1 INTRODUCTION

This Advisory Note provides a summary of issues related to the effects of moisture, and the means of avoiding moisture damage in asphalt pavements, and replaces Advisory Note 9 issued in 1995 under the title “Asphalt Rutting and Stripping”.

Moisture sensitivity is primarily concerned with the potential for loss of adhesion between the binder and aggregate in the presence of moisture, commonly called stripping. It is self-evident that stripping can only occur if there is moisture in the pavement, although the mere presence of moisture does not necessarily result in stripping. Critical situations leading to stripping largely relate to the extent of moisture saturation in the mix and level of traffic stress. The first step in avoiding moisture damage is thus to consider those pavement design, mix design and construction factors that can lead to moisture saturation.

Sensitivity to moisture damage in a particular asphalt mixture is further influenced by the characteristics of component materials. A great deal of research and testing has been directed at such factors, particularly the type and proportion of aggregates, filler and binder. While these factors are relevant, they should not be over-emphasised in relation to pavement design and construction factors.

Stripping can be a complex interaction of environment, pavement design, materials, mix design, manufacture and construction. This advisory note provides a summary of those factors and the actions in avoiding stripping in asphalt mixes.

2 BACKGROUND

Stripping in asphalt was highlighted as a major issue in Australia in the mid 1990s with a series of major failures on heavily trafficked roads in NSW. Some of those problems were referred to in Advisory Note 9 (1995). Initially, investigations focussed on materials issues, but pavement design, asphalt mix design and construction standards were subsequently identified as the critical factors. With changes to specifications and pavement design practice, such problems have largely been eliminated.

More recently, problems associated with SMA surfacing in Queensland have again emphasised the importance of controlling permeability in asphalt layers. Permeability of asphalt mixes, as well as compactability, has thus become the focus of a review of asphalt design criteria and specifications in that state.

3 MOISTURE DAMAGE IN ASPHALT MIXES

The result of stripping is a loss of strength of the asphalt in the asphalt mixture. In severe cases this leads to cracking and loss of shape (rutting). Fines released from the mixture may be seen as light coloured material leaching from the surface of the asphalt (Figures 1 & 2). The appearance of surface fines is often the first visual indicator of moisture damage in the underlying material, as stripping tends to commence at the base of the susceptible asphalt layer and can be substantially advanced before there are any visible signs on the surface.

Cracking, shape loss, and leaching of surface fines can also be an indicator of weakness and moisture damage in underlying granular base materials so that further investigation is often required.

Where stripping has taken place in the asphalt, samples removed from the pavement will have poor cohesion, low strength and uncoated aggregate particles may be observed in the mixture. In such cases, the samples are also generally found to be saturated with moisture.

Simply removing the source of moisture cannot reverse the effects of severe stripping. In most cases, badly affected materials must be removed and replaced.
4 AVOIDING MOISTURE DAMAGE
Avoiding moisture damage in asphalt mixes has two major dimensions: keeping moisture out and sensitivity of the mixture to the effects of moisture.

Keeping the moisture out, or least controlling the degree of moisture in the asphalt to avoid critical levels of saturation, is a fundamental requirement. Design air voids and compacted density (insitu air voids) are important factors in the permeability of the asphalt mix. Grading and nominal size can also be contributing factors. Asphalt is rarely completely waterproof, so some level of moisture is inevitable. Relative permeability of adjacent pavement layers can have a significant effect on development of critical levels of moisture saturation in particular layers.

Factors that affect moisture sensitivity of the mixture itself include the nature and condition of aggregates, and the type and proportion of filler and binder. Manufacture, to the extent of achieving good coating of bitumen and aggregates, can also be a contributing factor. These factors are largely controlled by the selection and testing of component materials as well as tests applied to the final mixture.

5 KEEPING MOISTURE OUT
5.1 Pavement configuration
The greatest risk of asphalt stripping occurs when an asphalt layer becomes saturated with moisture. Moisture saturation is most likely to occur where a slightly permeable asphalt layer sits on a layer of lower permeability such as a high bitumen fatigue layer or waterproofing membrane. Where such layers are incorporated in the pavement, particular care must be taken to avoid moisture accumulating in the layer immediately above the layer of lower permeability.

Pavement drainage to avoid excessive moisture entry, as well as control of moisture infiltration, are also relevant.

Consideration must be given to the permeability of underlying asphalt layers when placing porous surfacings. Particular instances of stripping failures have occurred in asphalt base layers surfaced with open graded asphalt or other permeable asphalt mixes. Failures have even occurred in asphalt layers that have previously given long periods of satisfactory service as a surfacing layer (Figure 3). This type of failure is largely attributed to the additional surface water retained in the porous surfacing layer leading to a build-up of moisture in the underlying layer. Without the porous surfacing, small amounts of moisture entering during periods of rain could subsequently escape without reaching critical saturation levels. Where there is doubt regarding the permeability of an asphalt layer to be surfaced with a porous layer, a waterproofing membrane should be applied. If the membrane is required to reduce permeability only, and not provide additional crack sealing or prevention, then a heavily modified SAMI treatment is not required.

5.2 Asphalt mix design
Critical design factors influencing permeability of an asphalt mix are:
- Air voids
- Aggregate grading
- Nominal size of mix
- Binder film index
- Workability/compactability.

Asphalt mixes are generally designed to achieve insitu air voids of around 3% to 7%. At air voids of less than about 7% the extent of interconnected voids, and hence permeability in an asphalt mix, is relatively low, although grading, nominal size and binder film index will also have a contributing influence. Coarser grading, larger nominal size and decreased film index can lead to a slight increase in permeability for the same level of air voids. Achievement of low insitu air voids (less than 7%) thus becomes more critical with larger mix sizes and coarser grading.

Workability, or compactability, is a function of aggregate shape, grading and surface texture as well as filler and binder types. Workability has an effect on the ease of achieving compacted density (see Section 5.3).
5.3 Construction

A high standard of compacted density (insitu air voids close to design values) is an important factor in controlling the permeability of an asphalt mix. Standards of compacted density are generally established in relevant specifications.

A further construction factor in keeping moisture out is to ensure that joints, particularly longitudinal joints, are adequately constructed to avoid coarse segregated or poorly compacted materials that can provide a path for entry of moisture into the pavement.

6 COMPONENTS

6.1 Coarse aggregates

Aggregate qualities that can influence moisture sensitivity include:

- Cleanliness
- Rugosity
- Mineralogy

Dirty aggregates, particularly clay contamination on the surface of the aggregate, can reduce effective adhesion between binder and aggregate and should be avoided. The potential risk of poor performance of aggregates from any particular source may be assessed by the moisture sensitivity test (see Section 9).

Surface texture of aggregates may have a minor influence on effectiveness of aggregate bond. Bond may be reduced with smooth faced aggregates but would only be viewed as a contributing factor in combination with other more significant factors.

Aggregates are classified as acidic or basic depending on the proportion of silica (SiO₂) in the source rock. Acidic rock types, particularly coarse grained materials such as granite, granodiorite, quartz and quartz gravels, have a poorer affinity for bitumen than basic rock types (e.g. basalt, hornfels, greywacke, limestone).

This property is more relevant to sprayed seals where rate of development of binder adhesion to cold, damp aggregates is an important characteristic. It is less important in asphalt where binder coating is established by heating and drying the aggregates.

Assessment of the mixture (Section 9) may be used to establish the benefit of using adhesion promoting additives, such as hydrated lime or liquid anti-strip agents, in the mixture (see also Section 6.3).

The use of liquid anti-strip agents in conjunction with aggregates of poor bitumen affinity used to be common practice but there is doubt as to whether the criteria used to establish the use of anti-strip agents are a proper reflection of the long term behaviour of asphalt mixes. Hydrated lime is the preferred additive where adhesion improvement is necessary.

6.2 Fine aggregate

Plastic materials and clay contamination in fine aggregates should be avoided. Appropriate standards for crushed fines and natural sands are generally established in relevant specifications.

6.3 Filler

Filler is that portion of mineral finer than the 0.075 mm sieve and may comprise the fine component of aggregates and bag house dust as well as materials specifically added as filler. Added fillers are generally selected on the basis of their ability to increase the stiffness of the binder mastic or improve adhesion between the binder and aggregate. Materials commonly used as added filler include hydrated lime, fly ash and cement kiln dust. Filler materials containing clay should be avoided. The stiffening effect of filler is largely related to particle size, which is measured as the value of dry compacted voids. Adhesion improvement is considered to be derived from the presence of active lime (CaOH).

Hydrated lime is substantially CaOH. As well as having high values of dry compacted voids, hydrated lime is generally regarded as effective in improving adhesion in acidic aggregates (Section 6.2). The proportion of added hydrated lime should not generally exceed 2% of the total mixture to avoid excessive stiffening of the binder mastic.

6.4 Binder

All other factors being equal, an increase in binder stiffness may result in increased resistance to stripping. This relates to service temperature as much as selection of binder grade. Higher temperatures result in lower binder viscosity and hence increased susceptibility to moisture damage. Modified binders may improve viscosity at higher service temperatures.

The ability of the binder to adequately “wet” or coat the aggregate is also relevant but is more particularly applicable to sprayed seal applications. In asphalt manufacture, adequate binder coating is achieved by the use of appropriate mixing temperatures. Efficiency of aggregate coating may be determined by the Degree of Particle Coating (AS 2891.11) or the Stripping Potential of Asphalt AG:PT/T232 – see Section 9.

7 MANUFACTURE

The influence of manufacturing on the moisture sensitivity of asphalt mixes largely relates to efficiency of drying of aggregates and coating with binder. This is a function of the mixing plant design, mixing temperatures and characteristics of component materials. The Stripping Potential of Asphalt test, AG:PT/T232 (previously AST 02) may be used to assess the effectiveness of the manufacturing process. The test should not, however, be used as routine process control, but as a check on the efficiency of a particular manufacturing plant/component materials combination.

8 ENVIRONMENT

Environmental factors leading to increased risk of stripping in asphalt include:

- High traffic loading
- High service temperature
- High rainfall
- Inadequate provision for pavement drainage.

None of these factors, alone, will lead directly to stripping but can interact with other factors to increase the risk or severity of moisture damage.
9 ASSESSING THE ASPHALT MIXTURE

A variety of methods have been used in various countries to test the characteristics of components, aggregate/binder interaction and moisture sensitivity of the asphalt mixture. In Australia, Austroads members and the asphalt industry have agreed on the use of Austroads Test Method AG:PT/T232: “Stripping Potential of Asphalt – Tensile Strength Ratio” as the primary indicator for moisture sensitivity of asphalt mixtures. Other tests to characterise components are also used in some states.

AG:PT/T232 was adapted from ASTM D 4867-92 and AASHTO T 283 (Modified Lottman Test). It determines the tensile strength of the asphalt mixture dry, and after a defined level of moisture saturation. It provides an indication of the influence of component materials and some mix design factors on moisture sensitivity of the mixture. It can also be used to assess manufactured samples. It does not, however, measure the potential for moisture saturation in service. Potential for moisture saturation must be controlled by those factors related to the permeability of the asphalt mixture and permeability of adjacent pavement layers.

Table 1 Summary of Moisture Sensitivity Risk Factors

<table>
<thead>
<tr>
<th>Category</th>
<th>Property</th>
<th>Risk factor</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keeping Moisture Out</td>
<td>Mix permeability</td>
<td>Design air voids</td>
<td>Design air voids is a fundamental requirement</td>
</tr>
<tr>
<td></td>
<td>Asphalt grading, nominal size and film index</td>
<td>Coarser grading, larger nominal size or reduced film index, increase risk of interconnected voids in the mixture.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Compacted density</td>
<td>In situ air voids are directly related to permeability.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Permeability of adjacent pavement layers</td>
<td>Permeability of adjacent layers and/or the use of waterproofing membranes affect moisture movement through the pavement and potential for moisture saturation in critical locations.</td>
<td></td>
</tr>
<tr>
<td>Pavement drainage</td>
<td>Surface drainage</td>
<td>Rainfall should readily drain from pavement surface</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Subsoil drainage</td>
<td>Pavement design must consider means of removal of accumulated moisture from the pavement and prevention of moisture infiltration from unsealed shoulders, subsoil, etc.</td>
<td></td>
</tr>
<tr>
<td>Assessing Components</td>
<td>Coarse aggregates</td>
<td>Cleanliness</td>
<td>Dirty aggregates, particularly clay contamination may inhibit good binder/aggregate coating and adhesion</td>
</tr>
<tr>
<td></td>
<td>Rugosity</td>
<td>Aggregate surface texture may have small influence on binder bond.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mineralogy</td>
<td>Coarse grained acidic rock types may benefit from adhesion improvement provided by certain filler types or anti-strip agents.</td>
<td></td>
</tr>
<tr>
<td>Fine aggregates</td>
<td>Presence of clay</td>
<td>Plastic fines should be avoided</td>
<td></td>
</tr>
<tr>
<td>Filler</td>
<td>Chemical composition</td>
<td>Active lime (hydrated lime) may improve adhesion with some aggregate types.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Particle size</td>
<td>Fine particle size (high dry compacted voids) will increase stiffness of binder/filler mastic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Absence of contamination</td>
<td>Clay and other plastic materials should be avoided</td>
<td></td>
</tr>
<tr>
<td>Binder</td>
<td>Viscosity</td>
<td>Stiffer binders (binder grade/service temperature) provide greater resistance to stripping</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Type</td>
<td>Binder type may influence wetting characteristics and effectiveness of binder adhesion</td>
<td></td>
</tr>
<tr>
<td>Manufacture</td>
<td>Mixing efficiency</td>
<td>Effective binder coating is a function of mixing plant design as well as effectiveness of drying and temperature of materials.</td>
<td></td>
</tr>
<tr>
<td>ENVIRONMENT</td>
<td>Plant design</td>
<td>Effective binder coating is a function of mixing plant design as well as effectiveness of drying and temperature of materials.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Temperature</td>
<td>Effective binder coating is a function of mixing plant design as well as effectiveness of drying and temperature of materials.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Traffic</td>
<td>Most stripping failures in asphalt are attributed to a combination of high traffic loading and moisture saturation of the asphalt</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High traffic loading</td>
<td>Most stripping failures in asphalt are attributed to a combination of high traffic loading and moisture saturation of the asphalt</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Temperature and rainfall</td>
<td>Higher temperatures lead to lower binder viscosity High rainfall increases risk of moisture infiltration.</td>
<td></td>
</tr>
<tr>
<td>Assessing the Mixture</td>
<td>Test procedure</td>
<td>Identifying moisture sensitivity</td>
<td>AG:PT/T232 Stripping potential of asphalt – tensile strength ratio may identify susceptible mixtures.</td>
</tr>
</tbody>
</table>

10 SUMMARY

Stripping in asphalt is a complex mechanism. Where stripping occurs, it is often a combination of more than one of the following factors:

- pavement design/configuration
- environment – climate and traffic
- asphalt mix permeability
- type and class of binder
- poor coating of aggregates due to poor mixing or presence of clay or dust contamination on aggregates
- aggregate affinity for bitumen
- asphalt mix design including type of filler and use of other additives.

The importance of those pavement design, mix design and construction factors affecting permeability and potential for moisture saturation in asphalt pavement layers cannot be over emphasised. A summary of factors related to the moisture sensitivity of asphalt mixes is provided in Table 1.

11 REFERENCES


Disclaimer

Although the information contained in this Advisory Note is believed to be fundamentally correct, the Australian Asphalt Pavement Association does not accept any contractual tortious or other form of liability for its contents or for any consequences arising from its use. 8/05