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FIELD PERFORMANCE OF AMINE-BASED ANIT-STRIPS AND DEVELOPMENT OF A PRACTICAL TEST MODEL

Amine Based Anti-Strips

Moisture damage is a phenomenon that has plagued asphalt pavements since the early 19th century. Water infiltrates the pavement, weakening the adhesive bond between asphalt binder (glue) and aggregate (load bearing particles). To prevent the loss of the adhesive bond, amine-based chemical anti-strips have been used in Pennsylvania for nearly twenty years.

Amines are derived from oleochemicals (e.g., vegetable oils and animal fats) and are among the most widely used additives in moisture damage prevention. As a cationic surfactant, the amines are absorbed into the surface of the aggregate creating a hydrophobic layer (repels water).

Primary benefits of amines are their lower costs due to being readily available. They also provide initial adhesion improvements but tend to degrade under high temperatures or during extreme moisture exposure.

Amine Based Field Performance

In December of 2003, Pennsylvania mandated the usage of AASHTO T283 as a predictive means for moisture damage. AASHTO 283 is a nationally recognized test procedure that subjects asphalt specimens to freeze / thaw cycles and determines a tensile strength ratio (TSR). The lower the TSR, the more susceptible the asphalt material is to moisture damage. To increase the TSR, amine based chemical anti-strips are added, or their dosages are increased. Opposition to the effectiveness of amines or to TSR field correlation have been limited.

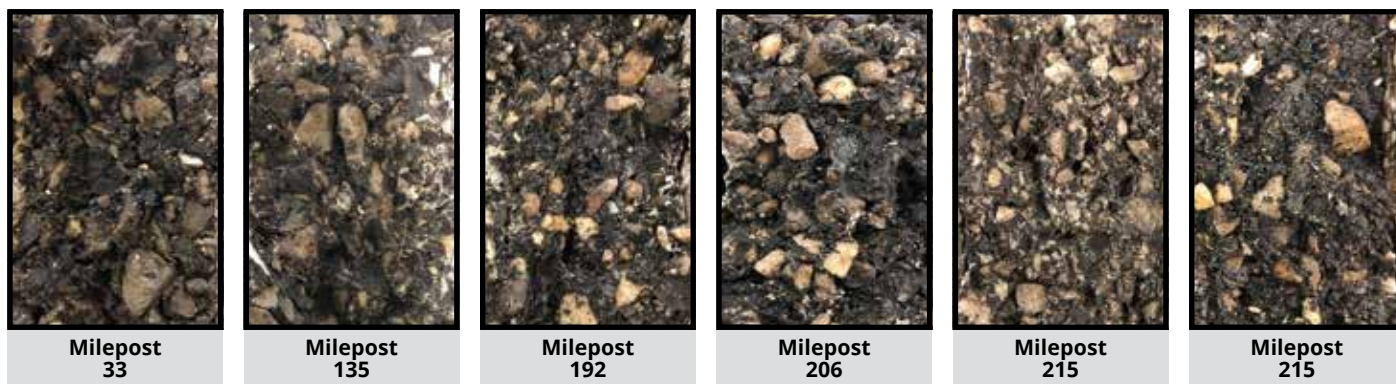
While performing an annual assessment of a three-year-old reconstructed pavement, the agency owner (*Pennsylvania*

Turnpike Commission or *PTC*) observed the occurrence of rutting within a heavily travelled truck lane. Designed to withstand extreme traffic loads for fifteen years or more, the premature failure caused great concern among the agency representatives. Opinions developed that subbase failure or poorly designed asphalt material had caused the rutting. However, after extracting cores from across the rutted pavement it became evident that the cause of the rutting was severe moisture damage.



Moisture damage? The asphalt material utilized during construction had contained amine-based anti-strip protection and successfully passed laboratory predictive testing, AASHTO T283. Having all moisture damage preventive measures fail, the greatest concern for agency representatives was whether this was an isolated incident or much greater issue.

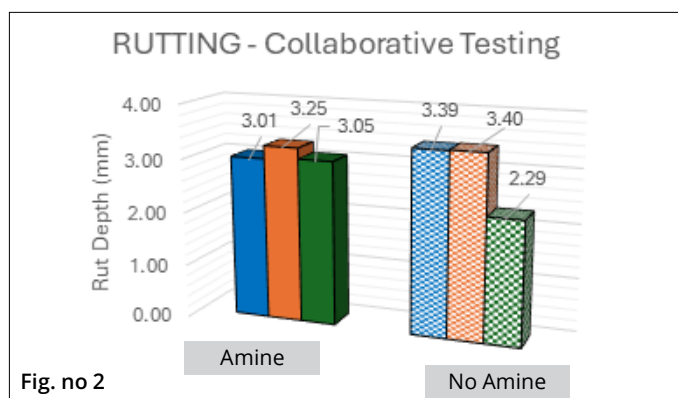
Additional studies took place over a span of nearly two years. One thousand six hundred additional cores were extracted from pavements across the agency's ownership. A staggering seventy percent of all cores had evidence of severe moisture damage. These cores represented over five million tons of failed asphalt materials; equating to nearly \$3.5 billion dollars to replace. The confidence in amine based anti-strips and AASHTO T283 had completely diminished.



Severe moisture damage was not an isolated incident but occurring across the agency's system.

The potential of a more effective moisture damage predictive model had been developed under the guise of Balance Mix Design; labelled as the Hamburg Wheel-Tracking Test or AASHTO T324. This procedure consists of subjecting specimens to loaded steel wheels while in a 50°C water bath. Intended purposes are to measure deformation underload and to simulate cyclic hydraulic pressures created by vehicle tires in wet environments. With specimens tested in water, Hamburg is marketed as being a more proficient predictor of moisture damage by providing a Stripping Inflection Point (SIP). The SIP is derived from the tertiary portion of a creep curve that is provided upon completion of the test.

Agency representatives determined to perform an extensive study utilizing AASHTO T324, in hopes that it was more effective at predicting moisture damage. Numerous sets of asphalt specimens were prepared utilizing the same geological composition, aggregate fractions, and asphalt binder content that correlated with the premature failure in the initial study. The differing factor between the sets was that one contained amine-based anti-strip while the other contained no anti-strip. To validate the study, specimens were tested at three laboratories: owner agency, academia and industry. Limiting biased results, no indication of which sets contained the amines were provided.



Results from the three laboratories showed no significant differences in rut depth between the two sets (Fig. 2). Specimens with and without anti-strip had been around three millimeters. Unexpectedly, there was no indication of moisture damage, even in samples without chemical anti-strips. Results perplexed agency representatives as the tested specimens were modeled after material obtained from moisture damaged pavements. Being unable to correlate AASHTO T324 results with field performance, the hope of having an effective moisture damage predictor appeared to be rapidly decreasing.

With newly constructed pavements failing due to moisture damage and having no apparent preventative measure nor predictor, what options remain? >>

Developing a Test for Vetting Anti-Strips

Available predictive tests fail to consider potential moisture damage influences within water. Test procedures require the use of distilled water without contamination. This contradicts the actual environmental conditions placed upon pavements. Can outside influences, such as pH of water and winter deicers negatively impact the benefits of anti-strips? To prove / disprove the hypothesis, extensive studies have been performed. Specimens were prepared utilizing aggregates with high propensity to moisture damage failure and amines.

Preliminary studies have looked at the effects of pH levels in water. The test procedure developed during the study had slightly modified the ASTM D3625 or Boil Test. Samples were prepared using coarse aggregate fractions and binder and amine anti-strip. Prior to proceeding with ASTM D3625, samples were soaked in acidic, neutral, and alkaline water for 72 hours. After the samples completed the 72-hour soak, the ASTM D3625 process was followed.



Acidic pH 2.5



Neutral pH 7.2



Alkaline pH 8.5

Moisture damage observed on samples subjected to the alkalinity soak (D) compared well to the field cores obtained from failed pavements (A). Conventional ASTM D3625 (B) and AASHTO T283 (C) samples did not compare as well.



At the completion of the testing, samples soaked in acidic and neutral water showed no loss of asphalt adhesion. In comparison, samples soaked in alkaline water indicated a significant amount of asphalt loss. From an agency's perspective this was the first laboratory experience that correlated with the failures occurring in the field.

As more samples were tested, agency confidence increased with the modification of ASTM D3625. Amines consistently performed poorly when subjected to alkaline water. This trend continued as characteristics such as aggregate geological composition and dosage rates were varied.

Silane Based Anti-Strip

A new type of chemical anti-strip had been developed outside of the United States utilizing an organo-silane. Unlike amines which are absorbed into an aggregate's surface, silanes chemically modify the aggregate surface by forming strong covalent Si-O-Si bonds. This chemical reaction creates a water-repellant layer that resists moisture infiltration.

Primary benefits of silanes are that they offer a more permanent adhesive bond, have longer lasting durability and are effective at lower dosage rates. They also offer greater resistance to extreme weather conditions but can be more costly.

Silane Based Laboratory Performance

Having gained confidence in the alkalinity test with amines, an opportunity had been presented to test silanes in the same manner. Samples were prepared with the same geological composition and binder as those tested during the amine alkaline study. The only differing component was the addition of silane based anti-strip rather than amine based.

Upon completion of the alkaline soak, samples continued testing according to the ASTM D3625 procedure. Results with the silane anti-strip (A) had significantly outperformed the amine based (B). There were obvious differences in appearance and tackiness of the silane samples as well.

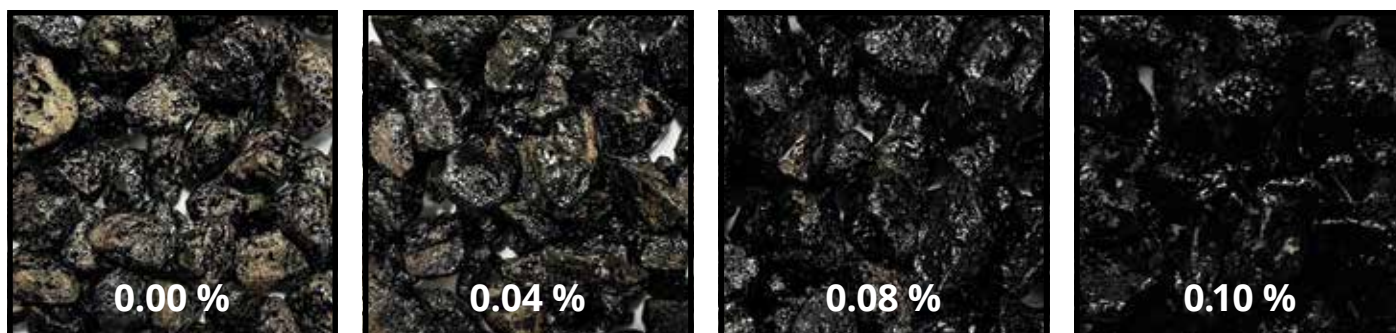


Silane samples retained tackiness

According to silane anti-strip representatives, the additive can be effective at lower dosage rates. To discover the optimum dosage, additional specimens were prepared with silane anti-strip dosages of 0.00%, 0.04%, 0.08% and 0.10% respectively.

Results indicated that samples with dosage rates of 0.10% had the greatest moisture damage protection; equating to a 500% decrease compared to average amine dosage.

While silanes proved to be superior to amines in alkaline water, would silanes have potential to negatively impact crack resistance. In Pennsylvania, the cracking test of choice is the IDEAL-CT. >>



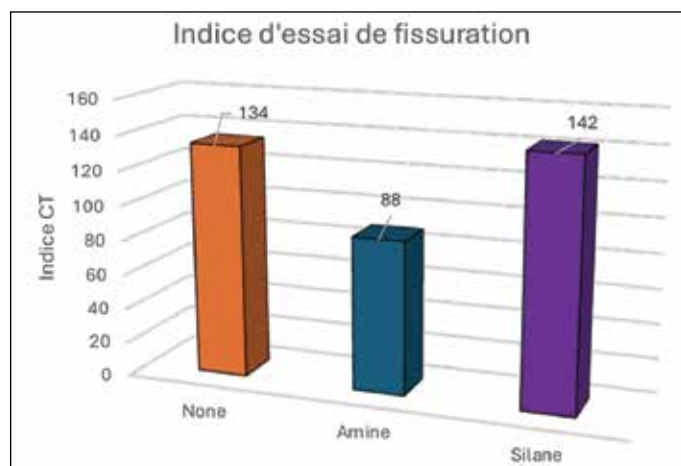
The Indirect Tensile Crack Testing (IDEAL-CT) is procedure that is intended to predict the crack resistance of asphalt materials. At the completion of the test, a measurement of crack resistance is provided in the form of a CT Index. The higher the CT index, the greater the crack resistance.

Specimens were prepared without anti-strip, with amines and with silanes. Results had shown that the amines decreased crack resistance when compared to specimens without anti-strip. The silanes improved crack resistance slightly over those without anti-strip.

Deicers

While developing the modified ASTM D3625 procedure, sodium bicarbonate was used as the catalyst to increase the alkalinity of water. In real world environments, asphalt pavements are not subjected to sodium bicarbonate. However, they are in contact with highly concentrated sodium brine for winter deicing purposes. The common characteristic with both is, obviously, sodium. Does sodium play a role in the deterioration of the adhesive bond?

An additional study ensued to determine whether alkaline water, sodium concentration or both negatively impacted anti-strip protection. Specimens were prepared, having the same composition and amine based anti-strips as in previous testing. Rather than soaking the specimens in alkaline water, 100% sodium brine was used prior to proceeding with the ASTM D3625. Soaking time had been increased from 72 hours to 160 hours.



Alkaline

Specimen had lost 3.0g of asphalt at the completion of the test.

Sodium

Specimen had lost 2.7g of asphalt at the completion of the test.

Results demonstrated distinct similarities. Observations and quantitative measures identified significant moisture damage had occurred in both specimens. The hypothesis that alkaline water negatively impacted the anti-strip protection had not been disproved. However, additional questions were raised after the similar sodium brine results. Researchers continue to pursue answers, but the validity of the testing has merit.

Author's viewpoint

As a representative of the agency, the fiscal responsibility of maintaining pavements is becoming increasingly overwhelming. Premature failure of newly paved roadways is simply unsustainable with replacement costs increasing from millions to billions of dollars. It is unethical to discover the failure of amine based anti-strips and continue to utilize the technology. If moisture damage continues to occur with amines, the agency would be in better position to withhold the additional cost and utilize no anti-strip. However, in doing so the problem wouldn't be solved.

With the development of the modified testing of silane based anti-strips, hopes are that a remedy may be possible. There are still uncertainties but being vigilant and determined to find a cure to the leading cause of pavement distress is the primary goal. A move to permit the usage of only silane based anti-strips is the beginning. How well Silanes perform under the strenuous environmental conditions pavements face is still unknown.

Agency and its traveling customers deserve more durable, longer-lasting asphalt pavements. If a simple switch of anti-strip technologies can be beneficial, it would be prudent to make the change. ■