European Journal of Science, Innovation and Technology

ISSN 2786-4936

Vol. 2 No. 2 (2022)

Asphalt and Bitumen Ageing

Kerim Hrapović
EUR ING Civil Eng., Ph.D., Mst., Austria

Abstract. The ageing of asphalt and the associated changes in its performance are largely due to the ageing binder it contains. Ageing makes bitumen harder and more brittle. The hardening and embrittlement of the binder has a direct effect on the performance characteristics of the asphalt. To date, there is no laboratory method for addressing the ageing of asphalt that can be used to simulate ageing processes in a practical manner analogous to the long-term ageing of bitumen.

Keywords: Ageing, asphalt, bitumen, embrittlement, short-term ageing, long-term ageing

Introduction

Ageing of Asphalt

The ageing of asphalt and the associated changes in its performance are largely due to the ageing of the binder it contains. The ageing of binders is divided into distillative ageing, oxidative ageing and structural ageing. For bitumen ageing in the laboratory, there are procedures with which short-term ageing and long-term ageing can be simulated.

The second main cause of ageing concerns the installed asphalt layer. Asphalt roads are subject to progressive fatigue due to the constant dynamic traffic load. The traffic load leads to a constant alternation of compressive and tensile stresses on the underside of the bound layers, analogous to an elastically supported beam. This permanent stress causes the formation of micro-cracks in the asphalt, which are initially not visible to the naked eye, and detachment phenomena between the stone and the mastic (bitumen and filler). This fatigue phenomenon conditions the technical service life of asphalt construction and, if no appropriate maintenance measures are carried out, leads to the structural destruction of the structure: the micro-cracks gradually connect with each other, visible cracks form, which finally penetrate from the underside of the bonded layers upwards until the asphalt construction has reached the end of its service life, riddled with net cracks.

A distinction is made between ageing methods for asphalt mixes, ageing methods for asphalt test specimens and asphalt test slabs, and ageing methods for binders or bitumen.

Ageing of Asphalt Mixes or Mixtures of Aggregate and Bitumen

Examples of ageing processes for asphalt mixes or mixtures of aggregate and bitumen (Hase at al., 2019):

Model pot according to Potschka (1987)

The model pot according to Potschka (1987) is an electrically heated and externally thermally insulated vessel in which loose chippings coated with bitumen are stored and aged. Synthetic air (20 % oxygen and 80 % nitrogen) is circulated around the sample for one hour at a temperature of +140 °C (Potschka & Tabert, 1987) (Figure 1).

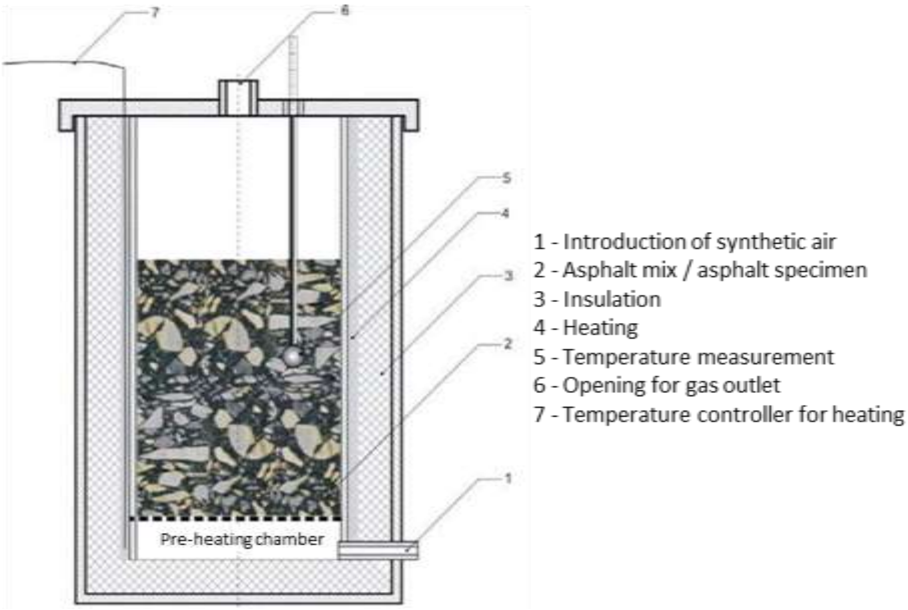


Figure 1: Principle sketch "Model pot" (Bald et al., 2005)

Brunswick ageing method (BSA)

In the Brunswick ageing procedure (BSA) (2010), granulated asphalt mix is spread on a wire sheet/grid and stored in a drying cabinet at a temperature of +80 °C for 96 hours. During conditioning, air is always circulated around the sample (Büchler & Wistuba, 2010) (Figure 2).

Several sheets of asphalt mix are pushed into a climatic chamber that can control the required ageing temperature of +80 (± 0.1) °C. The temperature must be kept constant. There must be extensive air circulation within the climatic chamber. (The climatic chamber used for this purpose has a total volume of 34,560 cm³ ≅ 34 *l*. The air circulation volume cannot be stated exactly, but the fan has a diameter of 180 mm and rotates at approx. 1,350 rpm). The samples are stored in the heating cabinet for a period of four days (corresponding to 96 hours). A reference bitumen (25/55-55 A) then usually shows an increase in the softening point ring and ball by approx. 12 Kelvin after recovery, which corresponds approximately to the distance between two bitumen classifications (Renken & Wistuba, 2018).

Figure 2: Material test cabinet and storage grate for Brunswick ageing (BSA) (Renken & Wistuba, 2018)

Ageing Procedures of Asphalt Test Specimens and Asphalt Test Panels

Ageing method with Warmbold ageing table

On the Warmbold ageing table (1996), asphalt test specimens are exposed to a combination of temperature (+40°C) and UV radiation. From the underside of the table, +40°C warm air is supplied to the specimens through holes, which, due to a lateral sealing of the system, flows through the specimens (Figure 3). The pressure on the underside of the specimens is 0.02 bar (Hase et al., 2019).

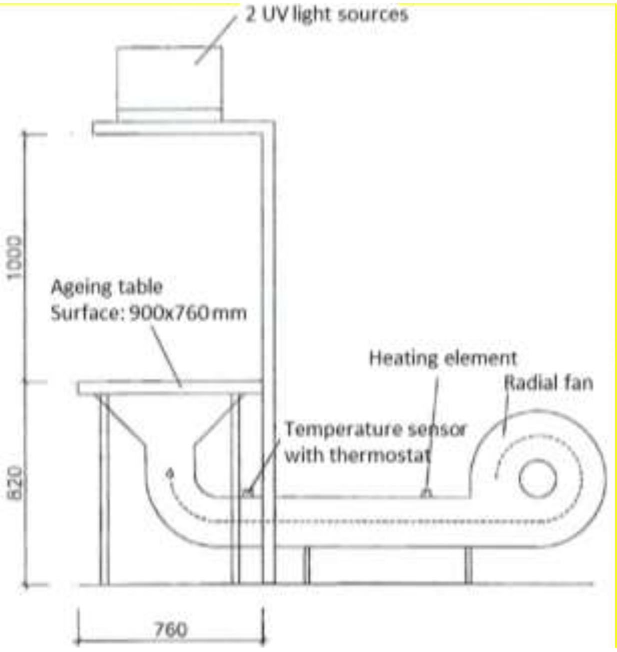
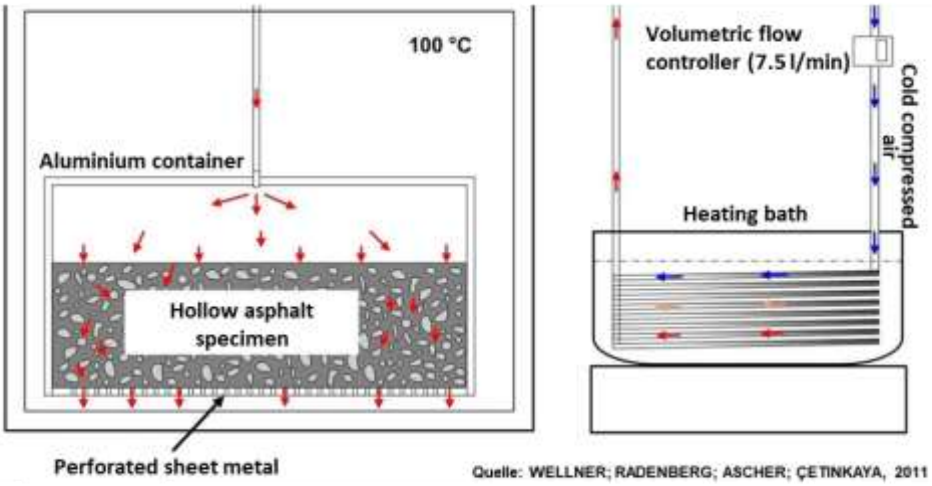


Figure 3: Warmbold ageing table (Hase et al., 2019)

Ageing procedure with the Bochum ageing method (BAV)

In the Bochum ageing process (BAV) (2011), asphalt slabs with a large void volume are installed in an aluminium container and the side walls are sealed (airtight). A defined quantity of 7.5 l/min of compressed air at +100 °C is introduced into the container with the asphalt slab from above. The heated compressed air is guided through the asphalt plate and can escape through a perforated plate on the underside of the aluminium container. In a research project, stress durations of 72 and 120 hours were selected (Cetinkaya, 2011) (Figure 4).



Quelle: WELLNER; RADENBERG; ASCHER; ÇETINKAYA, 2011

Figure 4: Bochum ageing method (BAV) (Cetinkaya, 2011)

Ageing procedures within the framework of a diploma thesis at the Vienna University of Technology (TU Wien) (2006)

As part of a diploma thesis at the Vienna University of Technology (2006) (Chulk, 2006), test specimens were stored in a pressure ageing vessel (PAV) at a pressure of 2.07 MPa and a temperature of +100 °C for two or seven days. Due to a structural disturbance caused by the conditioning, the asphalt mixture had to be compacted again in this procedure for subsequent investigations.

Ageing processes of asphalt test specimens in France

In France, a testing device (ageing machine) was tested for conditioning asphalt test specimens for skid resistance tests, with which a natural climatic stress is to be simulated in a time-lapse manner for the purpose of accelerating binder ageing (Do, Kane, & Cerzo, 2014). With this testing device, conditioning is carried out by means of heat, irradiation and humidity. Test devices of this type are commonly used in the plastics and coatings industry for addressing and testing weathering resistance and are regulated in standardised procedures (Figure 5).

Figure 5: Ageing test: a) weatherometer for accelerated test; b) specimens artificially and naturally aged (Do, Kane, & Cerzo, 2014)

Viennese Aging Procedure (VAPro)

This method was developed in recent years at the Vienna University of Technology based on findings in the FFG project "Oekophalt" (834203) as an alternative method for ageing compacted asphalt test specimens in the laboratory. The approach of the method is to select the ageing parameters in such a way that it is possible to simulate the ageing of compacted test specimens under realistic boundary conditions (ambient pressure / temperatures max. +60°C). In order to nevertheless achieve a time-lapsing effect, strongly oxidative gases are used to accelerate ageing. The air/ozone/nitric oxide mixture is produced with the aid of an ozone generator and passed at a slight overpressure (max. 1 bar) at moderate temperatures (+60°C) through cylindrical test specimens (Ø 100 mm) installed in a triaxial cell (Figure 6 and Figure 7). The mechanical properties of the asphalt can be determined both before and after ageing on the same specimen. In addition, mechanical and chemical properties can be tested on the recovered bitumen. A clear change in the properties can be observed. The presence of a certain void content in the specimens is important to ensure uniform flow through the specimens. This is in the range of 5-8 V. % (Maschauer et al., 2017).

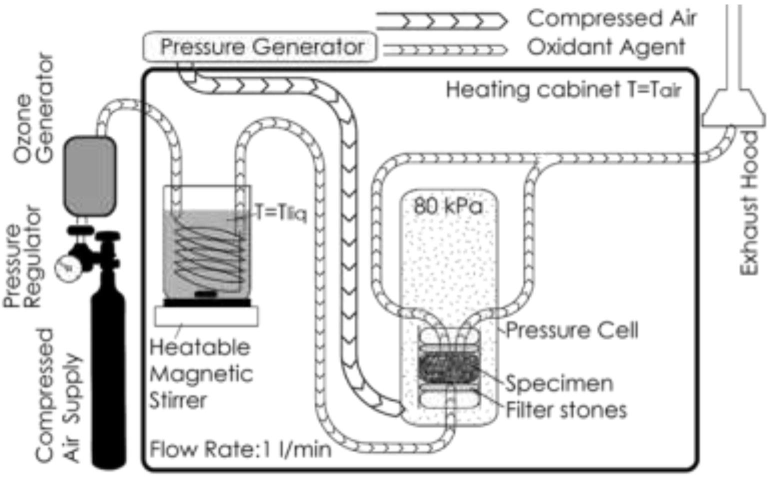


Figure 6: Schematic representation of the Viennese Aging Procedure (VAPro) (Maschauer et al., 2017)

Figure 7: Photo of VAPro in the laboratory (Maschauer et al., 2017)

Bitumen

Bitumen Types according to ÖNORM EN 12591 (ASI, 2009)

The harmonised Austrian standard ÖNORM EN 12591 (ASI, 2009) is part of the family of European standards for bitumen, as shown on Figure 8:

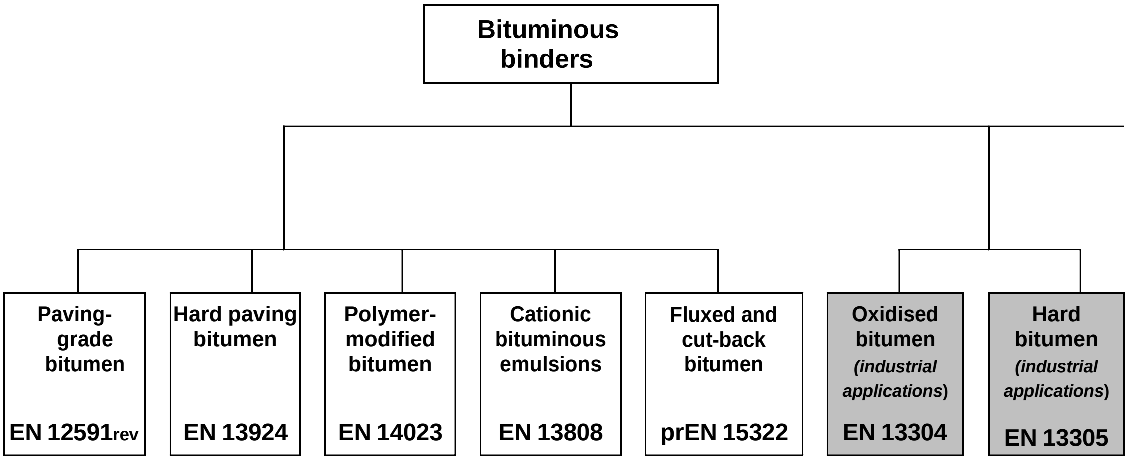


Figure 8: European standards for bitumen (ASI, 2009)

Road bitumen

Road bitumens are the bitumens used to produce asphalt for the construction and maintenance of traffic areas and in hydraulic engineering. They are classified as sol-type bitumens (Figure 9). Road bitumen is produced in the refinery as a product of the second distillation stage and is therefore also called distillation bitumen. The needle penetration values of standard road bitumen range from 20 tenths of a millimetre (1/10 mm) to 330 1/10 mm. These values provide information about the hardness of the bitumen used. The numerical values in the designation of a bitumen (e.g. bitumen 50/70) indicate the range in which the needle penetration depth may lie. In Europe, the most commonly used grades of road bitumen are defined by their needle penetration at +25 ^{0}C up to a maximum value of 900 1/10 mm. The temperature range between softening and embrittlement, the so-called "plasticity range", is around 70 K (Stoyanova, 2014).

Model Presentation Bitumen

Model presentation: Structure bitumen

Bitumen is usually depicted in a highly simplified way as a colloidal 2-phase system of higher-molecular particles (asphaltenes) in a low-molecular gel (maltenes) (Figure 9). Accordingly, a distinction is made between the main components

Maltene: plasticising, liquid oily phase; aromatic, light, soluble in n-heptane (petrol component), molecular weight 500...1000.

Resins: meltable, solid phase depending on temperature, layer around asphaltenes.

Asphaltenes: shape-defining, solid soot-like phase; heavy, insoluble, molecular weights 5000...100,000, size ~ 5 nm.

Micelles: Particles formed from resins and asphaltenes, size > 25 nm (Partl, 2011):

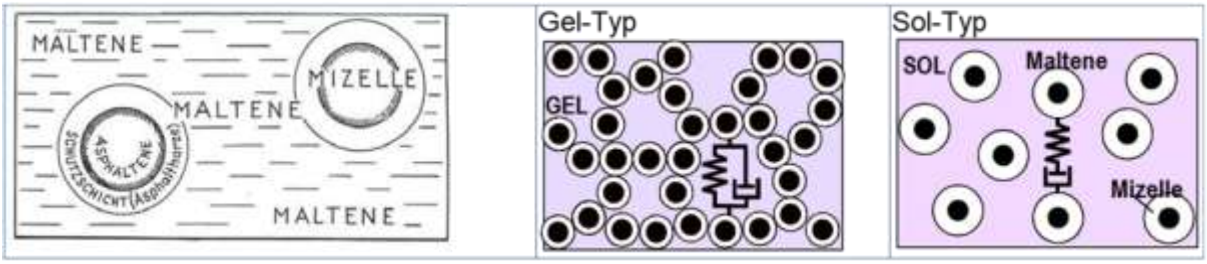


Figure 9: Classic simplified model for the structure of bitumen (Partl, 2011)

The adhesion behaviour in asphalt is determined by the mutual, molecular attraction (adhesion; Latin "adhaerere" for "to adhere") between bitumen and rock as a result of mechanical, chemical, physical and thermodynamic bonds. The interface between rock and bitumen was visualised during the investigations using analytical methods of surface physics and surface chemistry. A distinction is made between the following levels of observation (Grothe & Wistuba, 2010) (Figure 10):

- Micro level
- Macro level
- Meso level 1 (mortar)
- Meso level 2 (asphalt)
- Nano level (bitumen)

Electron microscopic techniques such as cryogenic environmental scanning electron microscopy (cryo-ESEM) were used to study the microplane. At 8,000 to 10,000 times magnification, the interlocking between bitumen 70/100 and rock can be seen (Maschauer et al., 2017).

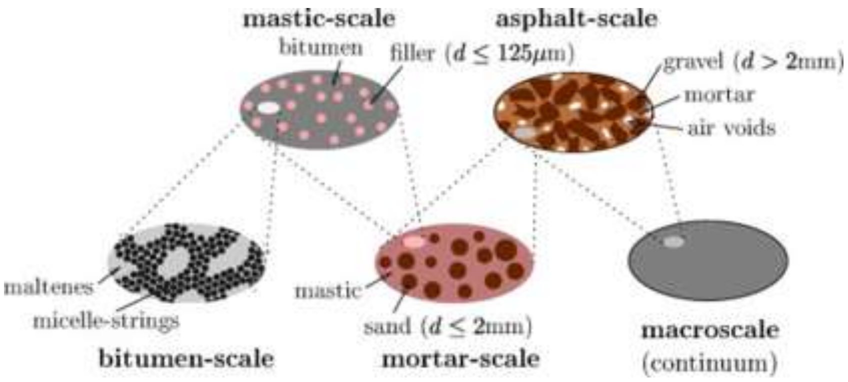


Figure 10: Different level of consideration of the connection between bitumen and rock (Grothe & Wistuba, 2010)

New studies show that the oxidation potential of atmospheric oxygen O_2 at the temperatures present in the field is not sufficient to trigger oxidation to the extent observed on surface layers. Rather, highly reactive oxygen-containing gases (so-called Reactive Oxygen Species, ROS), which are available in lower concentrations but just as permanently, must be taken into account in the ageing process. These are primarily ozone, nitrogen oxides and OH radicals, so-called photo smog. As a general rule, areas near the surface oxidise much more strongly than deeper layers. Higher void content favours the progression of ageing into the depths. Overall, ageing leads to hardening and embrittlement of the binder on a macroscopic, mechanical level. From a chemical-physical point of view, the hardening can be explained by an increase in the polar components due to oxidation, the embrittlement mainly by a change in the polarity structure in the colloidal system. As shown in figure 11, progressive oxidation of the mantle around the particle centres results in an increasingly steep polarity gradient between the core of the particles and the surrounding matrix, which leads to a change in the microstructure and thus to a mechanical predetermined breaking point (Maschauer et al., 2017).

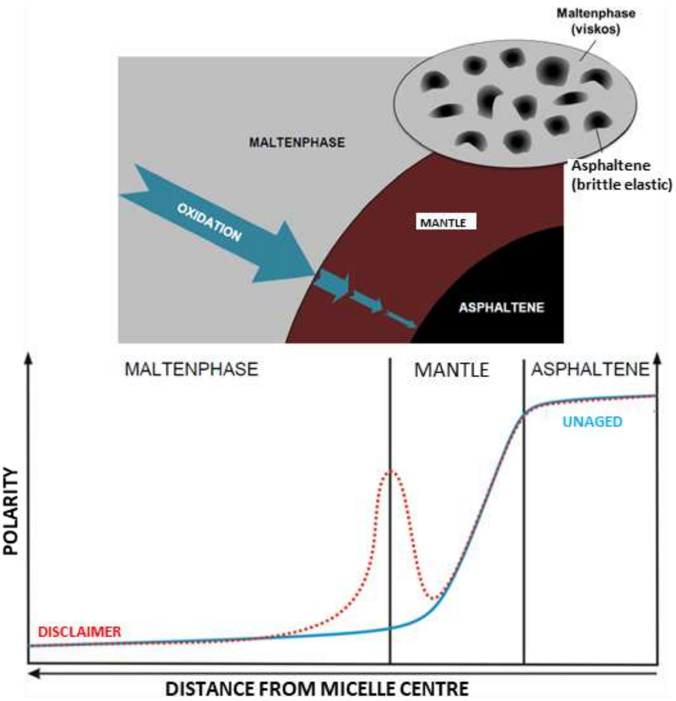


Figure 11: Model for the change of the polarity structure in the colloidal system due to oxidation (Maschauer et al., 2017)

Figure 12 shows three images of bitumen under the electron microscope. Figure (a) shows the bitumen sample in the as-received state. Clearly visible is a network-like structure, so-called asphaltene strings, which give the binder its elastic stiffness properties. This network structure is embedded in an oily phase of maltenes and resins, which are responsible for the viscous flow properties of the bitumen. After mixing and paving, the binder changes and is in a state of short-term ageing. Figure (b) shows this stage: While the asphaltene stings tend to increase in diameter and storage density, the viscous, oily phase decreases slightly. The change in the bitumen in the surface course is dramatic after about 10 years on the road. Figure (c) shows such a long-term aged bitumen sample. The asphaltene strings show a very dense and compact storage, while hardly any oily phase of maltene and resins is visible (Blab & Hofko, 2012).

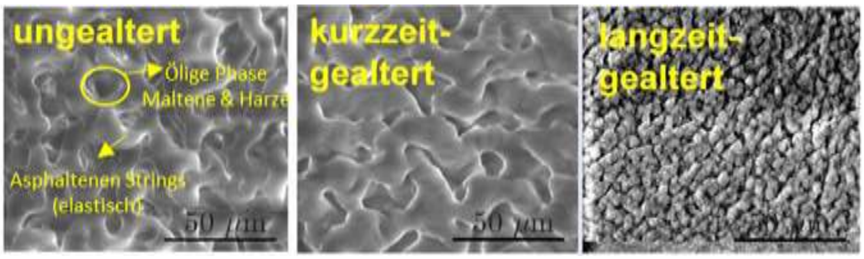


Figure 12: Bitumen under the electron microscope: (a) as delivered (unaged), (b) in the state of short-term ageing after mixing and paving, (c) in the state of long-term ageing after 10 years in the surface course (Blab & Hofko, 2012)

These observations are also consistent with the change in properties of the bitumen during ageing. Aged bitumen shows higher stiffness and lower viscosity compared to the unaged reference sample. This is mainly expressed by a lower crack resistance of the asphalt construction in the low temperature range.

Polymer Modified Bitumen (PmB)

There are two processes for modifying bitumen: wet process and dry process. The first takes place after refining and the second in the asphalt mixing plant during mixing with aggregate. A special case is polymer modified bitumen (PmB), which is typically modified with 3 to 8 wt% of an organic polymer. Similar to asphaltenes, the polymers form network-like structures and influence the thermoviscous and elastoviscous behaviour of bitumen.

The main objectives of polymer modification are to improve bitumen properties, namely:

- Higher cohesion
- Greater extensibility (ductility)
- Higher adhesion (bond) to aggregates
- Greater plasticity range: higher heat resistance with improved cold behaviour at the same time
- Large elastic recovery after unloading

Model presentation: structure polymer modified bitumen

The mode of action of polymer-modified binders is essentially determined by their structural composition and by the micro- and nanostructural interaction between polymer and bitumen. For road pavements and sealants, the elastomer SBS (styrene-butadiene-styrene block polymer) is typically added, which exerts a very positive effect on elasticity, but has the disadvantage of being relatively sensitive to oxidation and temperature. EVA (ethylene vinyl acetate copolymer) and EPDM (ethylene propylene diene monomer) are of lesser importance. In road construction, approx. 5 - 8 M-% SBS polymer is added to bitumen and approx. 10 - 15 M-% SBS is added to sealing compounds (e.g. for sealing membranes) The miscibility plays a major role on the binder properties (e.g. bitumen with 4 M-% SBS) (Partl, 2011).

The plastomer APP (atactic polypropylene), plays a certain role in the waterproofing sector. While polymer bitumen waterproofing membranes with SBS are generally easier to apply in cold weather than APP products due to their good cold bending behaviour, APP products prove to be more resistant in hot climates as APP is less sensitive to oxidation at high temperatures. The structural mode of action of SBS and APP is shown schematically in figure 13 (Partl, 2011).

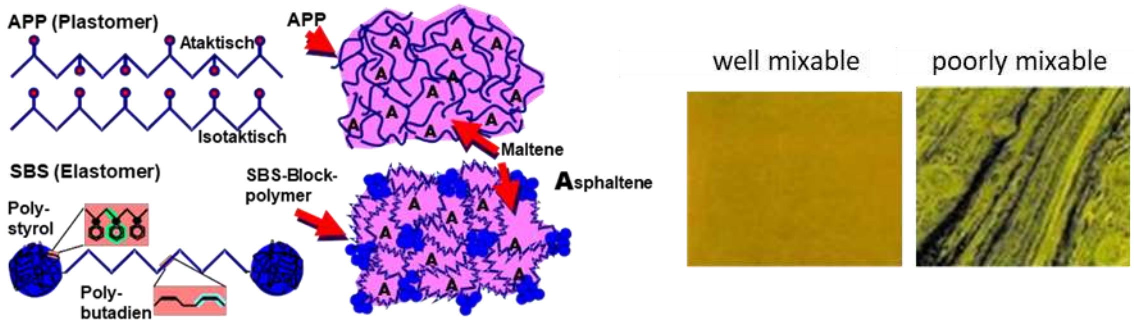


Figure 13: Left: Model of the structure of APP and SBS; Right: Fluorescence microscope images of bitumen with 4 mass% SBS (Partl, 2011)

Ageing of Bitumen

The term ageing describes the changes in the physical and chemical properties of bitumen during storage, processing or use. These property changes can be caused by internal structural transformations or rearrangements as well as by external influences such as light, heat, oxygen or moisture. Depending on the cause, the three main types of structural ageing, distillative ageing and oxidative ageing can be distinguished, whereby oxidative ageing leads to the most severe changes in properties (Hase et al., 2019).

Types of Ageing of Bitumen

Structural ageing

During this ageing, the colloid structures of the bitumen change towards a coarser system, with the asphaltenes and petroleum resins combining to form larger colloid-dispersed particles. In this way, the successive and irreversible transition of a bitumen sol type via a structured sol and a coagel to a gel type occurs. However, even after reaching the gel state, the bitumen continues to age by releasing the oily phase, causing the coagulated colloids to become increasingly dense. As a result of this ageing, hardening and an increase in viscosity of the bitumen occur, as well as the loss of elasticity and plasticity. The cause of the structural ageing lies in the bitumen's striving towards a thermodynamic equilibrium, which does not exist due to the high free interfacial energy of the concentrated and aggregated micelles (Stephan & Weigel, 2018).

Distillative or evaporative ageing

Distillative ageing leads to an accumulation of the heavier components in the bitumen due to the evaporation of the more volatile components. This concentration of heavy components leads to bitumen hardening, an increase in viscosity and a loss of mass. In general, distillative ageing is exacerbated by the increase in bitumen surface area, rising temperatures, longer residence times, greater air ingress, and the content of volatile components, which increases as bitumens become softer (Stephan & Weigel, 2018).

Oxidative ageing

During oxidative ageing, radical reactions occur between the hydrocarbons of the bitumen and atmospheric oxygen in the form of molecular oxygen. During these irreversible reactions, oxygen is continuously incorporated into the bitumen components, whereby ketones, alcohols, phenols, aldehydes and carboxylic acids are formed as intermediate products in addition to hydroperoxides. However, due to condensation reactions taking place and the associated splitting off of water and carbon dioxide, the acid character is reduced again, while at the same time the average molar mass of the molecules increases. The remaining polar hetero compounds, on the other hand, are firmly incorporated into the newly formed asphaltenes. In addition, hydrogen bonds can form between the oxygen-containing intermediates, whereby the resulting associates can also grow into colloid-disperse asphaltene particles. Furthermore, increasing exposure to UV radiation leads to stronger decomposition and thus accelerated radical formation in the bitumen, so that oxidation and the subsequent hardening are favoured (Stephan & Weigel, 2018).

A surprise in road construction research: Contrary to previous assumptions, visible light clearly contributes to the ageing of bitumen, which can ultimately destroy the asphalt. By chance, researchers from the Institute of Transport Sciences at the Vienna University of Technology have now come across a surprising effect there: contrary to what was previously thought, visible light in the blue and green range can cause bitumen to age more intensively - and within a very short time. This light-induced change in bitumen has now been studied in detail at the Vienna University of Technology. In any case, future research and service life estimates must also take solar radiation into account (Mirwald et al., 2021).

Bitumen samples were specifically illuminated with different precisely defined light colours - from long-wave red to the shorter-wave UV range. Until now, it was assumed that high-energy UV light had the strongest influence on the ageing of bitumen. Visible light was not expected to have any significant effect. However, the measurements clearly showed that changes in the bitumen surface could already be detected after 15-20 minutes at all light wavelengths examined. The strongest effect actually occurs in the UV range, but the effects of visible light are similarly drastic - with an additional maximum in the wavelength range of blue and green light. If we now take into account the light condition on the earth's surface and the influence of the atmosphere, whereby UV light is significantly more attenuated than blue or green light, it can be seen that blue light causes the most ageing on road surfaces (Mirwald et al., 2021).

The light accelerates the oxidation of the material - and when bitumen oxidises, its mechanical properties change. It becomes stiffer and thus more susceptible to cracking. The oxidation under the influence of light initially only takes place in the uppermost layers of the material - in the outermost micrometres of the bitumen sample. This is merely the initial spark for a far-reaching effect: small cracks ensure that oxygen can penetrate deeper into the material, stresses develop inside the material, the cracks become deeper and ultimately this can lead to lasting damage to the asphalt. Until now, ageing experiments with bitumen have mainly been carried out in the dark - this will now change. The measurements in these investigations show: If you want to predict the durability of asphalt, then you definitely have to take solar radiation into account. Where solar radiation is particularly high, one also usually has to deal with high temperatures, which further intensifies the effect (Mirwald et al., 2021).

Light ageing was performed using a Nikon light microscopy setup, as schematically shown in Figure 14.

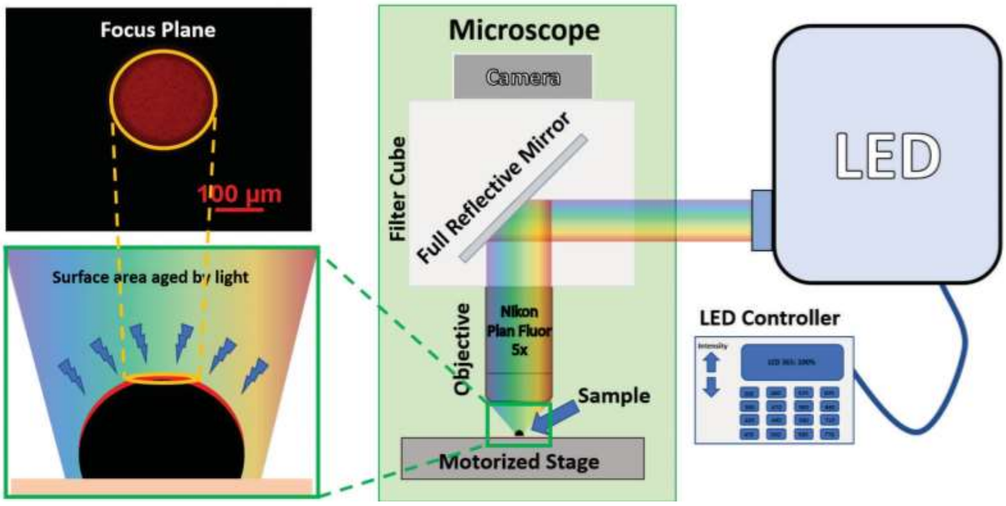


Figure 14: Chemical drawing of the light ageing structure (Mirwald et al., 2021)

Ageing Stages of Bitumen

The bitumen life cycle comprises the following three ageing states:

(1) Stage A "Unaged":

The unaged state, subsequently referred to as fresh bitumen, is unused ready-to-use bitumen from the refinery.

(2) Stage B "Short Aged":

The short-term aged condition is intended to represent bitumen transport to the asphalt mixing plant, hot storage, pumping operations, mixing with mineral aggregates, asphalt transport to the construction site and mix paving.

(3) Stage C "Long-term aged"

The long-term aged condition combines short-term ageing with a long service life on the road. The long-term aged condition is reached after 5 to 10 years of service. A more precise specification is not possible due to the dependence on environmental conditions. Figure 15 shows the schematic course of ageing over time. The exact ageing process in reality depends on the type of bitumen, the processing and the environmental influences in the installed state (Cetinkaya, 2011).

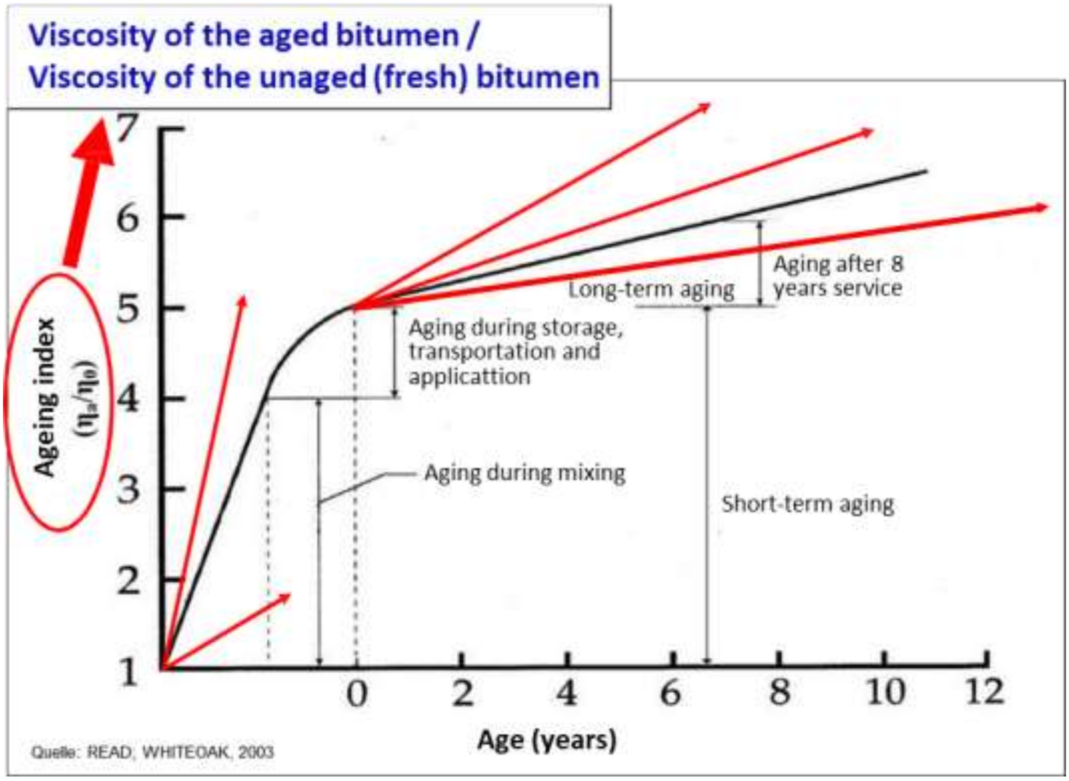


Figure 15: Schematic representation of the ageing process of bitumen (Cetinkaya, 2011)

Short-term aging

In addition to these mechanisms, a fundamental distinction is made in bitumen ageing between short-term and long-term ageing. Short-term ageing includes the ageing processes that occur during mix production, storage, mix transport and the paving process. Three methods are currently standardised for the simulation of short-term ageing in laboratory tests, including the Rolling Thin Film Oven Test (RTFOT, ÖNORM EN 12607-1 (ASI, 2014a)), the Thin Film Oven Test (TFOT, ÖNORM EN 12607-2 (ASI, 2014b)) and the Rotating Flask Test (RFT, ÖNORM EN 12607-3 (ASI, 2014c)). The RTFOT method is the reference method for this simulation, but a direct comparability of both methods was found for both road construction and polymer modified bitumen.

Long-term aging

Long-term ageing, on the other hand, describes the changes in bitumen properties during the service life of the asphalt. For the simulation of long-term ageing, the two standardised methods Pressure Ageing Vessel (PAV, ÖNORM EN 14769 (ASI, 2012)) and Rotating Cylinder Ageing Test (RCAT, ÖNORM EN 15323 (ASI, 2005)) are available, whereby the PAV method is the reference method. There is also a Long-Term Rotating Flask Test (LTRFT).

Ageing Process of Bitumen

Rolling Thin Film Oven Test (RTFOT, ÖNORM EN 12607-1)

The short-term ageing of the bitumen is simulated with the RTFOT. Eight jars each are filled with 35 g of bitumen. These jars are then inserted horizontally into the holder (Figure 16 left). The test lasts 75 minutes and is carried out at +163 °C. The glasses rotate during this 75 minutes. During these 75 minutes, the jars (Figure 16 bottom right) rotate at a speed of 15 rpm and hot air (4 litres/minute) is constantly blown into the jars via a lance (Figure 16 top right). This process is intended to simulate ageing during the processes of mixing, transport and installation (Hospodka, 2017).

Figure 16: Apparatus for RTFOT: Rolling Thin Film Oven, top right: Air lance and vertical rotating drum, bottom right: RTFOT bottles (Hospodka, 2017)

In addition to the ageing itself, RTFOT can also determine the mass loss of the sample. After the test has been carried out and the RTFOT bottles have cooled down, they are weighed or the mass loss is determined. The RTFOT test does not give us results like the other bitumen tests, but provides us with a bitumen aged in the laboratory for further testing methods such as BBR, MSCR, etc. (Hospodka, 2017).

Thin Film Oven Test (TFOT, ÖNORM EN 12607-2)

TFOT stands for "Thin Film Oven Test" and is a conditioning method used for soft road bitumen as well as oxide and industrial bitumen. In contrast to the RTFOT method, the bitumen surface is not moved in this method. (50.0 ± 0.5) g of bitumen is weighed into at least two cylindrical metal trays (Figure 17). After cooling, the metal trays are placed on a horizontal turntable located in a heating chamber and exposed to heat for 5 hours. Before preparing subsequent tests, the bitumen samples aged by the TFOT method should also be combined in a composite sample. As the bitumen surfaces are not moved in the TFOT process, a skin of aged bitumen can form on the surface (Arbit, 2014).

Usual experimental conditions TFOT:
Temperature: (+120 ± 1) °C (for soft road bitumen).
Duration: 5 h, maximum 5 h + 15 min

Figure 17: Performance of Thin Film Oven Test (TFOT) according to ÖNORM EN 12607-2 (Arbit, 2014)

Rotating Flask Test (RFT, ÖNORM EN 12607-3)

The RFT method (Rotating Flask Test) corresponds to the method with rotating flask in the rotary evaporator that was standardised in Germany in the past. Although this method is not referred to in any requirement standard, it is still standardised to ensure that laboratories work under the same conditions. (100 ± 1) g of the bitumen to be aged is weighed into a 1000 ml round-bottomed flask, which is suspended in the oil bath of a rotary evaporator (Figure 18). After ten minutes of tempering without air supply, the air flow is introduced into the round flask and conditioning is carried out for 150 minutes. In this procedure, too, samples from several conditioning processes may have to be combined and homogenised in order to obtain sufficient material for the subsequent tests (Arbit, 2014).

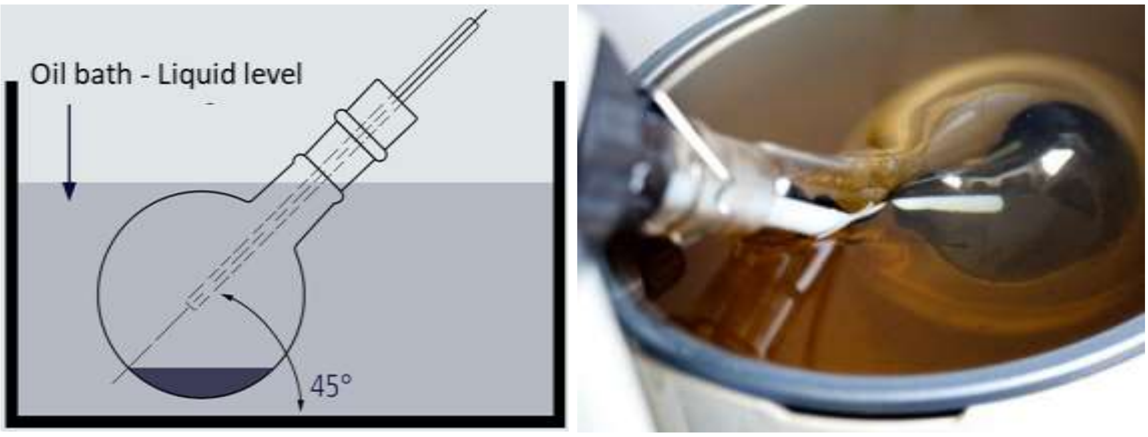


Figure 18: Principle sketch and implementation of RFT (Arbit, 2014)

Usual experimental conditions RFT:
Temperature: (+165 ± 1) °C
Air volume: (500 ± 10) ml/min
Duration: (10 ± 1) min without air supply, then (150 ± 1) min with air supply

Pressure Ageing Vessel (PAV, ÖNORM EN 14769)

The PAV apparatus consists of a heatable pressure vessel, ten metal trays and a tray holder (Figure 19). The ageing of the bitumen by means of PAV is to prove the changes of the bitumen during a lying time of approx. 10 years.

Figure 19: The apparatus for the PAV test: left: Pressure Aging Vessel, middle: Pressure vessel, right: Tray holder with filled trays (Hospodka, 2017)

First, the bitumen aged by means of RTFOT tests is filled into ten sheet metal trays approx. 3 mm thick, 50 g per tray. The trays are then placed in the tray holder and the tray holder is then placed in the pressure vessel preheated to +110 °C. The pressure vessel is then closed with a lid. After closing the lid, the pressure vessel is pressurised to 20.7 bar (300 PSI). When the temperature inside the pressure vessel reaches ±2 °C, the 20-hour ageing process begins. At the end of these 20 hours, the pressure in the boiler is slowly released over a period of 8-10 minutes and then the metal trays are placed in a drying oven at a temperature of +163 °C for another 30 minutes. Finally, the bitumen is emptied into cans. Bitumen conditioning with the PAV (just like with RTFOT) does not give us results like the other bitumen tests, but provides us with a bitumen that is long aged in the laboratory for further testing methods like BBR, MSCR etc. (Hospodka, 2017).

Rotating Cylinder Ageing Test (RCAT, ÖNORM EN 15323)

RCAT stands for "Rotating Cylinder Ageing Test" and refers to a conditioning procedure that can be used to simulate both short-term and long-term ageing. In particular, both conditioning procedures can be carried out immediately one after the other. 525 to 550 g of the sample to be conditioned are weighed into a heated metal cylinder, which is then fitted with an internal shaft and inserted into a pre-tempered heating chamber (Arbit, 2014) (Figure 20).

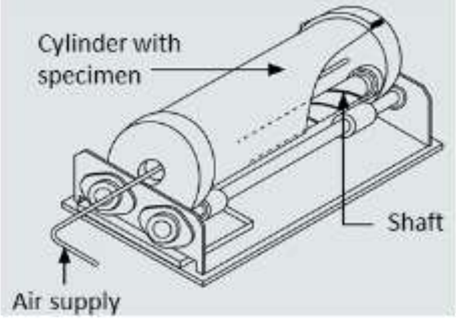


Figure 20: Principle sketch RCAT (Arbit, 2014)

After one hour of static storage in the cylinder at the pre-selected conditioning temperature, rotation of the cylinder and continuous oxygenation is started. Ageing is continued for 140 hours. The cylinder is then opened and stored upright in a heat chamber for the bitumen to run out (Normallab France SAS, n.d.) (Figure 21).

Figure 21: Accessory kit included with the NRC 210 for the Rotating Cylinder Ageing Test (RCAT) (Normallab France SAS, n.d.)

Usual test conditions RCAT:
Temperature: +90 °C
Rotation speed: 1/min
Flow rate of oxygen: (4.5 ± 0.5) l/h
Duration: (60 ± 5) min without oxygen supply, then 140 h ± 15 min under oxygen

References

Arbit 01/14 (2014). Arbeitsgemeinschaft der Bitumen-Industrie e.V. (ARBIT), Alterung von Bitumen, Laborverfahren zur Simulation von Kurzzeit- und Langzeit-Alterung, Hamburg.

ASI – Austrian Standards Institute (2005). ÖNORM EN 15323 - Bitumen und bitumenhaltige Bindemittel - Beschleunigte Langzeit-Alterung mit dem Verfahren mit rotierendem Zylinder (RCAT) / Bitumen and bituminous binders - Accelerated long-term ageing/conditioning by the rotating cylinder method (RCAT), Wien.

ASI – Austrian Standards Institute (2009). ÖNORM EN 12591 Bitumen und bitumenhaltige Bindemittel - Anforderungen an Straßenbaubitumen / Bitumen and bituminous binders - Specifications for paving grade bitumens, Wien.

ASI – Austrian Standards Institute (2012). ÖNORM EN 14769 Bitumen und bitumenhaltige Bindemittel - Beschleunigte Langzeit-Alterung mit einem Druckalterungsbehälter (PAV) / Bitumen and bituminous binders - Accelerated long-term ageing conditioning by a Pressure Ageing Vessel (PAV), Wien.

ASI – Austrian Standards Institute (2014a). ÖNORM EN 12607-1 Bitumen und bitumenhaltige Bindemittel - Bestimmung der Beständigkeit gegen Verhärtung unter Einfluss von Wärme und Luft - Teil 1: RTFOT-Verfahren / Bitumen and bituminous binders - Determination of the resistance to hardening under influence of heat and air - Part 1: RTFOT method, Wien.

ASI – Austrian Standards Institute (2014b). ÖNORM EN 12607-2 Bitumen und bitumenhaltige Bindemittel - Bestimmung der Beständigkeit gegen Verhärtung unter Einfluss von Wärme und Luft - Teil 2: TFOT-Verfahren / Bitumen and bituminous binders - Determination of the resistance to hardening under influence of heat and air - Part 2: TFOT method, Wien.

ASI – Austrian Standards Institute (2014c). ÖNORM EN 12607-3 Bitumen und bitumenhaltige Bindemittel - Bestimmung der Beständigkeit gegen Verhärtung unter Einfluss von Wärme und Luft - Teil 3: RFT-Verfahren / Bitumen and bituminous binders - Determination of the resistance to hardening under influence of heat and air - Part 3: RFT method, Wien.

Bald, S., Böhm, S., Johannsen, K., Root, V., & Wellner, F. (Oktober, 2005). Optimierung der Zusammensetzung wasserdurchlässiger Asphaltbefestigungen, Forschungsauftrag des Deutschen Asphaltinstitutes e.V. Mitglied der Arbeitsgemeinschaft industrieller Forschungsvereinigungen – AIF, Schlussbericht, Tu Darmstadt, TU Dresden, Darmstadt, p. 19.

Blab, R. & Hofko, B. (2012). Gestrata Journal 135 – Anti-Aging Anforderungen an Asphalt, Gestrata - Gesellschaft zur Pflege der Straßenbautechnik mit Asphalt, Linz, p 26.

Büchler, S. & Wistuba, M. (2010). Das Braunschweiger Verfahren zur Alterung von Asphaltmischgut und deren Einfluss auf die Kälte- und Ermüdungseigenschaften. Straße und Autobahn, Heft 1.

Cetinkaya, R. (2011). Bewertung der Einflussfaktoren auf die thermisch-oxidative Alterung von Bitumen im Asphalt, Heft 23, Ruhr-Universität Bochum, Asphalttage 2011.

Chulk, J. (2006). Diplomarbeit, Aging of Bituminous Materials an ist Effects on the Stifness Properties, TU Wien, Institut für Straßenbau und Straßenerhaltung, Wien.

Do, M.-T. Kane, M. & Cerzo, V. (2014). Laboratory test methods for polishing asphalt surfaces an predicting their skid restistance. Conference Paper, 92nd Annual Meeting Transport Research Board (TRB) at Washington, p. 9.

Grothe, H. & Wistuba, M. (2010). Gestrata Bauseminar 2010 - Affinität Bitumen / Gestein - Eine dauerhafte Verbindung, Gestrata - Gesellschaft zur Pflege der Straßenbautechnik mit Asphalt, Linz.

Hase, M., Beyersdorf, W., Hase, A. & Rademacher, K. (Februar, 2019). Bast – Berichte der Bundesasntalt für Straßenwesen, Straßenbau Heft S 129, Verfahren zur Prognose des Alterungsverhaltens von Asphalt, Bergisch Gladbach.

Hospodka, M. (2017). Diplomarbeit, Alterungsmechanismen von Bitumen und Simulation der Alterung im Labor, Universität für Bodenkultur BOKU Wien, Wien.

Maschauer, D., Hofko, B., Eberhardsteiner, L., Grothe, H., Koyun, A.N., Wistuba, M. P., Büchner, J., Patzak, J., & Wiese, C. (2017). Optimales Asphaltmischgut-Alterungsverfahren zur Berücksichtigung in der rechnerischen Dimensionierung OptiMAl, Forschungsprojekt finanziert im Rahmen der D-A-CH Kooperation Verkehrsinfrastrukturforschung 2017, Wien, Braunschweig, Dresden, Berlin, Bern, D-A-CH.

Mirwald, J. et al. (2021). Impact of UV–Vis light on the oxidation of bitumen in correlation to solar spectral irradiance data. *Construction and Building Materials*, *316*, 1-4.

Normallab France SAS (n.d.). Rotating cylinder Ageing Test for Bitumen (RCAT Method), Model NRC 210, REF 941878 Leaflet 14rev1.

Partl, M. N. (2011). Asphalt und Bitumen, Vorlesung Werkstoffe 1, ETHZ – Eidgenössische Technische Hochschule Zürich / Swiss Federal Institute od Technology, Zurich.

Potschka, V. & Tabert, A. (1987). Veränderung der Bindemitteleigenschaften während Herstellung, Verarbeitung und Liegezeit von Asphalt. Forschung Straßenbau und Verkehr, Heft 512.

Renken, P. & Wistuba, M. (März, 2018). Bast – Berichte der Bundesasntalt für Straßenwesen, Straßenbau Heft S 118, Untersuchung der Dauerhaftigkeit unterschiedlicher Asphaltbinderkonzepte, Bergisch Gladbach, pp. 28-29.

Stephan, D. A. & Weigel, S. (Juli 2018). Bast – Berichte der Bundesanstalt für Straßenwesen, Straßenbau Heft S 123, Bindemitteldesign für Asphaltstraßen - Definition eines chemisch-rheologischen Anforderungsprofils, Bergisch Gladbach, pp. 18-19.

Stoyanova, M. (2014). Diplomarbeit, Untersuchungen der Feldalterung auf das rheologische Verhalten von Bitumen, TU Wien, Technische Universität Wien, Institut für Verkehrswissenschaften Straßenwesen, Wien, p. 18.