Black Magic; Improving HMA Performance with Anti-strip Additives

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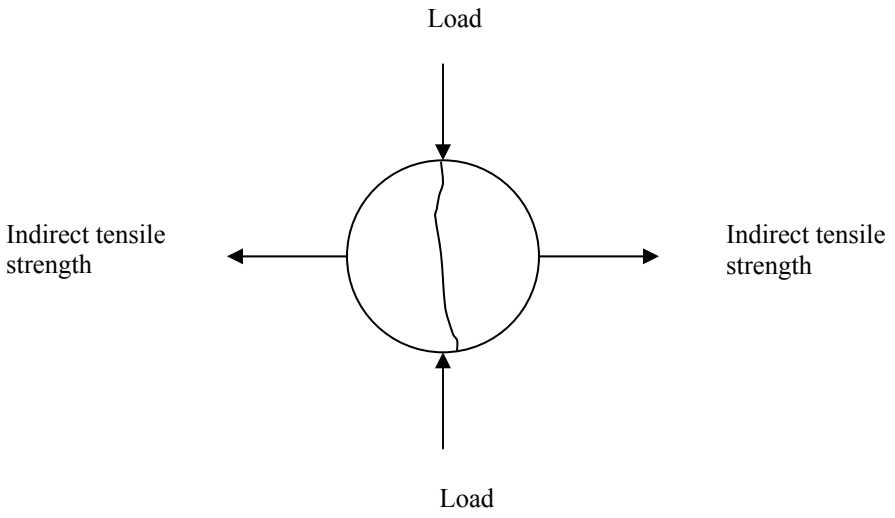
In the process of preparing this article, one of the resources from FHWA coined the problem so well that we just had to quote it. *"Oil and water don't mix – and nowhere is that more evident than in asphalt pavement. The asphalt binder, a petroleum-based product, 'glues' the aggregates in a hot-mix asphalt pavement together. But water that seeps into the pavement can cause the asphalt to strip away from the aggregate. This type of moisture induced damage, known as stripping, leaves the pavement extremely vulnerable to cracking, rutting and other serious damage".*[1] Inadequate drainage, either on top of, or underneath the surface is a primary contributor to pavement damage from stripping. Anti-strip additives are chemicals that improve the resistance of an asphalt pavement to water damage. Anti-strip agents that improve the initial bonding of the asphalt to the aggregate are also called "adhesion promoters". Adhesion can also be thought of as the aggregate's affinity for asphalt.

Oklahoma Department of Transportation specifies the standard laboratory method, AASHTO T 283 to measure the "Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage"[2]. This test is also known as the Modified Lottman test. AASHTO T-283 is also a recommended part of the SHRP mixture design procedure. Eight 6-inch molds of dense graded field mix are compacted to 7% air voids in a Superpave® gyratory compactor. The air void level of 7 % is used to represent the initial construction density of the asphalt pavement. Three of the compacted specimens are set aside as a **"control"** group and three are subsequently **"conditioned".** The conditioned specimens are subjected to water saturation, hot water soaking (140° F), and freeze/thaw procedures. After the prescribed preparation of the specimens, the Indirect Tensile Strength $_{(ITR)}$ of the specimens are measured and averaged by group. The indirect tensile strength can be considered a measurement of both the mixture's cohesion and adhesion characteristics. It indirectly measures the bond of the asphalt to the aggregate and the bond between the asphalt coated aggregate particles. The Tensile Strength Ratio (or TSR) on the field mix is determined by dividing the [Average Conditioned $_{(ITR)}$] by the [Averaged Control $_{(ITR)}$].

For Example: 180 psi (Conditioned Avg. ITR) – divided by – 200 psi (Control Avg. ITR) = 0.90 TSR



For field mixes ODOT defines a TSR that is greater-than-or-equal-to 0.75, as passing .In other words a conditioned mixture must have an indirect tensile strength that is greater than 75 % of its unconditioned strength. For this article, Mr. Danny Gierhart, ODOT Bituminous Engineer provided data on field mix samples, which were tested during calendar year 2003.

ODOT 2003 RESULTS FROM FIELD SAMPLES – AASHTO T 283												
		- - - PG64-22 - - -					**- - PG70-28 - -**			**- - PG76-28 - -**		
Mix Type ⇒	Total	*S2*	*S3*	*S4*	*S5*	*S6*	*S3*	*S4*	*S5*	*S3*	*S4*	*S5*
Observations	188	45	35	23	4	2	25	26	1	20	6	1
Avg. TSR	0.84	0.82	0.85	0.88	0.89	0.90	0.80	0.89	0.92	0.81	0.89	0.80
Mixes %Passing	79.8	73.3	77.1	95.7	100.0	100.0	68.0	88.5	100.0	75.0	83.3	100.0
Conditioned ITR, Avg,	154.4	167.2	157.6	141.1	149.0	157.4	147.7	133.9	160.0	170.1	155.1	167.6
Control ITR, Avg.	185.0	206.0	186.9	161.5	166.9	174.3	186.8	152.1	173.4	207.9	179.2	208.3

Mix Type, Nominal Max. Aggregate Sizes: S2 (1"), S3 (3/4"), S4 (1/2"), S5 (3/8"), S6 (No. 4 Size)

- ◊ ODOT data shows that approximately 20% of the field samples failed the TSR minimum specification of 0.75.
- ◊ It is interesting that the field data shows that TSR improves as the nominal aggregate size decreases.
- ◊ As the PG Grade (and viscosity) of the asphalt binder increases – stripping increases (TSR decreases). Note also, the failure rate (<0.75 TSR) increases as the PG Grade increased.

Of the 188 samples tested, ODOT did not determine which field mixes contained adhesion promoters and which did not. Before the findings are discussed, let's look at what adhesion promoters (anti-strips) do.

Aggregates are generally hydrophilic (water loving) and lipophobic (oil hating). Since asphalt is oil based, it may not spread out and bond effectively on the surface of the aggregate. Visualize the analogy of beads of rain on a freshly waxed car. The use of an adhesion promoter (or "anti-strip") can effectively reduce the surface tension of the asphalt against the aggregate, causing it to spread easily rather than "bead up". Adhesion promoters categorized as "active" can perform this function in the presence of moisture in the plant mix drum. The asphalt binder film will displace water present on the aggregate surface.

Asphalt, predominately a hydrocarbon, itself is a chemically non-polar compound. Aggregates have polar surfaces and in most cases exhibit a negative (-) charge. Adhesion promoters, predominately amine or amide type organic compounds, have a polar end (+ or - charge) and a non-polar hydrocarbon tail. When the "anti-strip" is added to the asphalt binder (and subsequently to the mix), it orientates such that it's long hydrocarbon tail attaches to the asphalt and the amine function attaches to the aggregate. This creates a bridge between the asphalt and the aggregate, creating a strong chemical bond.

Proper Dosage to Achieve Performance

Anti-strip additive dosages typically range from 0.25% to 1.00% by weight of the asphalt binder. Using dosages below 0.25% generally provide no improved TSR performance. The additive is added to the asphalt binder prior to the asphalt mixing with the aggregate. In most mixes, using more than 1% will not improve anti-stripping performance and may actually reverse performance and weaken the strength of the compacted material. Anti-strip additives in general have much lower viscosity than asphalt. Using more that 1% of the additive can reduce the PG grade of the asphalt.

Proper Anti-strip Type for the Mix

Siliceous (silica) aggregates, such as feldspar, granite, river gravel are more susceptible to moisture damage than calcareous (calcium) aggregates such as limestone. There are several different anti-strip types and qualities. Mix designers generally screen several types of anti-strip additives to optimize dosage and costs relative to achieving good TSR performance for the aggregates they normally work with.

What About Smaller Nominal Aggregate Size Providing Better TSRs ?

Anti-stripping performance and mix strength is all about how well the aggregate is initially coated with the asphalt binder. There are trends that show that smaller nominal size aggregate mixtures have higher TSR values than larger nominal size mixtures. The voids in the mineral aggregate (VMA) is a function of the nominal aggregate size. The smaller the nominal aggregate size, the greater are the voids in the mineral aggregate. The total void space between the larger particle sizes is smaller than the void space between the smaller particles. When the mixture's air voids or density is held constant, more asphalt binder is put into

mixtures with higher VMA. These will create a higher asphalt film thickness on the aggregate particles, generally the larger ones. Greater asphalt film thickness on the aggregate creates an asphalt mixture that is more resistant to water damage. The surface area of the aggregate increases as its nominal size decreases, also creating a greater demand for asphalt to coat all of the particles. Mixtures that have the air voids interconnected typically have lower TSR values than mixtures with isolated on unconnected air voids.

Higher PG Grades / Poorer TSR Performance

Higher PG grades (PG76, PG70), have much higher viscosity that PG64-22. It is not surprising than on average they have poorer TSR performance. The 'wetting out" or spreading of the asphalt binder on the aggregate is directly correlated to its viscosity, with the thinner asphalt coating an aggregate particle more easily than a thicker one. An asphalt mixture with poor asphalt coating on the aggregate will be less resistant to damage by water and more than likely have a lower TSR value. In order to overcome the viscosity effect and improve coating of the aggregate, adhesion promoters and higher mixing temperatures are highly recommended. The adhesion promoter improves the wetting out characteristics of the asphalt binder, allowing it to coat the aggregate at lower mixing temperatures.