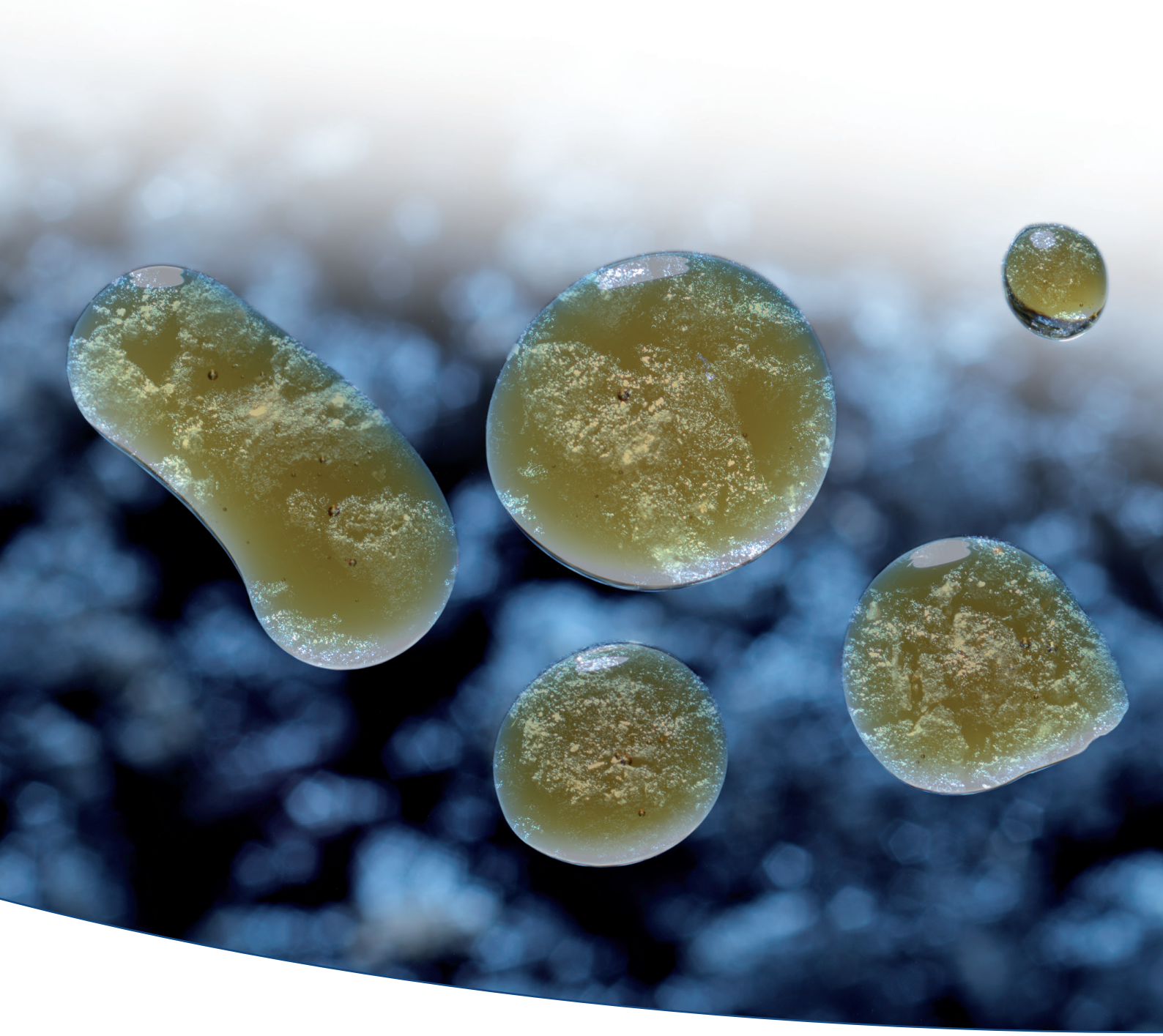


Adhesion promoters

Technical bulletin

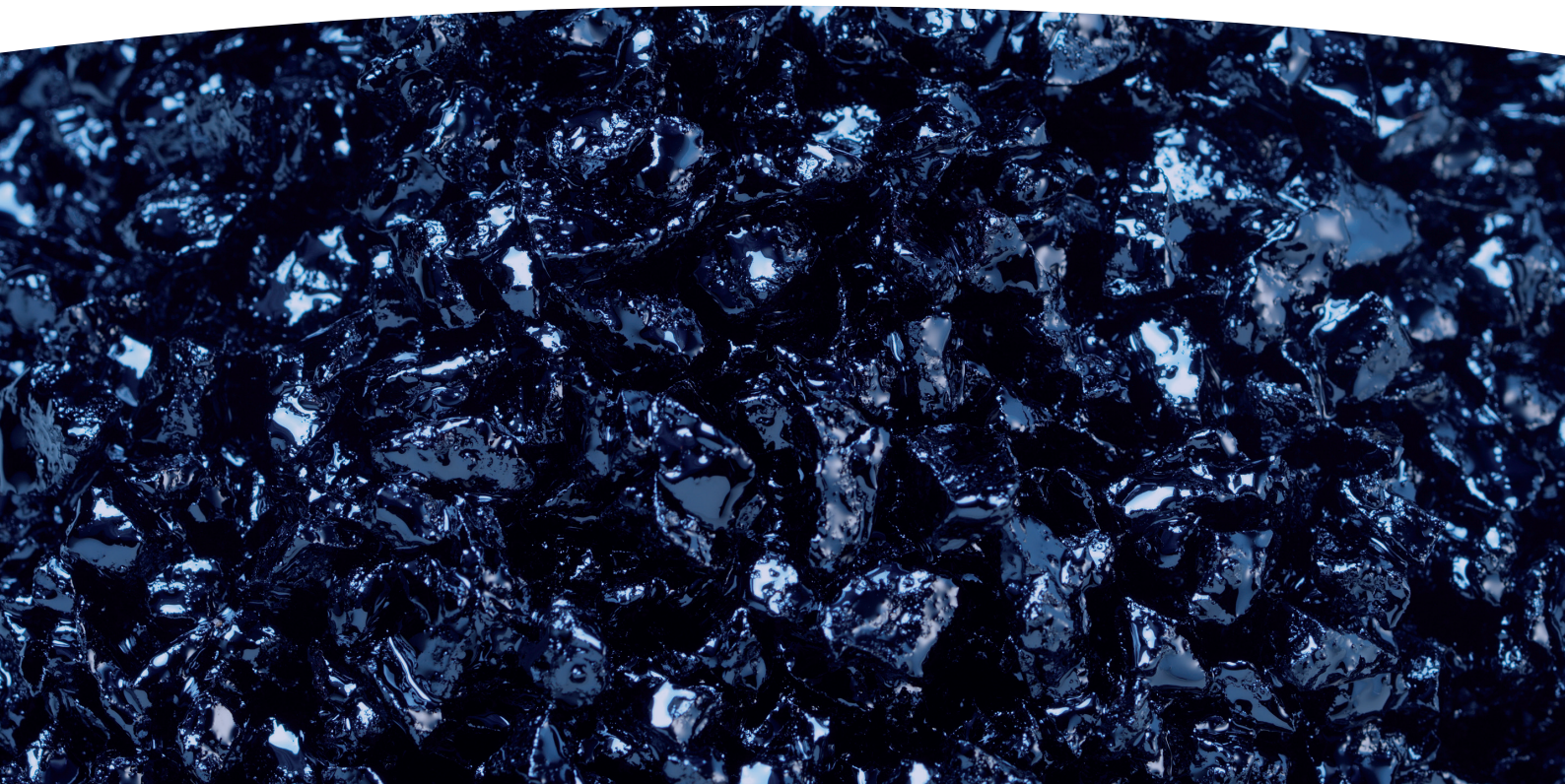
Nouryon

Adhesion promoters for bitumen

This booklet gives an introduction to the challenge of adhesion between bitumen (asphalt cement) and aggregate surfaces and how this adhesion can be improved by additives known variously as adhesion promoters, **anti-stripping agents**, wetting agents, **anti-stripps** or **adhesion agents** in the different regions of the world. In this booklet we have used the term **adhesion promoters** to include all additives to bitumen designed to improve adhesion.

The largest use of bitumen is in road construction and the discussion is mainly directed to adhesion in road building materials, but adhesion and wetting can also be an issue in bituminous coatings and filled bitumen as well as with related binders like tars and resins.

Some examples are given in the "Applications" section.



Adhesion in asphalt pavements

All asphalt pavements basically consist of two main components; bitumen and aggregate. The function of bitumen which typically represents 4-7% of the pavement is to act as a binder in-between the aggregate skeleton, giving the asphalt sufficient internal cohesion. It is, therefore, of vital importance that the bitumen has a strong bond (adhesion) to the aggregate surface.

The fact that roadways can suffer water damage is well established. The visible symptoms of water damage are various and include rutting and shoving, deformation, loss of chippings from surface dressings (chip seals), ravelling of surface layers. This leads to rough surfaces and eventually potholes, loss of structural strength, susceptibility to freeze-thaw damage and cracking. The underlying problem on a micro scale is loss of adhesion between the bitumen and the aggregate surface. Even though the aggregate is fully coated with bitumen, water could penetrate the bitumen film by various means, as for instance through wearing of thin bitumen films at sharp aggregate edges.

Experience has shown that there are few aggregate/bitumen combinations which completely resist the action of water under all conditions. One might think that asphalt is impervious but it has been found that water may enter the pavement structure in several ways:

- Rainfall seeping through shoulders, cracks or porous pavements
- Subsurface water from higher ground producing a hydrostatic head
- Water rising from the sub grade by capillary action
- The action of wheel loading from traffic pressing water into the surface in front of the tyre and sucking it out behind, leading to a pumping effect of water in the pavement
- Presence of salts

Water damage is more likely in wet climates and highly trafficked roads are liable to show the effects of any type of damage most quickly.

Consequence of poor adhesion

Raw materials, production, mix and pavement design

A great number of parameters that have an influence on the adhesion and durability are involved in road construction, from selection of raw materials to the completion of the final road pavement.

The following parameters normally make the pavement more susceptible to moisture damage:

- Aggregate with inherently poor adhesion properties
- Bitumen with poor adhesion properties
- Incompatible combinations of bitumen and aggregate
- Mix designs low in binder and open in grading
- Thin bitumen films
- Inadequate compaction leading to high voids in the pavement
- Inadequate subsurface drainage
- A high content of clay fines and dusty aggregate surfaces
- Incompletely dried aggregate
- Segregated mix
- Presence of hygroscopic additives – i.e. cellulose fibres

The use of adhesion promoters cannot eliminate all the moisture damage caused by poor design, bad construction techniques or poor materials, but it can reduce their effect in practice.

Adhesion related damage

A growing concern for society. Traffic volume and the number of heavy trucks on our roads is increasing in most countries but the national funds allocated to the road sector often remain on a limited level or even decrease in relative terms.

In order to get best value for money by extending the lifetime of pavements, several countries have, therefore, implemented national requirements of mandatory addition of adhesion promoters in asphalt mixes, to secure and maintain the adhesion and durability of asphalt pavements over time.

Implementation of functional contracts, where the contractor is responsible for the condition of the road for many years, has also motivated contractors to use adhesion promoters as the extra cost is relatively small in perspective with extended pavement life benefits.

Another advantage of using adhesion promoters is that locally available raw materials can be used to a greater extent leading to less transportation demand and reduced impact on the environment.

Adhesion between aggregate and bitumen

It is the presence of water at the interface of bitumen and the aggregate which is the primary cause of moisture-induced damage and the premature failure of road pavements.

Moisture damage may exhibit as adhesive or cohesive failure. The cause is water getting between the bitumen film and the aggregate surface. While stripping of bitumen from the larger aggregates clearly leads to ravelling and loss of stability, adsorption of water onto the surface of the filler (-75 micron) fraction of the aggregate may also have a profound effect on the cohesive strength of the mastic leading to damage in dense mixes.

Surface physio-chemical effects

In basic terms bitumen is an oily material and therefore very hydrophobic. This means it has excellent waterproofing ability but does not easily adhere to hydrophilic surfaces of most aggregates. Consequently, naturally hydrophilic aggregate materials have a greater affinity for water than bitumen under normal circumstances. This means that bitumen cannot adhere to a wet surface and can be replaced by water over time. In practice the adhesion between bitumen and aggregate depends on the chemical nature of the components and therefore the source of the bitumen and type of aggregate.

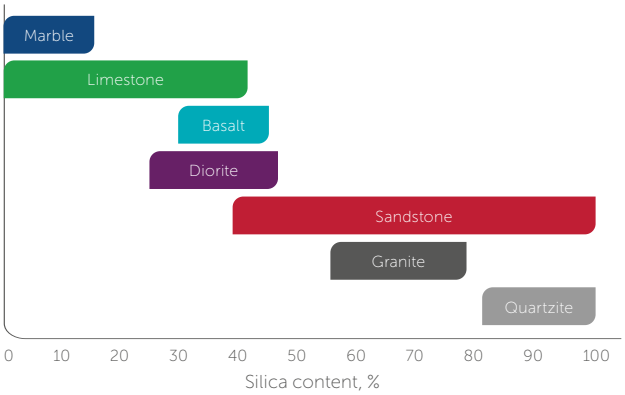
Other aggregate properties such as surface texture, porosity, shape and absorbtion will also influence the aggregate/bitumen adhesion.

Effect of polarity

Due to its chemical composition, bitumen has quite a low polarity whereas water is extremely polar. Aggregates may be of an "acidic" type, with surfaces that tend to be negatively charged, or "basic" with surfaces that tend to be positively charged. Acidic aggregates include those with high silica contents, while basic aggregates include carbonates. The chart illustrates silica content of some common aggregate types.

Bitumens, especially those with high acid value, have a tendency to be slightly negatively charged and thus adhesion problems occur particularly, but not exclusively, with acidic (negative) aggregates.

It is the function of the adhesion promoter to alter the relative surface properties and polarity of incompatible materials, thus facilitating a strong bond between the bitumen and the aggregate which resists the water displacing effect for the service life of the pavement.



Effect of adhesion promoter on soaked specimens, sample to the left contains adhesion promoter

Active and passive adhesion

There are two recognised aspects of adhesion when using surface active adhesion promoters; active and passive.

"Coating, formation and retention of strong chemical bond between aggregate and bitumen in the presence of water"

Active adhesion

A damp or water-wet surface will in most cases make it impossible for an untreated bitumen to coat the aggregate. As mentioned above, bitumen has much less affinity for the aggregate surface than water. The ability of a bitumen to displace water from an aggregate surface and maintain the adhesive bond to the aggregate is known as "active" adhesion.

Lack of active adhesion can be recognized by the presence of uncoated surfaces in mixes and early loss of chippings from surface dressings. But even when the aggregate is apparently well coated with bitumen, a dust or water layer may prevent intimate contact and the establishment of the adhesive bond.

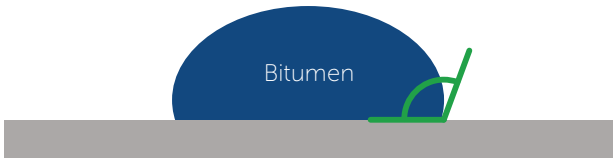
To achieve active adhesion an adhesion promoter is added. The dosage rate is normally 0.5-1.2% calculated on the bitumen. Active adhesion is achieved by the action of the surface active adhesion promoter decreasing the contact angle of the bitumen to aggregate interface thus allowing the bitumen to displace water and coat the aggregate surface, as illustrated in the diagram to the right.

"The process of forming and maintaining a strong chemical bond between bitumen and a dry aggregate surface"

Passive adhesion

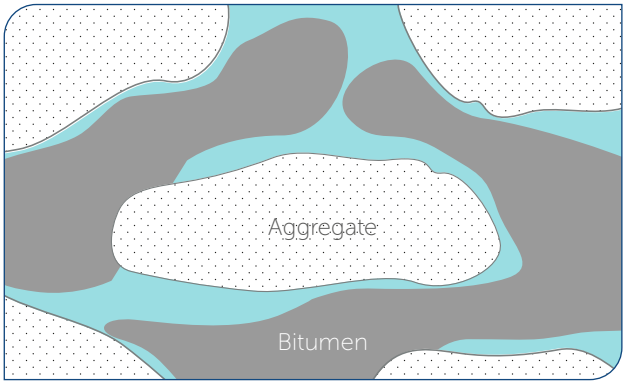
Passive adhesion is the ability of a binder to maintain the integrity of the adhesive bond with aggregate to prevent stripping under wet conditions.

Passive adhesion can be ensured by the addition of an adhesion promoter to the binder. Typically 0.2-0.5% calculated on bitumen (0.3% corresponds to 150-200 g/tonne of hot mix) is sufficient to impart water resistance.



Poor wetting – big contact angle

Good wetting – small contact angle



The use of untreated bitumen may result in stripping leading to detachment of the bitumen film from the aggregate surface

Wetting

Bitumen is highly viscous with little chemical affinity for the surfaces of most aggregates so it spreads only with difficulty. To ensure good wetting it is necessary to reduce its viscosity and to modify the chemical nature of the bitumen or the aggregate.

Bitumen viscosity can be reduced by heating or adding solvents. Additives like polymers or fillers which could have the effect of increasing binder viscosity can impede wetting and may require the use of higher temperatures or longer mix times. A liquid adhesion promoter on the other hand improves the wetting.

Selection of adhesion promoters

The type of liquid adhesion promoter to be used depends on the nature of the aggregate, type of bitumen and production temperature. Asphalt mixes are sometimes produced with soft bitumen at a lower temperature around 100°C, an active adhesion promoter is in such cases required due to the presence of water during the mixing process.

The choice of adhesion promoter is also dependent on the chemical nature of the aggregate (alkaline or acidic).

We offer adhesion promoters under the trade names Wetfix®, Kling®, Perma-Tac® and Diamine® in different parts of the world.

Stone losses on a surface dressing due to poor adhesion

Long-term effect evaluation

Bitumen treated with an adhesion promoter coats the aggregate and reinforces the adhesive bond between the aggregate and the bitumen thereby improving long – term resistance to bitumen detachment by ingress of water.

There are several different investigations conducted over the years to asses the long term effect of liquid adhesion promoters.

The National Cooperative Highway Research Program conducted a field evaluation over a period of 6 to 8 years (Report 373) and the report concludes that "The long term performance of the nine additives after 6 to 8 years was found to be satisfactory in eight cases".

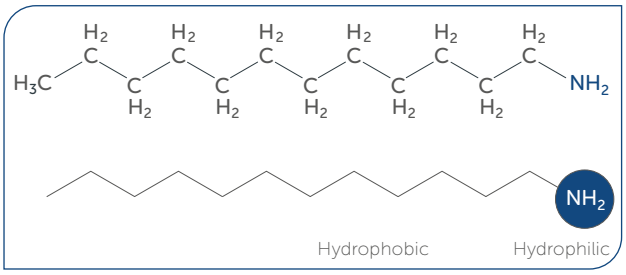
Drilled cores without (left) and with Wetfix liquid adhesion promoters (right) from pavements after twenty years in service

How surface active adhesion works

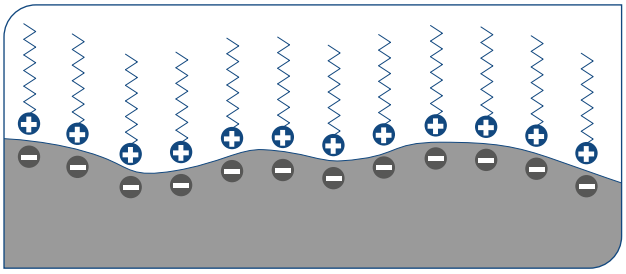
Adhesion promoters are cationic surface active molecules which concentrate at the bitumen – aggregate interface.

While the positive/ hydrophilic head groups on the surface active agents bind strongly to the negative sites on the aggregate surface, the hydrophobic hydrocarbon "tails" of the molecules anchor into the bitumen. The adhesion promoter thus acts as a bridge or glue between the bitumen and the aggregate surface which resists the displacing effect of water.

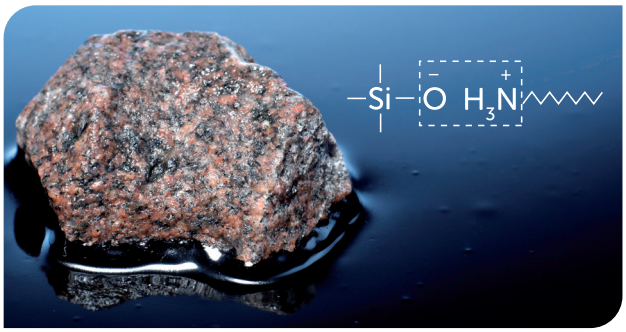
Adhesion promoters can be introduced into a system by addition to the bitumen. Although added to the bitumen, adhesion promoter molecules quickly migrate into the bitumen – aggregate interface.



Chemical structure of adhesion promoters



Adhesion promoter molecules act as bridge between aggregate and bitumen



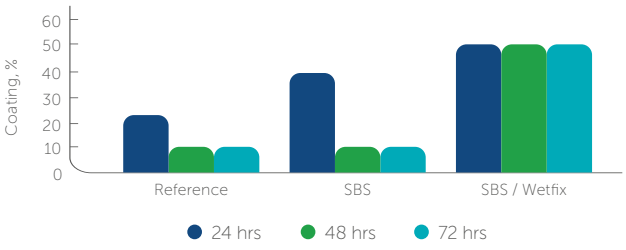
Other additives

There are different types of additives used in asphalt pavements to improve different properties as for example resistance to deformation. Such additives do not necessarily guarantee adhesion, hence adhesion promoters are often used in combinations with these additives.

Polymers

Polymers are often used to improve low and high temperature properties such as flexibility, elasticity and toughness over a wide temperature range.

Rolling bottle test (SBUF Report 0025)



Typical advantages with polymers are:

- Reduced permanent deformation (rutting) at high temperature
- Reduced crack formation at low temperature
- Improve shear resistance allowing thinner layers to be applied
- Reduced fretting

Polymers and adhesion promoters are often used in combination, as polymers do not necessarily improve the bonding between the bitumen and aggregate. As shown in the diagram.

Fibres

Different types of fibres such as modified cellulose and synthetic are sometimes added to the asphalt mix to improve resistance to deformation.

Fibres also allow a high percentage of binder to be added into the mix without negatively affecting the asphalt mix by preventing the binder from draining off the mineral aggregates.

Wax

The addition of various wax products to the base bitumen is a growing trend and produces a marked reduction in bitumen viscosity at elevated temperature. This enables mixing and handling temperatures of the asphalt mix to be reduced – so called "Warm mix" technology.

Cement and lime

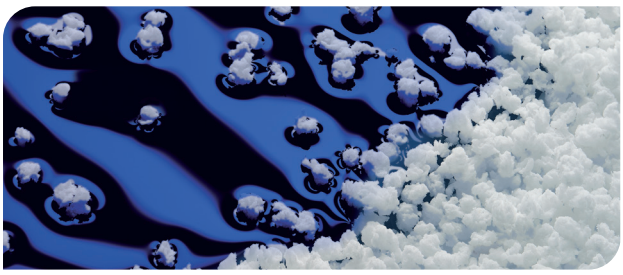
Cement and lime is sometimes used to adjust fine aggregate grading, improve the durability and to increase the stiffness of the mix.

Cement and lime can have the effect of increasing the asphalt mix viscosity and can impede wetting during mixing process, therefore a higher mix temperature or longer mix time may be required. Cement and lime might also promote cracking in the pavement as they often make the asphalt mix more brittle in service.

Cement and lime are normally used at a dosage level between 1-2% calculated on the **aggregate weight in hot mix**. In the case of liquid adhesion promoters, only 0.3% calculated on the **bitumen weight** is normally needed.

This means that the required mass of material is significantly higher when cement and lime are used; about 100 times higher compared to liquid adhesion promoters, which leads to increased need for transport capacity and excess handling. Coupled with the much higher energy demand required to produce hydrated lime and cement, it can be seen that these additives have a much higher carbon footprint. The use of liquid adhesion promoters is, therefore, very beneficial when environmental considerations are taken into account.

In many cases, hot mix plants experience problems with excess filler. This means that filler often has to be transported to a depot resulting in extra costs and transport demands. The addition of external mineral filler contributes further to the excess filler problem.



Polymer inclusion into hot bitumen during highshear mixing.
Photo: Nynas AB

Applications

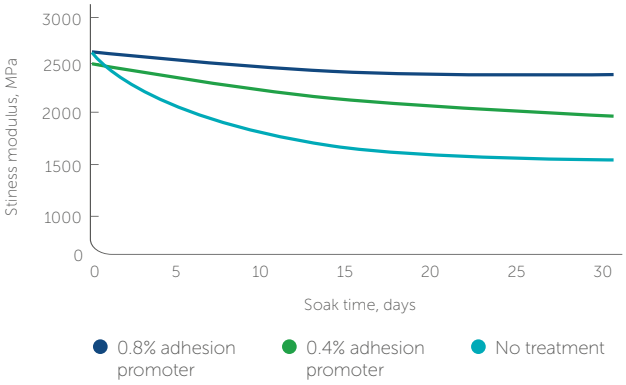
Hot mixes

Most asphalt mixes are made hot with dry aggregate. The use of adhesion promoters ensures complete coating of aggregates that are difficult to coat and also improves the adhesion and durability of the final asphalt pavement. Typical use levels range from 0.2-1.0% in the bitumen.

Tests on asphalt specimens using the Nottingham Asphalt Tester show that mixes containing treated bitumen maintain their load bearing capacity (stiffness modulus) even after being immersed in water.

Indirect tensile stiffness modulus after immersion

28 mm base course using 100 pen bitumen



Compacted hot mixes containing adhesion promoters resist the effect of water

Hot recycling

Recycling of asphalt pavements is growing rapidly due to the environmental benefits and cost of disposal of asphalt planings as landfill. The material arising from asphalt planings can be variable in quality and in general if partly coated surfaces are obvious in the reclaimed asphalt, adhesion promoters should be used.

Low temperature Hot mix (Warm mixes)

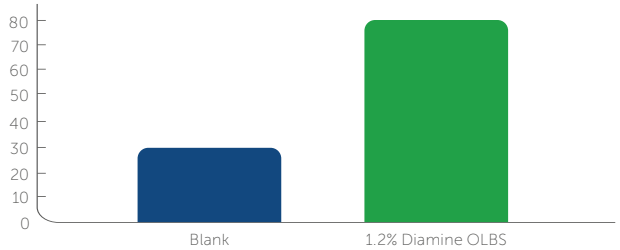
There is a growing interest within the road building industry to reduce the temperature when producing hot mixes.

Energy savings, improved working environment and reduction of CO_2 emissions (carbon footprint) are all important objectives for the industry.

Since the aggregate often are heated to a lower temperature than normal hot mix production, water may not be completely removed and therefore it is important to use an adhesion promoter in those cases.

Some of the techniques even deliberately introduce water during the mixing process.

Indirect tensile strength ratio after salt, freeeze and thaw conditioning of soft bitumen specimens



Test results from an investigation conducted by The Swedish Road Authority

Soft bitumen mixes

Asphalt mixes can be produced at lower temperatures if the binder is of sufficiently low viscosity. This type of application, so called soft bitumen mix, is frequently used in Scandinavia and is manufactured with fluxed bitumen (bitumen diluted with heavy solvent).

Those mixes are routinely used as carriageway courses to alleviate the problems of cracking due to the low ambient temperatures. Due to the mix design and conditions, deformation is not normally a problem in this case.

Because the process is carried out at a temperature around 100°C, the aggregate is not completely dried and the softbitumen has to be able to displace water from the aggregate surface during production. An active adhesion promoter is, therefore, essential.

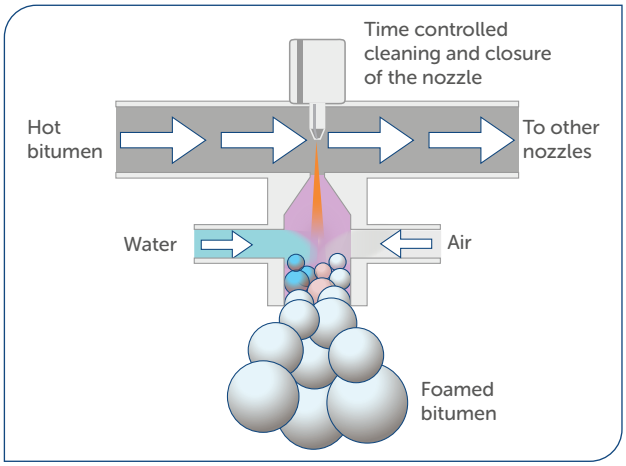
Typical use levels range from 0.5-1.2%. The adhesion promoter also ensures that stripping does not occur during the stockpiling of the mixes and during the life time of the pavement. Often a combination of virgin and recycled material (RAP) is used in this application.

Foam

Foamed bitumen is sometimes used in road construction. The purpose of foaming is to increase the bitumen surface area and reduce the viscosity of the bitumen during the mixing process. Foamed bitumen is created by injecting a small amount of water into the bitumen by means of specialised equipment depicted above. The foam has a limited life span and must be quickly mixed with aggregate before it collapses. Additives are sometimes used to extend the half life of the foam.

It is important that an active adhesion promoter is used as water is present during the mixing process. Typical use levels range from 0.5-1.2% in the bitumen.

Test results with and without adhesion promoter in foam mixes



Schematic illustration of the foaming process

Surface dressing / chipseal

Surface dressing, also known as chipseal or spray seal, is a quick and convenient method of rejuvenating a worn out road surface. Hot penetration grade or cut-back bitumen is sprayed onto the road surface and chippings are spread on top and normally rolled to ensure proper embedment and alignment. This provides an economical and water impervious surface seal and also a much-improved surface texture. However, little or no surface regulation is achieved with surface dressings.

The binder cools rapidly on the road surface leading to high viscosity which can make good wetting of the aggregate by the bitumen difficult. This is exacerbated by wet aggregate.

In order to overcome these issues this is an application where "active" adhesion is essential and typically 0.5-1.2% adhesion promoter is added to the binder.

There have been several field studies which demonstrate beyond doubt that the use of adhesion promoters in surface dressing leads to resistance to early rain, an increased ability to cope with more dusty aggregate and less loss of chippings in the long term.

The use of adhesion promoters in surface dressing is specified by many national authorities.

Spreading of binder and chippings during surface dressing application

Penetration macadam

Penetration macadam is a technique in which bitumen emulsion or cut back bitumen is sprayed on to an open graded aggregate mix, and then compacted. Damp to wet aggregates are often used and an active adhesion promoter is therefore required when cut back is used as binder. Typical use levels range from 0.5-1.2% in the bitumen.

Not surprising that one authority concluded:
"Although the cost of adding a small amount of adhesion promoter is minor, the savings to be made are incredible"

Prime coats

In some countries, cutbacks or road oils are used for priming and to control dust on unbound aggregate road bases during construction. Because the road base is cold and damp, adhesion promoters should be added to the prime coat to ensure active adhesion and rain fastness.

Pre coated chippings

Single sized chippings used in certain applications are precoated with a thin layer of oil or bitumen to ensure good adhesion to the primary binder. Chippings precoated with oil or bitumen is sometimes used for surface dressing, especially when using highly viscous rubber-modified binders, or when the aggregate is dusty. Stones rolled into hot rolled asphalt are always pre-coated with bitumen. To ensure good coating and adhesion, adhesion promoters are added to the bitumen.

Bituminous coatings

Bitumen and cut-backs are used for waterproofing, sealing and corrosion protective coatings. Many of the same problems with coating and water resistance seen in road construction materials also apply to these coatings. Where the substrate is cold and could be damp, then it is necessary to ensure active adhesion by the use of adhesion promoters at a level of 0.5-2% on the binder.

Emulsions

The use of cationic bitumen emulsions usually ensures good adhesion in road applications. There may be cases where additional water resistance is required and then adhesion promoters can be added to the binder before emulsification and usually at a level of 0.1-0.5%.

Anionic emulsions often used in industrial applications and for road applications in certain parts of the World generally provide poor adhesion to siliceous (acidic) aggregates and to metallic or stone substrates. Adhesion of anionic emulsions is improved by adding adhesion promoters to the binder before emulsification, typically at a level of 0.1-0.5%.

Use of adhesion promoters

Dosage
Dosing of adhesion promoters can be done at different stages in the mixing and application process.

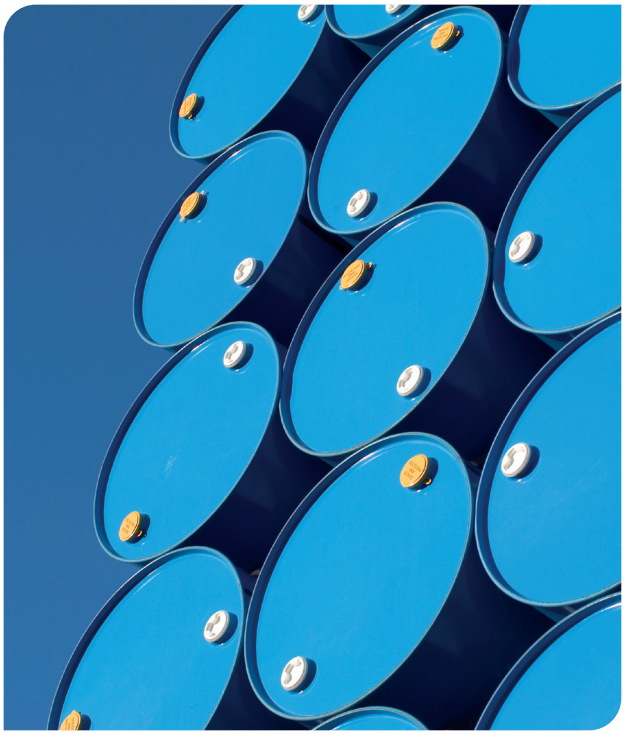
Since adhesion promoters have variable sensitivity to storage in hot bitumen, it is preferable to add the promoter late in the process. There are dosage systems for adding in line in to the bitumen stream in mixing plants or in connection with load out at bitumen depots.

At hot mix plants the adhesion promoter can also be added into a day tank, but then care should be taken to compensate for possible break down if the bitumen is not used within the appropriate timescale.

As an alternative to the liquid form, adhesion promoters are also available as prills or pellets delivered in bags. This facilitates convenient dosing in the field in connection with, for example, surface dressing operations.

Heat stability
Adhesion promoters are extremely stable in cold bitumen and maintain their adhesion effect over many years. However, adhesion promoters slowly lose activity in hot bitumen prevalent during the various road building processes. This loss in activity depends on the source of the bitumen and is mainly due to the reaction of the alkaline amine with the acidic components in the bitumen. In general, activity is lost more quickly in bitumen's with higher acid values such as those from Venezuelan crude's and particularly at higher temperatures.

Treated bitumen should not be overheated and should be stored for as short a time as possible before use. If extended storage of treated binder is unavoidable, then a special heat stable product should be selected to enable storage for up to 5 to 7 days. The effect could also be prolonged by using a higher dosage level.



Storage and handling equipment
Carbon steel tanks are necessary for storage of liquid adhesion promoters in order to resist corrosion. Paste products must be heated before use but also some higher melting point liquid ones may also require slight heating in cold weather conditions. Care should be taken not to overheat the products since this may affect performance. Consult product data sheets for guidance. Contamination with water often cause the products to gel or sometimes even to degrade, hence water ingress into storage containers must be prevented.

Carbon steel is generally a suitable material in pumps and other equipment. PTFE (i.e. Viton C) or polyamide seals or gaskets may be used. Copper alloys and aluminium and butyl and natural rubbers will be adversely affected.

Waste packaging
IBC's as well as drums can often be recycled via various organisations. IBC's are normally taken back by the manufacturer and contact details are given on the container labels.

Local regulations should be followed when disposing any waste packaging.

Health, safety and the environment

Recommendations for handling of Wetfix® products.
The handling should be in accordance with our recommendations as given in our safety data sheets, preferably using equipment for in-line dosage to the bitumen before the mixer. In doing so, direct contact with the products is avoided. Suitable facemask or goggles, gloves and protective clothing should always be worn when handling the Wetfix® products.
For more information please consult our HSE brochure and the Safety Data Sheets.

Inhalation

We have reduced volatile components in adhesion promoter products. The most severe, in terms of possible fume concentration, was done during the building of Stockholm's ring road tunnel system. The tests were conducted in a tunnel to create a worst-case scenario, creating maximum concentration of volatile compounds in the air. These actions were made to create an artificially polluted situation but even so, no amines could be detected in the collected air samples. Considering that the detection limit was at least 200 times lower than the occupational allowed value, giving a safety margin of at least 200 times on a value that is already considered to be safe, we firmly believe that it is safe to handle our Wetfix® products if they are used in a correct way.

Human health – ingestion

Wetfix® products have a relatively low acute toxicity normally above 2000 mg/kg bodyweight making them not classified in the respect to acute toxicity. However, some products fall in the range of 200-2000 mg/kg making them classified as harmful. The lower limit of 200 mg/kg corresponds to a table spoon dose for an adult and 2000 mg/kg to a cupful. It is extremely unlikely that anyone would digest these amounts by accident.

Skin and eye exposure

A more conceivable scenario would be that drops and spills of Wetfix® could come in contact with skin and eyes if the correct protective equipment is not used. If a drop actually enters the eye it could cause sever eye damage if the eye is not treated immediately. If available, we recommend that the eye is flushed with a certified solution of 0.5% acetic acid in water followed by plenty of clean water if an accident occurs. If 0.5% acetic acid is not available then irrigation with water should begin immediately.

The same procedure applies with skin contact except that it is a good idea to use soap and water as a middle step. However, the best "cure" is to prevent the occurrence of the accident by using proper protective equipment.

"If an accident occurs a doctor should always be consulted"

When protective equipment has been contaminated it is very important that the equipment is replaced or properly cleaned due to the fact that repeated contact could cause sensitizing.

Environmental toxicity

Many cationic surfactants show high toxicity against aquatic organisms such as certain fish, daphnia and algae. This is due to the inherent property of adsorption to surfaces and is especially apparent in test systems where no competing moieties exist.

In practical situations where the products might collect in places such as the road ditch and at the road bank, there are enormous amounts of particulate matter present onto which the surfactants will readily adsorb making them mostly unavailable to organisms. This is supported by experimental data showing a strong reduction of the actual effect of cationics using river water instead of pure water. Another factor that should be considered is that in reality, the amine is adsorbed on the aggregate and then covered with a sealing layer of bitumen.

Carbon footprint

Energy usage and emissions (carbon footprint) of industrial operations are now very much in focus from the authorities and society. The Wetfix® products are excellent choices in this respect. Investigations show that if the lifetime of a road is increased by as little as 2% the adhesion promoter has paid back the strain on the environment during its production cycle. Of course in reality the increased lifetime is far longer than this.

Compared to other adhesion additives like hydrated lime and cement, amine based liquid adhesion promoters are very favourable in this respect. A full life cycle analysis has shown that the carbon footprint of Wetfix® adhesion promoters is less than 5% that of hydrated lime and cement.

Laboratory tests

The adhesion between bitumen and aggregate can be predicted by means of laboratory test methods. The procedures can be used to evaluate the effect of moisture on a given aggregate-binder combination with or without adhesion promoters. It could be difficult to simulate field conditions in the laboratory and consequently difficult to exactly evaluate the field performance. The laboratory tests are concentrated on examining the effect of water on coated aggregate (passive adhesion) or the ability of bitumen to adhere to wet aggregate (active adhesion).

Tests of passive adhesion

Static immersion tests

Dry, single-sized aggregate are coated with bitumen at a temperature related to the binder viscosity, and then immersed in water. The stripping is expressed by visual inspection of the degree of bitumen coverage on uncompacted bitumen-coated mineral aggregate after storage in water. An example of this type of test method is the Total water immersion test. The static test is a subjective test that can cope with high PSV-aggregates.

When the water temperature is increased to 100°C, the method is known as the Boiling water stripping test. The affinity is expressed by determine the degree of bitumen coverage on bitumen coated aggregate after immersion in boiling water under specified conditions.

In modified tests the aggregate may be covered with a solution of salt to simulate the effect of de-icing chemicals.

References to typical procedures:

A. European Standard EN 12697-11: Part B Static test
B. European Standard EN 12697-11: Part C Boiling water stripping test
C. USA ASTM D3625-91: Effect of water on bituminous coated aggregate using boiling water
D. Nouryon AA2: Total water immersion test

Dynamic immersion test / Rolling bottle test

The bitumen coated single-sized aggregate is transferred to a bottle filled with water. The bottle is sealed and placed on a bottle-rolling device. The bottles are rolled at ambient temperature at specified speed and after different time intervals the degree of bitumen coverage on the aggregate is visually estimated. The method is not appropriate for aggregates that are highly abrasive.

Bottles containing bitumen covered single sized aggregate chippings and water in the rolling device

Visual estimation of aggregate surface area covered with bitumen

References to typical procedures:

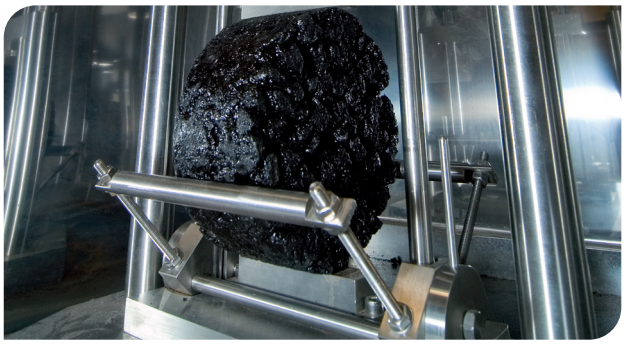
A. European Standard EN 12697-11: Part A Rolling bottle method
B. Nouryon AA1: Rolling bottle test

Tests of water sensitivity on compacted asphalt mixtures

Indirect tensile strength ratio

The specimens is compacted to a density and air voids level corresponding to what is expected in the field but the method can also be applied on cores taken from an asphalt pavement. After compaction one subset is maintained dry at room temperature while the other subset is saturated and stored in water at elevated conditioning temperature.

After conditioning the indirect tensile strength of each subset is determined at the specified test temperature. The ratio in indirect tensile strength between the water conditioned subset and the dry subset is expressed in percent.



The Nottingham asphalttester can be configured for different tests

References to typical procedures:

A. European Standard EN 12697-12: Determination of the water sensitivity of bituminous specimens
B. USA ASTM D 4867-92: Effect of moisture on asphalt concrete paving mixtures
C. USA ASTM D 1075-94: Effect of water on compressive strength of compacted bituminous mixtures

Modified Lottman test

The specimens is again compacted to a specified air voids level. After compaction the specimens is submerged in water and vacuum saturated and subjected to one or more freezethaw cycles. The indirect tensile strength (ITS) of the water conditioned samples is compared with the ITS obtained on the dry specimens. The ratio is expressed in percent.

References to typical procedures:

A. USA ASTM D4867-92: Effect of moisture on asphalt concrete paving mixtures
B. USA AASHTO T238: Resistance to moisture induced damage

Exposure to moisture vapour

Asphalt mixes are made and exposed to a moist atmosphere. The stability of the mix is determined after exposure.

References to typical procedures:

A. USA California CT307: Moisture vapour susceptibility

Wheel track test

In the wheel tracking test is the susceptibility of a bituminous material to rut measured by repeated passes of a loaded wheel at a fixed temperature, to simulate the effect of traffic. The method is applicable to specimens that have been manufactured in a laboratory or cut from a pavement. Specimens are conditioned in either air or water.

References to typical procedures:

A. European Standard EN 12697-22: Wheel tracking
B. Tex-242-F, Hamburg wheel-tracking test

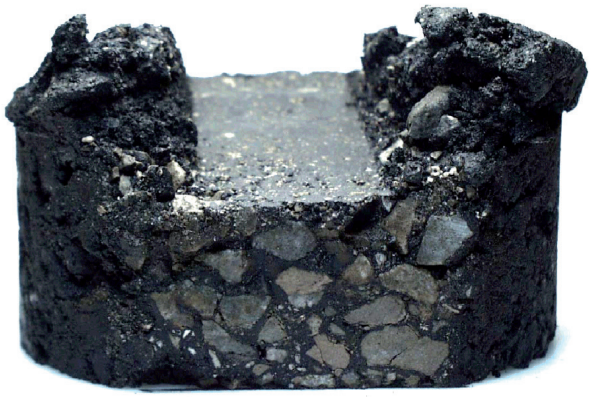
Test to estimate coating of hot mixes

Adhesion promoters may improve the coating of aggregates. The coating in hot mixes can be expressed in terms of the coating of the coarse aggregate and the time required for good coating can be determined.

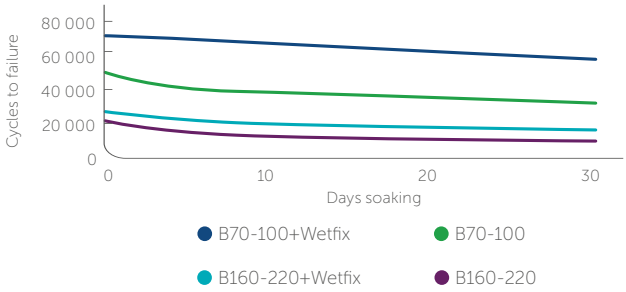
References to typical procedures:

A. USA ASTM D2489: Degree of particle coating of bituminous aggregate mixtures

Typical test equipment for measurement of slabs (KVD lab, Norway)



Wheel track test results from SBUF-report 0071



Tests of active adhesion

Tests for surface dressing (chip sealing)

Immersion tray

This method is design to determine "active" adhesion, the ability of the binder to coat a wetted aggregate. A film of cutback or softbitumen is covered with water and a specified number of chippings are passed through the water and pressed into the binder film. The percentage of binder retained on the chippings is assessed visually.

References to typical procedures:

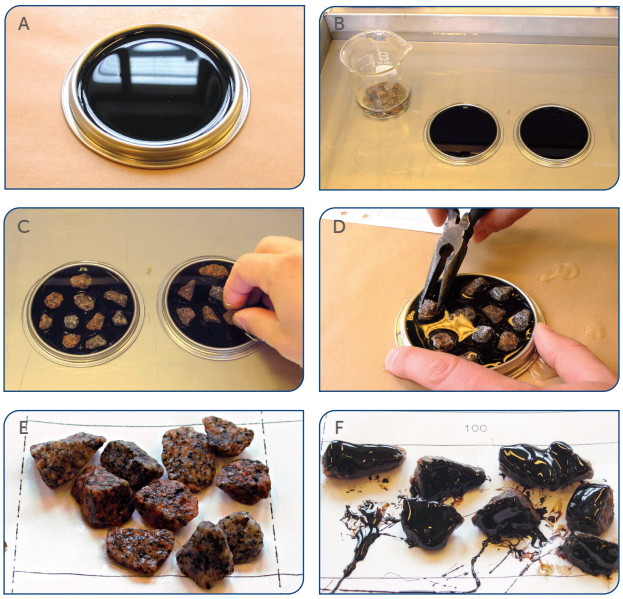
A. Nouryon AA5: Immersion tray test
B. Australia Victoria CRB 112.03 (1975): Adhesion of binder to stone

Plate tests / Vialit

A film of bitumen is placed on a metal plate. Wet or dry chippings are pressed or rolled into the surface. The plate is immersed in water, and the adhesion of the chippings is then determined by blows to the back of the plate. Chippings which fall off are weighed or counted. The use of wet chippings gives a measure of active adhesion.

References to typical procedures:

A. Australia HDSA 305.01 (1988): Determination of aggregate stripping value by the one day plate stripping test
B. Australia NSW T230: Resistance to stripping of cover aggregates and binders
C. New Zealand MWD B301-83: Method of measuring the active adhesion between a bituminous binder and a roading aggregate material



A. Cutback bitumen film on a metal lid
B. Aggregate and bitumen tempered in water bath
C. Chippings pressed firmly into the bitumen film under deionised water
D. Chippings removed after a specified time
E-F. Examine of the aggregate surface area covered with bitumen

Tests for soft bitumen mixes

Wet mix test

The method is primarily designed to evaluate semi-hot mixed materials. Moistures aggregate is mixed with soft bitumen and the percentage of aggregate surface coated with bitumen is estimated visually after different mix times.

Other tests

In modified tests the mixes could be treated in different ways as placed in a bottle-rolling device or stored in water and the coverage / stripping could then be estimated visually.

Indirect tensile strength ratio

Specimens could also be compacted to a density and air voids level corresponding to what is expected in the field. After compaction one subset is maintained dry at room temperature while the other subset is saturated and stored in water at elevated conditioning temperature. After conditioning the indirect tensile strength of each subset is determined at the specified test temperature. The ratio in indirect tensile strength between the water conditioned subset and the dry subset is expressed in percent.

References to typical procedures:

A. Nouryon AA4: Wet mix test
B. Nouryon AA: Modified rolling bottle test
C. Sweden: Road Authority testmethod: VVMB701

Glossary of terms

Adhesion promoter
Cationic surface active agent that ensures a thorough, irreversible water resistant bond between bitumen binder and aggregate

Adhesion promoter, heat stable
Adhesion promoter that maintains its performance after storage of treated binder at high temperature

Adhesion agent
Alternative name for adhesion promoter

Adhesion, active
Bitumen treated with active adhesion promoter displaces moisture from an aggregate surface and establishes a permanent bond between the mineral surface and the bitumen

Adhesion, dynamic
Adhesion between mineral aggregate and bitumen is resistant to the pumping effect of vehicles on wet surface layers

Adhesion, passive
The ability of an established bond between mineral surface and bitumen to resist the effect of water

Aggregate mix, dense graded
A mix containing aggregate which is graded from the maximum size down to filler with the object of obtaining an asphalt mix with a relatively low void content

Aggregate mix, open graded
A mix containing no or very little filler giving relatively large void spaces in the compacted mix

Anti stripping agent
Adhesion promoter providing passive adhesion

Binder
General term for asphalt cement which includes bitumen, coal tar or polymer-modified bitumens

Bitumen
Dark viscous liquid, residue of the vacuum distillation of petroleum. Predominantly aliphatic and cycloaliphatic. Known as asphalt in the USA.

Bitumen, acid value
Measurement of the acidity of bitumen expressed in milligrams of potassium hydroxide required to neutralise one gram bitumen

Bitumen, blown and oxidized
Bitumen that is oxidised by blowing air through it at an elevated temperature to give it stiffness characteristics desired for certain special uses, such as roofing, pipe coating etc

Bitumen sutback
Bitumen containing 10-15 % solvent, e.g. kerosene, boiling range 150-200°C

Bitumen emulsion
An emulsion of bitumen in water which contains a small amount of an emulsifying agent

Bitumen emulsion, anionic
Bitumen emulsion made with anionic emulsifiers in which the droplets of bitumen carry a negative charge

Bitumen emulsion, cationic
Bitumen emulsion made with cationic emulsifiers in which the droplets of bitumen carry a positive charge

Bond coat
European terminology for tack coat

Chipseal
U.S. terminology for surface dressing

Coal tar
Dark viscous liquid obtained from the carbonisation of coal. Predominantly aromatic in character. Rarely seen these days due to content of suspected carcinogens.

Deferred set macadam
Repair material based on fluxed or cut back binder

Flux, Flux oil
Thick, low-volatility petroleum fraction which may be used to soften bitumen

Gradation
A general term used to describe the aggregate composition of a bituminous mix. When the exact percentages of all aggregate essential to a good mix are controlled through the percentage of each size aggregate used.

Hot mix
Road material prepared from a hot mixture of bitumen and graded aggregate

Impervious
Resistant to penetration (by water)

Penetration
Specified method to measure of the hardness of bitumen by length of needle penetration over a set time. High penetration refers to soft bitumen.

Penetration macadam
Technique in which bitumen emulsion or cut back bitumen is sprayed on to an open graded aggregate mix, and then compacted

Porous asphalt
Open graded wearing course material with good drainage (reduces spray) and reduces noise levels for drivers properties

Pre coats
Chippings coated with a small amount of bitumen or kerosene used in surface dressing or rolled into the surface of hot rolled asphalt

Prime coat
Liquid binder sprayed on an unbound layer to provide a good bond with hot mix overlay

Ravelling
Loss of material from the wearing course of a roadway under the influence of traffic

Soft bitumen
Fluxed bitumen, viscosity 2000-20000 mPa.s at 60°C, popular in Northern Europe

Soft bitumen mix
Road material produced from a mix of aggregate and soft bitumen at a relatively low temperature, 100-120°C, popular in Scandinavia

Stripping
Process whereby water displaces bitumen binder from the aggregate surface. Includes processes where water penetrates the film of harder bitumen's causing debonding.

Surface dressing
Surface sealing technique in which chippings are spread on a sprayed film of hot bitumen, cutback bitumen or emulsion

Tack coat
An application of low viscosity liquid bitumen or emulsion between layers of bituminous materials to prevent slippage

Warm mix
Various techniques which allow manufacture of asphalt mixtures at lower temperatures than traditional hot mix

Wearing course
Top layer of the road pavement which is exposed to traffic. Also known as running surface.

Wetting agent
Alternative term for adhesion promoter reflecting the enhanced ability of treated binder to coat aggregates

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