ANTI-STRIPPING AGENTS: A DURABLE PAVEMENT FORMULA

The presence of anti-stripping agents improves asphalt-pavement durability and resistance to water sensitivity. It also delays the occurrence of raveling, as Shahin Eskandarsefat, a senior researcher with Iterchimica, explains*

To date, many additives have been introduced to the asphalt-pavement industry, mainly to improve the bitumen and asphalt rheological and mechanical properties. Nevertheless, without sufficient adhesion, even the best asphalt-mix designs will not guarantee longevity of the pavement.

This bonding between asphalt and aggregate is of utmost importance, given that it is the primary characteristic that influences the integrity of the pavement[1]. It is, however, well known that the bond of bitumen to certain aggregates can be quite poor and potentially lead to early material failure.

Stripping is one of the most commonly occurring distresses in bituminous pavements. It occurs as a result of the destruction of the bond between aggregate particles and the bituminous binder; water accelerates the loss of adhesion at the bitumen–aggregate interface[2].

Stripping, therefore, creates a serious and expensive problem that greatly decreases pavement ride quality and the expected life of our roadways. It has been well proven in many research articles that adhesion properties have a direct impact on the resistance to water sensitivity of asphalt[3] [4]. As a consequence – and besides other impacts on asphalt properties - stripping plays a crucial role in asphalt durability.

Accordingly, to promote the adhesion properties of bituminous binders, several types of anti-stripping technologies have been developed. Among them are liquid anti-stripping agents. These are the most commonly used technologies, where chemical additives are introduced into the bituminous binder. Such additives are surface-active agents, or surfactants. These allow the bituminous binder to coat the aggregate surface more evenly by reducing the surface tension. At the same time, the bituminous binder can displace adsorbed water on or near the aggregate surface[5]. In this way, the occurrence and strength of the binder to aggregate adhesion is enhanced; this mitigates stripping and the deterioration of the asphalt.

DIFFERENT NATURES

To date, several anti-stripping materials have been introduced by the pavement industry. However, the level of adhesion is highly dependent on the mineralogy, the surface characteristics of the aggregates and the bitumen's properties. Iterchimica's liquid anti-stripping agents are divided into four main groups, according to their chemical natures. They are as follows:

1 Amino-based with the recommended dose of 0.2% to 0.4% on weight of the bitumen; *Iterlene 400 IN*;
2 From phosphoric acids with the recommended dose of 0.2% to 0.4% by weight of the bitumen; *Iterlene PE-31* and which is more thermostable in the bitumen;
3 Vegetal-based with the recommended dose of 0.2% to 0.6% on weight of the bitumen; *Iterlene BIO 180* and which is not dangerous according to current provisions of the ADR**;
4 Silica-based with the recommended dose of 0.05% to 0.15% on weight of the bitumen; *Iterlene 100 SL* and which, similar to *Iterlene BIO 180*, is not dangerous according to current provisions of the ADR.

Thanks to the low quantity of the liquid anti-stripping agents added to the bituminous binder, the rheology of the binder is not changed. This guarantees the bitumen rheology-dependant properties of asphalt, which is of concern to any asphalt designer.

DEGREE OF AFFINITY

Currently, there are two methods most commonly used for testing the adhesion properties of bituminous binders and for determining the right dosage of anti-stripping agents. The first is the boiling water test, according to EN 12697-11 or ASTM D3625M – 20. The second method is the

DIFFERENT WEATHER; DIFFERENT MIX

When constructing new roads, choose a high-quality binder and a balanced mix of aggregates recommended for local weather conditions. Different climates and regions require specially formulated aggregates and binder content to allow pavements to function optimally and last longer without wearing down. Use a preventative sealant layer based on traffic volumes. This could be a fog seal, a seal coat, micro-surfacing or a thin overlay of hot-mix asphalt. Finally, the simplest and most cost-effective way to prevent raveling is to keep the streets clean.

→ rolling bottle test, according to EN 12697-11.

In the rolling bottle test method, the affinity between aggregates and bitumen is generally determined by applying different rolling times up to 96 hours, which allows the plotting of the affinity versus rolling time curves.

In a case study at Iterchimica, the affinity between three different aggregate sources and a PEN 50/70 bituminous binder with and without an anti-stripping agent was investigated by means of a boiling test. The additive *Iterlene PE-31* was of an amino-based anti-stripping agent. This was added to the hot bitumen with the dosage of 0.3% (by weight of the bitumen). In the boiling water stripping test, the affinity is investigated by determining the degree of bitumen coverage on uncompacted bitumen-coated aggregates.

According to EN standards (note 3), the boiling water stripping test is an objective test and has high precision. The test is usually carried out on the 8mm to 11.2mm fraction, where the coated aggregates are immersed in boiling water for 10 minutes. The aggregates are then removed from the boiling water and maintained at ambient temperature in order to dry.

Finally, the same as any affinity test, the degree of bitumen coverage on the aggregates is determined by pavement experts, done according to the standard guide. In the images of the aggregates in this article, the top row has the anti-stripping agent and the bottom row has none. Meanwhile, Table 1 summarises the determined bitumen coverage.

According to the results, it can be seen how the presence of the anti-stripping agents could improve the degree of bitumen affinity which plays a key role in any asphalt's durability.

As we have noted here, anti-stripping agents are used mainly to promote the adhesion properties of bituminous binders. However, through academic and field investigations, it has been demonstrated that anti-stripping agents can improve the resistance to water sensitivity of asphalt mixtures. With respect to water sensitivity, generally EN 12697-12 or AASHTO T 283 are applicable.

In an academic study[6], *Iterlene 400 IN* was used to investigate the effect of the anti-stripping agent on the water sensitivity of a surface-course asphalt mixture. The study was carried out according to AASHTO T 312 method in terms of tensile strength ratio (TSR) where asphalt specimens are divided into two subsets of dry-conditioned and wet-conditioned.

The dry-conditioned specimens are maintained generally at an ambient temperature of 25°C. Meanwhile, the wet subset is maintained in hot water at 40°C for three days. According to the results of this study, shown in figure 2 (reconstructed from[6]), the proper dosage of the additive improved the TSR value from 75% to 91%, where the minimum specification limit was 80%.

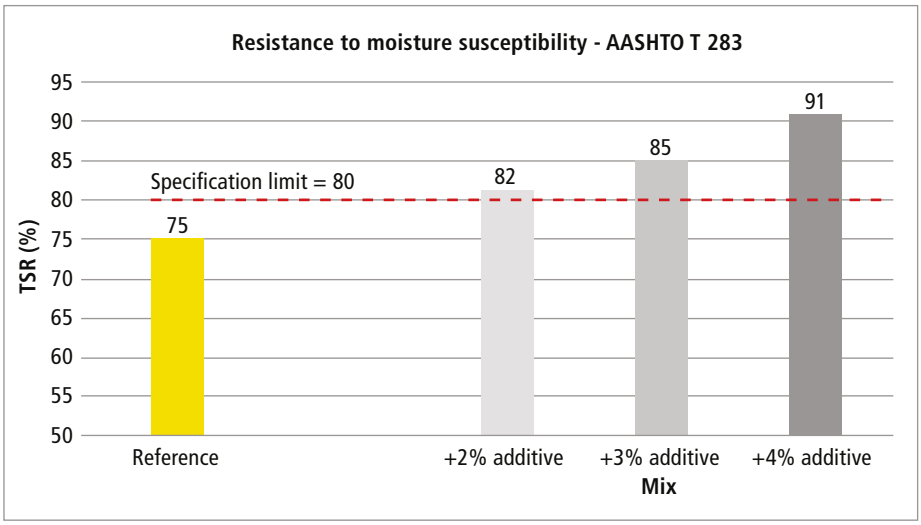
In a similar study, the aggregates shown in figure 1 were subjected to a water-sensitivity test, according to the European standard testing method EN 12697-12. The mixture was a surface-course, dense-graded mixture where the aggregate-particle distribution complied with the Italian specifications and contained the steel slags and calcareous aggregates. The test specimens were manufactured using 50 blows (each face) of the Marshall compactor. The manufactured specimens were firstly studied for volumetrics, including air void content and bulk density, in order to ensure consistency of the results.

The specimens were divided into two subsets of dry and wet conditioning. During the wet conditioning, the specimens were maintained firstly at ambient temperature for 24 hours, for curing. Then a vacuum system was applied for a determined time while the specimens were submerged in water at 20°C. The specimens were then conditioned in water at 40°C for 72 hours.

Both dry- and wet-conditioned subsets were subjected to indirect tensile tests at 25°C where the wet subset was conditioned for two hours in water at 25°C. According to the results, the mixture containing *Iterlene PE-31* showed an 8% superior TSR value compared to the reference mix without additive.

ABOVE: ***1. Basalt aggregate - with anti-stripping agent 2. Lime aggregate - with anti-stripping agent 3. Slag aggregate - with anti-stripping agent 4. Basalt aggregqate - no anti-stripping agent 5. Lime aggregqate - no anti-stripping agent 6. Slag aggregqate - no anti-stripping agent***

Aggregate source	Degree of affinity as a percentage	
	With anti-stripping agent	*Without anti-stripping agent*
Basalt	100%	30%
Calcareous	90%	20%
Steel Slag	80%	10%



WATER SENSITIVITY

According to the literature, besides the type of bitumen and aggregates, the effectiveness of anti-stripping agents on the resistance-to-moisture susceptibility is also dependent on the type of the asphalt mixture. Both lab-scale studies and field experience show that open-graded asphalt mixtures (porous asphalts) and gap-graded asphalt mixtures (stone mastic asphalts) with greater in-situ air voids are more susceptible to water sensitivity compared to dense-graded asphalt mixtures. Hence, the presence of anti-stripping agents technically plays a crucial role in pavement's water sensitivity and durability.

However, it is always suggested that the choice of the type and the quantity of the additive is determined within pre-qualification lab-testing.

**Iterchimica, based near Bergamo in northern Italy, is a global producer of high-tech additives and sustainable technologies for asphalt pavements: www.iterchimica.it.*
***ADR is an acronym of the French for the "European Agreement concerning the International Carriage of Dangerous Goods by Road", a United Nations treaty dating back to 1957 regarding the governance of international transport of dangerous goods by road.*

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Stripping along a road in the Lombardy region of Italy (image courtesy Iterchimica)

UNRAVELLING RAVELING

Anti-stripping agents promote adhesion between aggregate and bitumen. The loss of this adhesion is called stripping. When stripping progresses and the binder is aged, the aggregates lose their bonds and may become dislodged from the pavement surface, leading to a condition called raveling.

Asphalt raveling, therefore, is the progressive disintegration of a hot-mix asphalt layer from the surface downward as a result of the dislodgement of aggregate particles. Asphalt raveling results in loose debris on the pavement and roughness, as well as water collecting in the raveled locations which can result in vehicle-hydroplaning and loss of skid resistance.

The causes of raveling can be numerous and include the following:

- Loss of bond between aggregate particles and asphalt binder because of:
  - A dust coating on the aggregate particles that forces the asphalt binder to bond with the dust rather than the aggregate;
  - Aggregate segregation: If fine particles are missing from the aggregate matrix, then the asphalt binder is able to bind only the remaining coarse particles at their relatively few contact points;
  - Inadequate compaction during construction: High density is required to develop sufficient cohesion within the asphalt mix.
- Mechanical dislodging by certain types of traffic (studded tyres, snowplough blades or tracked vehicles).

Raveled pavement can be properly repaired when the root cause of the damage is determined. Pavement repair strategies relating to raveling generally fall into two categories. If the raveled pavement area is small and appears localised, then the repair strategy can be to remove the raveled pavement and patch the hole. However, if the raveled pavement area is large, it could indicate general asphalt failure. Repair strategy is then to remove the damaged pavement and overlay.

Some of this information is courtesy of Pavement Corporation, founded in 1995 and based in the US state of Maryland. The company specialises in asphalt repair and maintenance for roadways, driveways, walkways, parking lots and sports courts. For more information, visit https://pavementcorporation.com.