas. The use of solvent-containing products is not only life-threatening but is unnecessary from a technical point of view and ultimately uneconomic, because solvent concentrations have to be determined, ventilation systems installed and breathing apparatus probably worn. Manufacturers must decide whether solvent-containing paints used inside silos should continue to be available, given the circumstances.

The following example shows how workers and operations can be affected, even in nonfatal cases.

- *In summer 2001, the owner of a roofing company brought his employee to a site around 1 pm and arranged to collect him later in the afternoon.*

  A 15 m^2 windowless cellar had to be primed with bitumen, then bitumen membrane torched. A solvent-containing bituminous coating was first applied to the floor and about 15 cm up the walls. After it had been allowed to dry for 1 hour,

Cold-processed bituminous products, GISCODE

a burner was lit outside and brought into the room. A muffled explosion followed.

The accident insurance considered this a case of gross negligence on the part of the company and claimed the treatment costs (about 53,000 €) back from the company.

The Hanau district court found in favour of the accident insurance. The Frankfurt am Main court of appeal rejected the owner's appeal against the original judgement. Both courts rules that the company "had neglected to provide any protection in relation to the material used" and stated that the victim had been under huge time pressure (because the work had to be completed in the shortest possible time).

Appendix III

Study of cancers in asphalt workers

The International Agency for Research on Cancer (IARC) in Lyon, France, has been carrying out the international bitumen cohort study since 1992. France, Holland, Finland, Norway, Denmark and Israel are taking part in this study (Fig. 4). In Germany, the University of Bremen and the Bremen Institute for Prevention Research and Social Medicine (BIPS) are responsible for conducting the study under the guidance of Prof. Ahrens (www.bips.uni-bremen.de/projekte.php?cat=abt&projID=181; contact Dr. Behrens). The study is being carried out in close association with German employer's liability insurance associations, organisations and companies in the asphalt industry and is supported by various international asphalt organisations.

The study population includes men currently or previously employed in an asphalt-processing organisation. In the first follow-up to the cohort study covering the period to 1999, a slightly increased occurrence of lung cancers was recorded in workers in asphalt-processing organisations. No clear association was established with occupational illnesses when working with bitumen. It certainly cannot be stated from the available data whether there is increased mortality as a result of inhaling vapour and aerosols or from skin contact with bitumen, or whether earlier contact with products containing coal tar, exposure risks from other occupations outside the asphalt industry, or breathing in diesel fumes or smoking cigarettes are responsible for the increase in mortality.

The mortality follow-up will be extended to a second investigation covering up to 2004, in order to identify further cases of lung cancer to include in the follow-up study.

A nested case control study will be appended to the mortality follow-up. This investigation will be more precise and include details obtained in interviews with cohort members about hygiene measures and working conditions when handling bitumen as well as potential exposure to coal tar containing products.

Occupational factors outside working in the asphalt-processing industry will have to be assessed in order to exclude influences from previous jobs or non-occupational factors. This will be achieved by drawing up a complete occupational history for all study participants in order to assess detailed information on individual occupations. Additional risks such as smoking will also be considered as behavioural influence when it comes to triggering or contributing to lung cancer, and will be detailed in interviews for particular kinds of tobacco.

Relatives will be interviewed if the person has died. Fellow workers employed at the same workplace

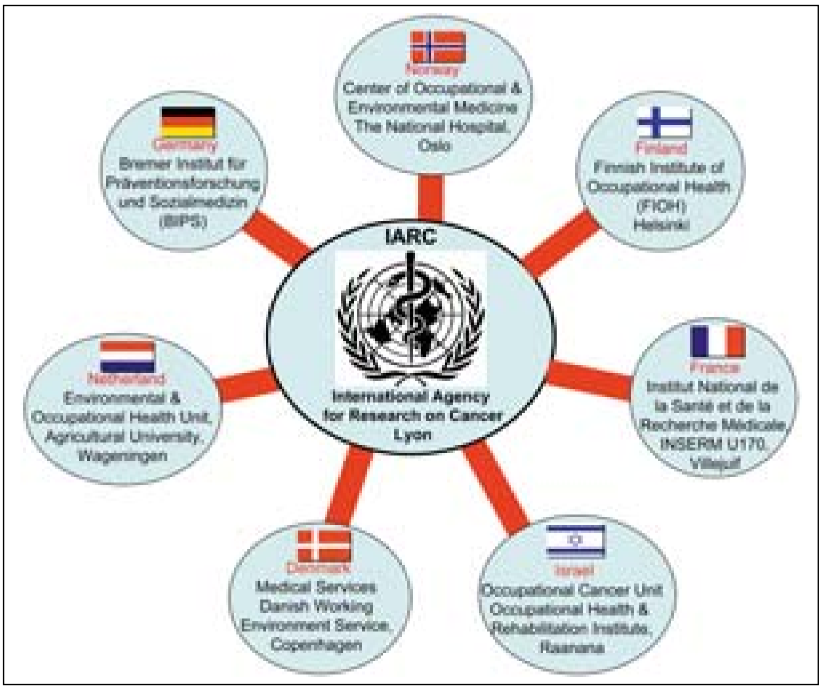


Figure 4:
Institutes taking part in the IARC study

and under the same conditions as the dead person will also be interviewed in order to obtain valid data on exposure in the workplace. Any differences between these two groups in past exposures to hazardous substances may reveal possible causes of lung cancer.

In the final analysis, asphalt workers (cases) who have died of lung cancer will be compared to a group of randomly selected workers without this illness (controls). The results of the case/control study may contribute to the identification of possible health risks in the asphalt and mining industries, and help in the future design of workplaces and the avoidance of health risks to the benefit of workers employed in said industries. The study will thus be useful to workers, companies and employer's liability insurance associations.

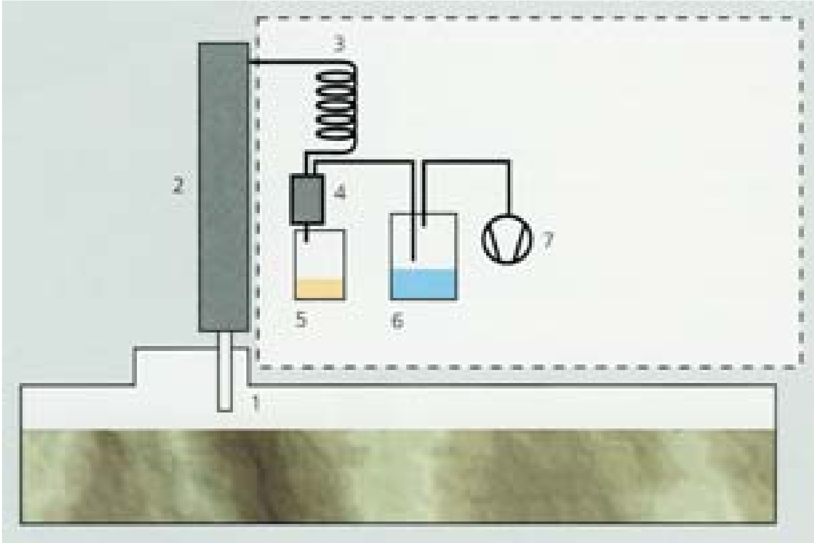


Figure 5:
Apparatus for collecting condensate from bitumen. The fume/aerosol mixture is collected in a cooler (4) and a vessel (5) from the heated (180 °C, 356 °F) bitumen tank using a heated tube (2) and a stainless steel coil (3). A further vessel (6) is used as a waterfall and protects the pump (7). It should be noted that this temperature is on the high side of those typical of rolled asphalt applications.

Inhalation study

The Fraunhofer Institute for Toxicology and Experimental Medicine (ITEM) in Hannover (Director: Prof. Heinrich) has carried out a long-term inhalation study designed to provide information on the carcinogenic potential of vapour and aerosols of bitumen. It was based on the 2-year exposure of rats to different concentrations of vapour and aerosols of bitumen and measurement of relevant biological results. The exposure atmosphere was comparable in its chemical composition, especially high-boiling polycyclic aromatic hydrocarbons, to typical workplace conditions during road construction.

The investigations were divided into:

- a technical pre-study,
- a study of acute toxicity,
- a 14-day and a 90-day dose range finding study and,
- the 24-month carcinogenicity study.

A method for generating the exposure atmosphere was developed and validated in the technical prestudy. The vapour and aerosols of bitumen were collected from the gas container of a large storage tank and condensed (Fig. 5). Different concentrations of vapour and aerosols of bitumen could be produced from these condensates for the animal tests using a specially developed generation system (Pohlmann et al., 2006).

The 24-month carcinogenicity study on rats began in March 2003. The study was carried out on four groups which were exposed to vapour and aerosols of bitumen (4, 20, 100 mg/m^3 total hydrocarbons). Investigation in the lung lavagate and cell proliferation studies were performed after 7 days, 90 days ans 12 months of exposure together with histopatholigical investigations which were also performed after 24 months.

A second study investigated vapour and aerosols of bitumen for their molecular/toxicological effects in an inhalation study on rats in an experiment involving 3 dosage levels (4, 20 and 100 mg/m^3) and 4 time points (5 days, 1, 3 and 12 months). The study looked at the gene toxic effects by determining the stable DNA adducts (^{32}P-Postlabelling, micronucleus and quantitative determination of the 8-OHdG adduct) in tissue in the respiratory system (lungs, alveolar epithelia, nasal respiratory epithelia) as well as lymphocytomic DNA. In addition, 14 polycyclic aromatic hydrocarbons (PAHs) and their metabolic decomposition products were investigated in using samples from exposed animals using HPLC-MS. Genomic gene chip analyses of animals exposed for three months enabled the identification of regulated genes. The 20 most regulated genes were analysed in relation to their exposure dosage and duration in lung and nasal epithelia as well as blood cells using RT-PCR.

The most important result of this study was summed up as follows by the bitumen industry union: "The inhalation of vapour and aerosols of bitumen over a period of two years showed in animal tests (rats) that there was no statistically relevant increase in cancer rates, either generally or in specific organs, compared to a control group which had only breathed clean air. On the basis of these results, vapour and aerosols of bitumen cannot be regarded as carcinogenic in rats. Irritations were identified in the nasal passages and lungs, which could be traced back to the effects of vapour." This irritation indicator was detected at the highest exposure levels which are not typical of worker exposures.

Further information can be found on the BITUMEN Forum's website www.gisbau.de/bitumen.html.

Dermal resorption of emissions from hot bitumen

The Institute and Polyclinic for Occupational and Social Medicine of the Gießen and Marburg University Clinic carried out a study aimed at improving the data on possible dermal resorption of bituminous emissions.

The project was divided into two experimental series: the reproducible generation of bituminous emissions at approximately 200 °C (392 °F) and the evaluation of appropriate quality criteria in a test chamber. In this chamber, in the second part of the project, 10 test subjects were exposed as standard to the then inside threshold of 20 mg/m^3 vapour and aerosols of bitumen. Commonly employed bitumen B 65 was used to produce these emissions.

The test took into account practical conditions at the workplace such as a total 8 hours of exposure or remaining in the test chamber bare to the waist. It was possible to guarantee a virtually identical composition of emissions for the entire exposure time. The test subjects wore a fan-assisted breathing mask to prevent inhalation. In a

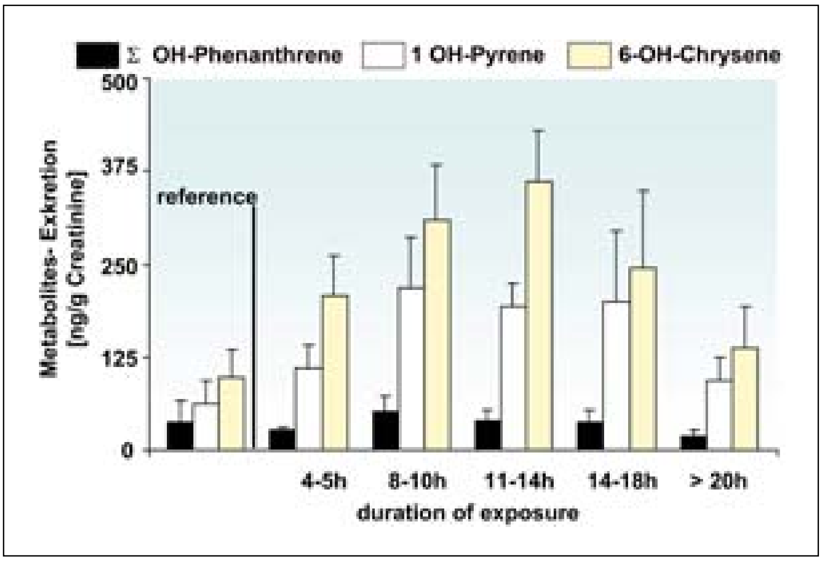


Figure 6:
Concentration of three PAH metabolites from 10 test persons wearing breathing equipment before, during and after exposure to vapour and aerosols of bitumen of 20 mg/m^3

further test, two of the 10 subjects were exposed under the same test conditions but without breathing equipment in order to provide an assessment of dermal and combined inhaled/dermal incorporation. Quantification of resorbed bitumen emissions was carried out by metabolite biomonitoring in the urine of the polycyclic aromatic hydrocarbons (PAHs), pyrenes, chrysenes and phenanthrenes in the emissions.

Fig. 6 shows clear dermal resorption of the PAHs in the bitumen emissions. Assessment of PAH urine concentrations in the test subjects exposed with and without breathing equipment showed partial resorption over the skin of chrysenes, phenanthrenes and pyrenes of 50-60 % of the total incorporated amount.

Research into the potential source, the nature and potential biological consequence of dermal absorption is ongoing in the United States. Application temperature is known to have a substancial impact on the quantity and nature of the generated vapour and aerosol.

Dermal resorption from contact with cold bitumen?

134 workers in a company producing bituminous damping pads were investigated for external and internal PAH exposure. The temperature of the bitumen with which they came into contact was mostly below 50 °C (122 °F). External exposure was determined using individual air measurements (16 EPA-PAH).

The internal PAH exposure was determined from the metabolites 1-hydroxypyrene; 1-, (2+9)-, 3- and 4-hydroxyphenanthrene and 1-and 2-naphthol in the urine. 64 persons not exposed to PAHs were used as controls (Table 8).

A significant difference was observed only in the 1-hydroxypyrene concentration in non-smokers in the bitumen-exposed and control groups. All concentrations of PAH metabolites in the urine lay within the basic excretion range for the general population. It can, therefore, be assumed that, given the type of bitumen processing investigated here, the additional health risk from PAH exposure can be disregarded under the set parameters.

Smokers generally exhibit higher values for all PAH metabolites investigated in the urine. This applies to people exposed to bitumen and to controls.

Smokers in the control group had higher PAH concentrations than non-smoking workers exposed to bitumen.

	Smoker		Non-smoker	
	n	µg/creatinine	n	µg/creatinine
Controls				
Office workers	24	0.16	40	0.05
Exposed				
Forklift driver	8	0.26	7	0.11
Roller driver	6	0.23	2	0.14
Equipment driver	4	0.23	4	0.08
Charger	6	0.18	6	0.05
Maintenance	8	0.19	9	0.07
Stacker	14	0.13	17	0.09
Other	18	0.23	25	0.07

Table 8:
Median values for 1-hydroxypyrene concentrations (µg/creatinine)

Mastic asphalt workers

Occupational medical care of mastic asphalt workers

In 2000 with the establishment of thresholds for mastic asphalt workers, the German Commitee for Hazardous Substances proposed intensive occupational medical care of these workers. Attempts would be made to determine whether this work was harmful to the respiratory system.

Help was sought from the german mastic asphalt assoziation (bga) and all contactable mastic asphalt processing companies to allow their employees to be tested. Testing was carried out by the Occupation Medicine Service of the BG BAU from August 1999 to January 2004.

165 companies, all members of the bga, as well as companies it was assumed carry out mastic asphalt work, were approached. 52 companies did not carry out mastic asphalt work or were among the 77 companies from which a total of 859 workers were tested.

Telephone investigations at the start of 2006 to the remaining companies established that there were a further 200 mastic asphalt workers in 25 companies. This showed a total of 1,100 mastic asphalt workers in Germany. The 859 tested workers were assessed against a control group of 517 people.

A survey form was devised for the test, which asked about employee problems in relation to the skin and the respiratory system. The form was supplemented by a concluding opinion from the investigating occupational health doctor.

The results showed that the problems investigated were significantly higher in mastic asphalt workers. Of those exposed, 24.5 % had at least one problem as opposed to 5.8 % among the controls. Breathing difficulties were the most common problem (Fig. 7). The number of complaints increased in relation to the time spent working with mastic asphalt. A significantly higher number of reservations were expressed in the medical assessment of exposed persons when it came to continuing with the work. The handling of epoxies and exposure to diesel engine emissions were cited many times as additional problems.

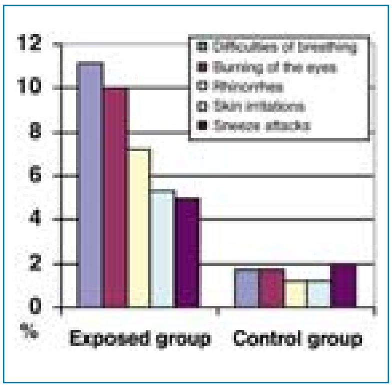


Figure 7:
Individual complaints

Human Bitumen Study

With the temporary suspension of the exposure limit for vapour and aerosols of bitumen during high temperature processing for mastic asphalt workers in May 2000 the German Committee for Hazardous Substances encouraged intensive pre- and post-shift medical examinations of a representative mastic asphalt worker group. Therefore, at the Berufsgenossenschaftlichen Forschungsinstitut für Arbeitsmedizin (BGFA, Director Prof. Brüning), Institute of the Ruhr-University Bochum, a research project with the principal aim to assess the possible irritative and genotoxic effects of vapour and aerosols of bitumen on the airways with a cross-shift design in mastic asphalt workers was initiated – the mastic asphalt worker study.

Mastic asphalt worker study

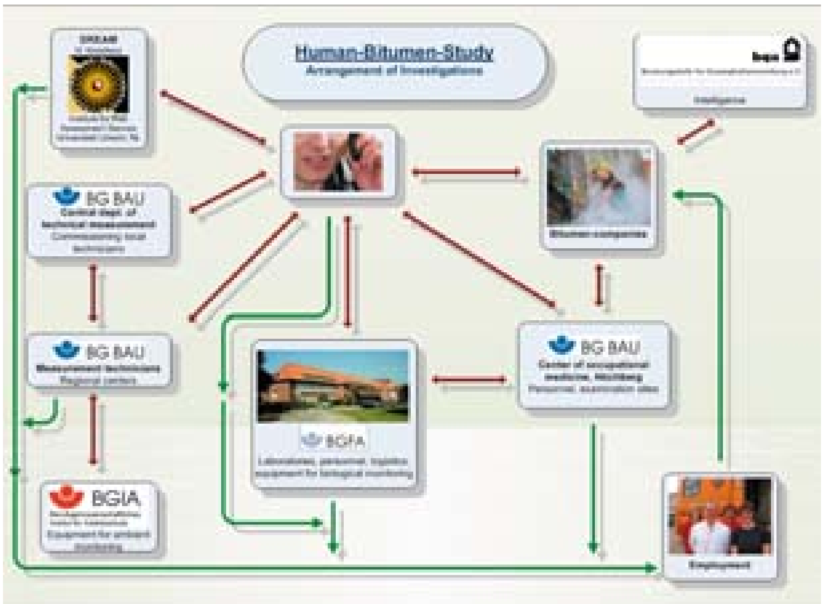
In cooperation with medical and technical colleagues of the BG BAU mastic asphalt workers who were exposed to vapour and aerosols of bitumen at high processing temperatures at their workplaces were examined pre- and post-shift (cross-shift). Roadside construction workers who did not work with hot-mix asphalt during the past five years served as reference group. A structured questionnaire was applied in a face-to face interview to assess potential confounders, chronic and acute health complaints, and detailed information on occupational history. All workers were examined immediately before and after shift. At both time points, spirometry was performed and nasal lavage fluid, induced sputum, spot urine and blood samples were collected. In addition to the analysis of polycyclic aromatic hydrocarbons (PAH) metabolites in urine personal air sampling in each mastic asphalt worker's breathing zone was carried out to measure exposure to vapour and aerosols of bitumen (Ambient monitoring).

The examinations started in May 2001 and till end of 2004 workers of 14 different construction sites were examined. Overall 66 workers with exposure to bitumen as well as 49 roadside construction workers without exposure to vapour and aerosols of bitumen as a reference group could be included in the study.

As 10 mg/m^3 is the current German exposure limit for vapour and aerosols of bitumen this threshold value was chosen as the cut-off for the classification of the mastic asphalt workers into workers with low ($\leqq$10 mg/m^3) (n=38) and with high (>10 mg/m^3) exposure to vapour and aerosols of bitumen (n=28) based of their individual personal ambient monitoring data.

The results of the study show that increasing external exposure to vapour and aerosols of bitumen during a shift was accompanied by significantly higher concentrations of PAH-metabolites (1-hydroxypyrene and the sum of hydroxyphenanthrene) post-shift. A clear dose-response relation was observed during the shift in mastic asphalt workers without any significant changes in the reference group. Airway diseases were frequently more mentioned in the high exposed mastic asphalt worker group. The decrease of the lung function values after the shift for the exposed showed an acute effect of vapour and aerosols of bitumen in shift course.

The better lung function performance pre-shift of the low exposure group indicates a "healthy worker-effect". Overall, the results emphasise an inflammatory response of the upper and lower airways under high exposure to vapour and aerosols of bitumen (Raulf-Heimsoth et al., 2006). In addition, genotoxic parameters, like DNA-adduct rates showed a relation to the bitumen exposure (Marczynski et al., 2006).



Organisation of testing during the Human Bitumen Study

As overall for the biological parameters the range and individual variability – expectedly – was relative high, larger working groups for a valide statistical evaluation and an assured conclusion are essential. Therefore the investigations are on-going including the analysis of increased numbers of exposed and control workers.

The study will be continued in an adjusted group within the scope of the "Human Bitumen Study".

Mechanical mastic asphalt laying

Mastic asphalt workers with mixed exposure

In the scope of the "mastic asphalt worker study" in urine samples of seven mastic asphalt workers collected after a work-shift significantly higher concentrations of PAH-metabolites were determined in comparison to the other mastic asphalt workers (Schott et al., 2004).

The cause for this purpose was an underground of coal tar plates, of which the hot mastic asphalt released PAH (Fig. 8). In the coal tar plates a benzo[a]pyrene concentration of 768 mg/kg was determined, in the mastic asphalt layer less than 0.3 mg/kg. This group of the seven mastic asphalt workers (Schwelm crew) was taken out of the further evaluation, because the enhanced PAH-exposure was due to the coal tar plates and beyond the bitumen.

Human Bitumen Study

Since January 2005 the Berufsgenossenschaftliche Forschungsinstitut für Arbeitsmedizin (BGFA), Institute of the Ruhr-University Bochum, in co-operation with the BG BAU accomplished the Human Bitumen Study (coordinator Mrs. PD Dr. Raulf-Heimsoth). The aim of this study is in the clarification of the possible irritative and accordingly genotoxic effect of vapour and aerosols of bitumen on the airways. Therefore it is necessary to examine a sufficient large group of appropriate exposed workers and a comparable reference group in consideration of dose-response correlations.

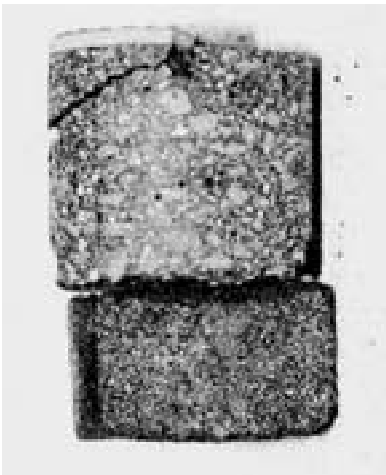


Figure 8:
Floor core from Schwelm crew; top carpet, middle mastic asphalt, bottom hard coal/pitch layer

The Human Bitumen Study, which is as well supported of the "Beraterkreis Toxikologie" as also of the "MAK-Kommission", bases on the results of the mastic asphalt study. That there used cross-shift study-design with defined endpoints of the ambient monitoring for the determination of exposure, the medical examination and the application of a work- and disease-related questionnaire, lung function examinations, determination of metabolites of the polycyclic aromatic hydrocarbons (PAH) in urine samples, the extraction and analysis of cell material and soluble inflammation mediators of the nasal mucosa and the deeper respiratory tract, the genotoxic effects as well as the determination of relevant enzyme polymorphisms are also continued in the Human Bitumen Study.

Altogether 600 subjects shall be included in the scope of the Human Bitumen Study as mentioned above, 450 workers, who are exposed to vapour and aerosols of bitumen and 150 workers without exposure to bitumen. This study will include also workers from applications other than mastic workers and will likely include a large number of paving workers, both rolled asphalt and mastic, and roofers.

The Human Bitumen Study is a multicentric study (Fig. 9), which is carried by both of all five competence-centres of the BGFA and also of external cooperation partners. The biological monitoring take place in the working group of Prof. Angerer of the Institut und Poliklinik für Arbeits-, Sozial- und Umweltmedizin (IPASUM) in Erlangen and the ambient monitoring by the BGIA. The latter is supplemented by the examinations of the 16 EPA-PAHs, which are initiated by the BG BAU and accomplished in the working group of PD Dr. Knecht (University Gießen).

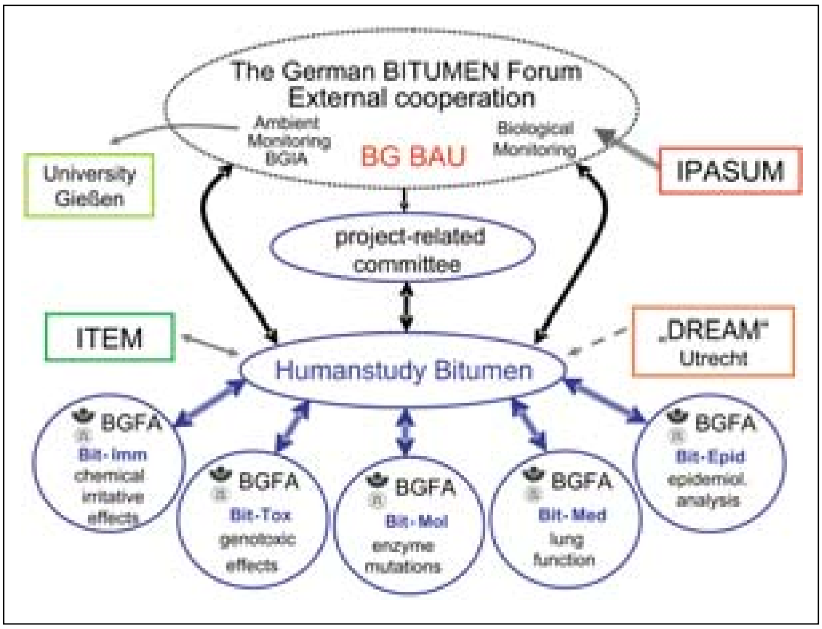


Figure 9:
Structuring the Human Bitumen Study. The BGFA will be joined by the Institute for Occupational, Social and Environmental Medicine of the University of Erlangen-Nuremberg (IPASUM), the Fraunhofer Institute in Hannover (ITEM) and the University of Gießen. The DREAM module from the University of Utrecht has been implemented.

Furthermore complementary examinations regarding genotoxic parameters are carried out additionally within the scope of this study at the "Fraunhofer-Institut für Toxikologie und Experimentelle Medizin" (ITEM) in Hannover. For this determinations blood samples pre and post shift of the workers are provided to the ITEM. Accessorily examination of gene toxic effects by ^{32}P-Postlabelling is intended.

In agreement with the German BITUMEN Forum the so called DREAM-Module (DeRmal Exposure Assessment Method) of Dr. Kromhout (IRAS, University Utrecht) are implemented in the Human Bitumen Study. This module is evidence of a semi quantitative survey of the exposure to vapour and aerosole of bitumen and for estimation of the dermale exposure. In addition to the personal-related and stationary exposure measurements, on some selected construction sites especially the dermal exposure ought to be assessed by skilled observers. The DREAM-Modul applies Europewide in a part of IARC-study cohort of mastic asphalt workers.

Besides the Hauptverband der Berufsgenossenschaften, which bears the predominant part of the costs for this project, also the BG BAU is involved in this project. Furthermore could, especially by the assignment of the German BITUMEN Forum industrial representatives obtained, which finance special aspects of the study.

Appendix IV

Bitumen in the environment

Only on very hot days do asphalt temperatures on roads reach as much as 80 °C (176 °F), and temperatures on roofing sheeting as much as 100 °C (212 °F), so no bituminous emissions occur. In addition, the surface of the bitumen is hardened by UV and oxygen in the air, sealing it – another reason no emissions arise from installed bitumen products.

Water does not leach any materials from bitumen and asphalt. This is why bituminous coatings are preferred in areas where drinking water is stored or collected. Bitumen is not broken down by plants or organisms.

Water pollution

Bitumen is not water-soluble. Nor are any substances in bitumen soluble in water. That is why bitumen is not classified as a water-polluting material in the Official Guidelines for Water-polluting Substances (VwVwS) cited in Annex 1.

Bitumen and asphalt have been used for decades is association with the provision of drinking water, especially for sealing and strengthening damns.

Transport

Since January 1997, bitumen as a hazardous material has been in Hazardous Goods Class 9 (hot materials) of the International Hazardous Materials Transport Regulations (ADR). The danger exists only when transporting it at temperatures above 100 °C (212 °F) needed to keep it fluid enough to be pumped.

The following regulations apply to the transport of rolled and mastic asphalt:

Rolled asphalt does not flow. Temperatures < 240 °C (464 °F) do not represent a hazard in the sense of the GGVSE.

There is a special regulation (No. 643) in the ADR for mastic asphalt: "Mastic asphalt does not meet the criteria for Class 9."

This means that the supply of mastic asphalt is exempt from the Hazardous goods transport regulations (e.g. in heated mixers).

Bitumen in enclosed spaces

After laying, the emission concentrations fall away rapidly to a very low level. No further emissions occur at all if the mastic asphalt is cooled below 100 °C (212 °F). This means the owner is not limited in any way after the usual period between laying and use.

Even bituminous products used for sealing do not release bituminous substances after laying.

Drinking water dam – sealed with asphalt

Appendix V

Note on Lowering the Asphalt laying Temperature

The Note on Lowering the Asphalt laying Temperature (M TA), published by the German Research Organisation for Roads and Traffics e.V. (FGSV; www.fgsv.de) saw this new construction method enter the technical regulatory mechanism for road construction.

Aside from reducing CO_2 emissions and contributing to climate protection, reducing the temperature during manufacture and processing achieves two further goals: saving energy from the point of view of resource conservation, and reducing emissions from the point of view of occupational safety.

The increasing availability of additives and special binders for reduced-temperature asphalts has made it necessary for this method of construction to become manageable for the workers involved, through a regulatory framework.

The Note provides advice and explanations on the special features involved in manufacturing and processing reduced-temperature asphalts. Two main options for reducing temperatures are described:

- One involves the use of mineral additives (zeolites),
- while the other involves the use of viscostatically altered organic additives (fatty acid amides, Fischer-Tropsch waxes and Montan waxes).

The area of application basically covers all asphalts used in hot laying. A definitive assessment of the technical characteristics of asphalts manufactured and processed using viscostatically altered organic additives at reduced temperatures will be available after an expected usage period of about 15 years. This is currently not yet possible for products available on the market.

The current state of knowledge has been published by the German Federal Institute for Roads (BASt) in a "Collection of experiences on the use of finished products and additives for reducing the temperature of asphalt". The FGSV Note cites this collection of experiences from the BASt.

A prerequisite for the adoption of a product in the collection of experiences was positive experiences over a lengthy observation period (min. 5 years). The first edition of the collection (March 2006) is concerned with follow-up investigations of test stretches.

These test stretches, which had been used for up to 7 years, sometimes with heavy traffic loads, were examined visually and laboratory tests carried out on binder ageing, adhesion, cold behaviour and chemical composition. The results indicated that the products SmB 35, Sübit VR 45, Sasobit and Asphamine can be used to reduce the temperature of rolled asphalt.

The collection of experiences will be updated as required. At present, it only contains products for rolled asphalt.

The initial results for mastic asphalt are expected towards the end of 2006 or 2007.

Positive experiences will have to be recorded in the same way as for the test stretches for other existing or newly developed products on the market for reducing the temperature of asphalt in order for them to be included in the experience collection.

The assessment itself will be made by the BASt in conjunction with an advisory group consisting of representatives from the construction and asphalt industries, the roads administration, the bitumen industry, testing laboratories and scientists.

The Note on Lowering the Asphalt laying Temperature and the experience collection from the BASt will provide road construction authorities with a basis for tendering for this construction method, which has until now been outside the regulatory framework.

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More information is available on the web page of the German BITUMEN Forum www.gisbau.de/bitumen.html

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