# EFFECT OF DEICING AND ANTI-ICING CHEMICALS ON HMA AIRFIELD RUNWAYS


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## ABSTRACT

The purpose of AAPTP Project 5-3 was to investigate the performance of hot-mix asphalt (HMA) airfield pavements subjected to deicing and anti-icing chemicals (DIAIC). The most commonly used DIAICs include potassium acetate, sodium acetate, urea, and ethylene and propylene glycol. Recently, several Nordic countries have reported what appears to be damage in HMA pavements related to the use of DIAICs. The exact mechanism of this damage is not clear, although it appears to be a form of moisture damage accelerated by the low surface tension and relatively high density of many DIAIC solutions. DIAIC-related damage does not appear to be common in airfield pavements in the U.S. and Canada. If it is suspected that an HMA mixture is susceptible to DIAIC-related damage, a simple procedure called the immersion tension test can be used to perform an evaluation. In cases where DIAIC-related damage is a problem, mixture performance can be improved by using a stiffer binder and/or by incorporating hydrated lime into the mixture. When an HMA mixture prone to DIAIC-related damage is used in an airfield pavement, it is essential to thoroughly compact the pavement to reduce the air voids to the lower end of the specified range.

## INTRODUCTION

The objective of this paper is to summarize research done as part of Project 05-03 of the Airfield Asphalt Pavement Technology Program (AAPTP). This purpose of this FAA-funded program is to deliver cost-effective, high quality applied research on asphalt pavements for airfields. The purpose of this project was to investigate the performance of HMA airport pavements subjected to deicing and anti-icing chemicals (DIAIC) used to minimize the effects of snow and ice on aircraft and airport pavement facilities.

The research included several components, as described in the objective for Project 05-03. The work was organized into two phases and a number of tasks. Phase I consisted of preliminary work, including a literature review, collection of information on usage of DIAICs, evaluation of various laboratory tests for identifying HMA damage related to exposure to DIAICs, and development of Phase II plans. Phase II was more focused and intensive, and included field investigations of selected airfields where DIAIC-related damage was suspected and a substantial laboratory test program to investigate DIAIC-related damage in a range of HMA mixtures.

## SUMMARY OF LITERATURE ON EFFECT OF DEICING/ANTI-ICING CHEMICAL ON HMA AIRFIELD PAVEMENTS

During AAPTP Project 5-3, a comprehensive domestic and international literature search was conducted to identify information related to the utilization of deicing/anti-icing chemicals used on aircraft and on airfields and their potential adverse impact on the performance of airfield asphalt pavements. The ultimate goal was to identify airports in the United States (U.S.) and Canada with asphalt pavement features (i.e., runways, taxiways, aprons, etc.) that have been subjected to deicing and anti-icing chemicals and which are exhibiting distresses suspected to be caused by these chemicals.

Based on a review of literature, it was found that, for most part, chemicals used for deicing and anti-icing practices are the same. Generally speaking, deicing is defined as the process of removing ice and snow from the airfield pavements or aircraft, therefore deicing is considered a reactionary operation. In contrast, anti-icing is referred to as a proactive operation i.e., surface treatment of airfield pavements or aircraft prior to ice or snow formation. Anti-icing reduce ice accumulation or facilitates ice or snow removal by reducing the bond between the surface and the ice [1]. As noted above, the acronym DIAIC is generally used throughout this paper to mean deicing and/or anti-icing chemicals for pavement usage.

Aircraft deicers are categorized into four general classes: Type I, Type II, Type III, and Type IV. Not all types are currently used (Type II, and type III are being discontinued). Fluid types vary by composition and allowed holdover times (i.e., the amount of time the residual fluid will protect an aircraft from ice formation). Type I is the most commonly used fluid and is used primarily for aircraft deicing [1]. Type I fluids are commonly purchased as concentrated propylene or ethylene glycol solutions (8% water, 90% glycol, and less than 2% additives) and diluted with additional water depending on the ambient temperatures.

Based on the literature reviewed and the information obtained from interviews with airport operation managers and airport superintendents at thirty-six (36) airfields across the U.S. and Canada, the most predominant deicing chemical used presently for airfield pavements is potassium acetate. In the past, urea and glycol based materials were used as the chemicals of choice for deicing, and anti-icing of airfield pavements, and a limited number of airports are still using such chemicals. In recent years; however, there has been a dramatic shift towards the use of acetate-based deicers, in particular potassium acetate. Overall, more than 90 percent of the airports interviewed use potassium acetate; a majority of these airports were from the northern tier of the North American continent. Other acetate and formate based chemicals used by some airports include sodium acetate, potassium formate, and sodium formate. However, a limited number of airports are still using urea and only one airport interviewed reported using ethylene glycol as a pavement deicing chemical.

The primary reason for the increased use of acetate based deicers in recent years appears to be because they are environmentally friendly, requiring much lower biological oxygen demand (BOD) to decompose, and are much less toxic than the traditionally used urea and glycol based chemicals. Based on interviews with airport officials in the U.S. and a review of the experience with Nordic Airfields it appears that the use of acetate-based deicers is not without concerns [2]. There is concern that these deicers damage airfield pavements and associated infrastructure such as airfield lighting systems. The purpose of this study is to evaluate the potential impact of deicing chemicals on the performance of asphalt pavements.

**Impact of Deicing/Anti-icing Chemicals on Airfield Asphalt Pavements**

Application of DIAICs to runways and taxiways is required by the FAA to ensure the safety of passengers and aircraft. These chemicals play a major role in the overall operation of cold region airports during the winter months. Unfortunately, chemical agents used in deicing and anti-icing processes impact natural resources by depleting the available oxygen in the receiving waters *and* their discharge into the environment is subject to stringent control by the U.S. EPA [3]. In addition to environmental impact, concerns have been emerging on the possible airfield asphalt pavement damage caused or accelerated by these chemicals. The few studies that relate possible adverse impacts of deicing chemicals to performance of airfield asphalt pavements are summarized in the ensuing paragraphs.

**Recent Studies of Deicer Damage to HMA Pavements**

In the 1990s, asphalt durability problems potentially caused by the use of new deicing chemicals were observed at some Nordic airports. Degradation and disintegration of asphalt pavements occurred and there was also softening and stripping effects on bitumen and asphalt concrete together with loose stones on runways. These problems occurred when airports in Norway and Sweden changed from urea to potassium acetate and potassium formate [2, 4]. A number of other research projects have been performed in Nordic countries and in Canada on the effect of DIAIC-related damage in HMA pavements [5, 6, 7, 8]. Based on these publications, it appears that there are several possible mechanisms for DIAIC-related damage in HMA Pavements:

1. DIAICs may decrease resistance to moisture damage in some asphalt/aggregate systems by decreasing the surface tension of the water and promoting attack of the asphalt – aggregate interface.
2. DIAICs may accelerate moisture damage in some systems because their hygroscopic nature causes HMA pavements to retain moisture for longer periods of time.
3. DIAICs may attack the asphalt-aggregate bond, either by neutralizing carboxylic acids within the asphalt binder, or by attacking acidic minerals (such as silica) at the aggregate surface.
4. DIAICs may decrease the resistance of aggregates to damage caused by alternate cycles of wetting/drying and freezing/thawing.
5. DIAICs may cause a softening of asphalt binders, decreasing HMA stiffness and strength and increasing the severity of other forms of distress, including moisture damage. This affect appears to be most pronounced with softer binders.
6. DIAICs may accelerate age hardening in HMA pavements.

It is possible that any number of these mechanisms may work simultaneously in some situations. Overall, based on the literature review and damage mechanism discussed above, a number of factors might affect DIAIC-related damage of HMA pavements: aggregate type, asphalt binder chemistry, asphalt binder modification, HMA permeability, deicer type and pavement temperature. It should be noted that most research in this area has indicated that DIAIC-related damage will only occur at relatively high temperatures—about 50°C and higher.

**Use of DIAICs on Airfield Pavements in the U.S. and Canada**

To identify specific airport projects in the United States and Canada for detailed investigation, a review of civilian (commercial and general aviation or GA) and military airports in the U.S. and Canada that (1) use DIAICs extensively and (2) contain HMA airfield pavements on their runways, taxiways, or aprons was completed. Based on the information procured from this review and the personal knowledge of the project team, thirty-six (36) airports in the United States and Canada were short-listed for preliminary interviews. An informal questionnaire was developed to interview the respective airport stakeholders at each of the short-listed airports on the usage of DIAICs and to identify if there were any known issues with the use of these chemicals on asphalt pavements. The questionnaire was mainly developed and used to guide the project team in assimilating a uniform set of information across the different airports surveyed. Airport managers, directors, and superintendents were then contacted to obtain information on their airports relating to airfield pavement type, DIAICs used, and possible adverse impact on their HMA pavements by the DIAICs. The following findings were made based upon these discussions:

- The majority of the airports interviewed to date use potassium acetate as the deicing/anti-icing chemical for their airfields followed by sodium acetate and urea.
- The two widely used chemicals for deicing/anti-icing of the planes are ethylene and propylene glycols.
- Most deicing pads for the aircraft are concrete.
- Of the airports interviewed, Boston Logan International Airport is the only one that indicated that they had some significant distresses detected in the form of stripping of their asphalt concrete pavements. While the exact cause of the stripping was subject to some discussion, it appears to be related to the type and source of asphalt cement and aggregates that were being used at the facility. An extensive research study that included participants from Applied Research Associates (ARA) and the Western Research Institute (WRI) resulted in the development of a standard protocol for the evaluation of existing hot mix asphalt pavements at Boston Logan International Airport [9]. The protocol uses a combination of field and laboratory observations and tests to identify the propensity of an asphalt concrete pavement to stripping. Given the observed stripping and extensive use of deicing chemicals at Boston Logan International Airport, it was considered to be a good candidate for the fieldwork portion of this project. Boston airport uses ethylene glycol for pavement deicing which is somewhat unusual.
- A number of other airports were experiencing pavement deterioration but were not sure of the cause.

**Selection of Airports for Site Investigations and Coring**

Final selection of airports for site investigation and pavement coring was based on two factors: (1) the possibility that observed damage was related to the use of DIAICs; and (2) the ability to obtain cores from the pavement in question. Based on these two criteria, the following four airports were selected for site investigation and pavement coring during Phase II of AAPTP Project 05-03:

- Boston Logan International Airport
- Colorado Springs Airport
- Boise, Idaho Airport
- Freidman Airport, Hailey, Idaho

During Phase II of AAPTP Project 5-3, these airports were visited to verify that significant damage had taken place—based upon visual inspection and engineering judgment—and that the damage had in fact occurred in an area where there had been significant exposure to DIAICs. Cores were taken from locations in which possible DIAIC-damage had occurred. These cores were used in the final stage of laboratory testing, to evaluate the HMA for susceptibility to DIAIC-related damage using laboratory testing as described later in this paper.

## LABORATORY TESTING

In the preliminary test program conducted during Phase I, two aggregates and two binders were evaluated using four procedures:

1. An ultrasonic horn test,
2. Fourier transform infrared (FTIR) spectroscopy
3. A modification of AASHTO T-283, and
4. A long-term durability test developed specifically for AAPTP Project 05-03

Of these tests, the modified T-283 procedure proved most promising, showing clear evidence of DIAIC-damage in mixes made with the chert/gravel. Furthermore, the procedure was quite simple and could be performed by most construction materials laboratory experienced with HMA testing. FTIR spectroscopy was evaluated to determine if it could be used to identify chemical "flags" indicative of DIAIC-related damage in HMA pavements. Preliminary FTIR analyses showed carboxylate salts in DIAIC solutions used to condition HMA specimens, and it was felt that this might be a useful indicator of DIAIC-related damage. However, further testing showed that these compounds were not in fact the result of any reaction between DIAICs and HMA constituents.

The two aggregates used were a diabase from Virginia (DB), and a chert gravel from Mississippi (CH). The two binders used were a PG 64-22 and a PG 58-28 supplied by Citgo and both widely used in the Mid-Atlantic States. Two DIAICs were evaluated: potassium acetate (PA) and sodium formate (SF). For all three tests, water was used as a control. The experiment was planned with two mixtures: the diabase aggregate with the PG 64-22 binder, and the chert gravel aggregate with the PG 58-28 binder. As discussed below, WRI tested four mixtures—both aggregates with both binders. AAT initially only performed tests on the diabase/PG 64-22 and chert/PG 58-28 mixtures, but later included the diabase/PG 58-28 and chert/PG 64-22 mixtures in the evaluation of the modified T-283 procedure.

In the modified T-283 test, gyratory specimens are vacuum saturated, frozen, and then soaked at 60°C. Three solutions were used—water, 2% PA, and 2% SF. The important comparison in this test is the tensile strength after conditioning in the PA and SF solutions relative to the tensile strength after conditioning in water. The results of these tests are summarized in Figure 1. Initially, only two mixtures were tested using this procedure—the diabase with the PG 64-22 binder, and the chert with the PG 58-28 binder. However, to better evaluate this test method, the remaining two mixtures were tested also, so that all four combinations of aggregate and binder were tested using this procedure. Both the diabase and chert aggregates appear to be moderately susceptible to moisture damage. The diabase mixtures had a water/dry tensile strength ratio (TSR) of 76 % and 73 % when combined with the PG 64-22 and PG 58-28 binders, respectively. The chert gravel mixtures exhibited TSR values of 81 % and 87 % for the PG 64-22 and PG 58-28 binders, respectively. TSR values above 80 % are generally considered acceptable. The results plotted in Figure 1 show that the tensile strengths for the diabase mixture, when conditioned in the DIAIC solutions, were not significantly different from the strengths when conditioned in water. However, the chert mixtures both show significant reduction in tensile strength when conditioned in DIAIC solutions, compared to their strength when conditioned in water. As should be expected based upon the literature review, the PG 64-22 binder appears to be somewhat more resistant to DIAIC-related damage compared to the PG 58-28 binder. The results of this test are highly significant in that it suggests that the relatively simple indirect tension (IDT) test can be used to evaluate the potential for DIAIC-related damage in HMA mixtures, and perhaps more importantly, that susceptibility to DIAIC-related damage is dependent not only upon binder grade and chemistry, but upon aggregate type as well.

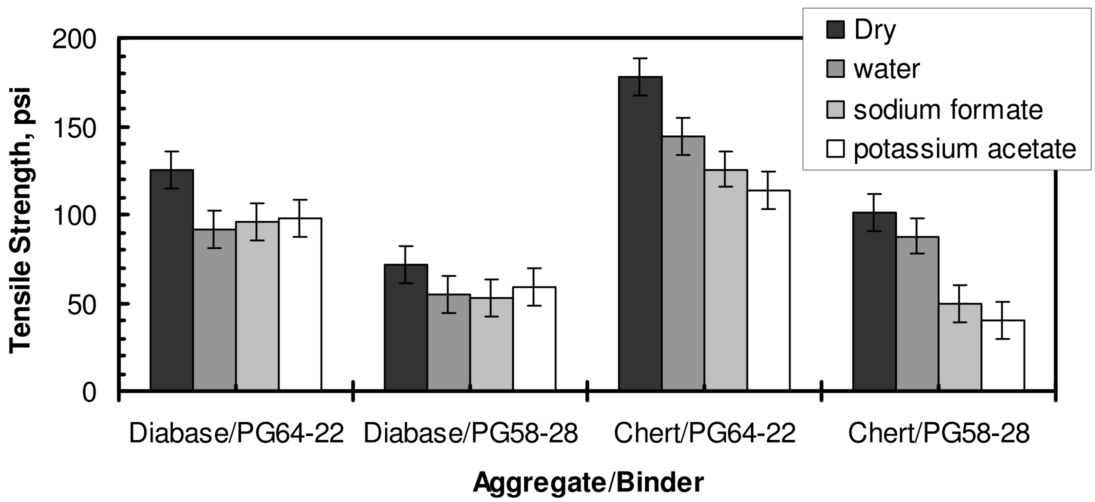


Figure 1. Results of T-283-Based Deicer-Resistance Test. *Error bars represent D2S precision calculated using a pooled estimate of standard deviation.*

**Aggregate Soundness Testing**

To verify that the DIAIC-related damage observed in the modified T-283 test was not simply the result of direct attack of the aggregate by the DIAICs, AAT performed soundness tests on both aggregates, using a standard magnesium sulfate solution, and using saturated solutions of PA and SF. All results show aggregate weight loss values below 15%, a typical allowable maximum value for soundness tests. Furthermore, the loss values for both DIAIC solutions were much lower than for the magnesium sulfate, strongly suggesting that the damage caused to the HMA mixtures was not related to a direct attack on the aggregate by the PA or SF solutions.

**Further Refinement of the Immersion Tension Test**

Because preliminary testing using the T-283 based procedure appeared to be just as effective in identifying DIAIC-related damage as the much more difficult and time consuming long-term durability test, the research team decided to use the T-283 based procedure for much of the laboratory testing. However, several changes were made in this procedure to make it simpler and more effective in evaluating DIAIC-related damage. In the final procedure, called the immersion tension (IT) test, specimens were soaked in either water or DIAIC solution at 60°C for 4 days, and then tested in indirect tension, just as in the T-283 procedure. Vacuum saturation was not used because it was felt that by simply soaking the specimens the test would be more sensitive to air void content and mixture permeability. The four day soak time was selected because in preliminary testing it appeared to provide results similar to vacuum saturation. No freeze cycle was used because most of the previous research suggested that it was elevated temperatures—and not freeze-thaw cycling—that was critical to DIAIC-related damage in HMA pavements. No dry specimens are tested in this procedure; instead, one set of specimens is conditioned in water and the other in a 2 % by weight solution of DIAIC. The tensile strength ratio/DIAIC treatment, abbreviated TSR/D, is simply calculated as the ratio of the DIAIC-conditioned tensile strength to the water-conditioned tensile strength, as a percentage. Because there is very little experience with this test as yet, only a preliminary guideline for interpreting the test can be given at this time; TSR/D values below 80 % should be considered as evidence of possible susceptibility to DIAIC-related damage. This is based solely on the use of similar guidelines in interpreting the T-283 test.

Phase II laboratory testing included a variety of experiments. The most important of these were tests performed at AAT's Sterling, VA, laboratory using the IT test. Additional work using FTIR analysis was performed at WRI, along with surface tension measurements on the binder/DIAIC systems studied during Phase II laboratory testing. The final activity in Phase II laboratory work was performing the IT test on field cores taken during site visits to a number of airfields to determine if the observed pavement distress was likely caused by DIAIC-related damage.

**Expanded Laboratory Program using the IT Test**

As discussed above, the IT test for evaluating DIAIC-related damage involves soaking laboratory specimens in 2 % DIAC solutions at 60 °C for 4 days, without vacuum saturation. The indirect tensile strength is then determined after conditioning in the selected DIAIC solution, and after conditioning in water as a control. The IDT strength is determined on three replicate specimens, in the same manner as used in AASHTO T-283. TSR/D values (strength after DIAIC treatment as a percentage of strength after water treatment alone) less than 80 % should be considered as evidence of potential DIAIC-related damage for a given HMA/DIAIC system.

*Materials*

The mixtures used in Phase II testing were composed of five different aggregates and four different binders. The aggregates used were a 12.5-mm fine-graded blend of chert/gravel from Mississippi; a 9.5-mm, coarse graded blend of diabase from Virginia; a 9.5-mm, dense-graded blend of limestone from Virginia; a 12.5-mm, coarse graded blend of crushed siliceous gravel from Virginia; and a 9.5-mm, coarse blend of greywacke sandstone from Pennsylvania. The chert/gravel and greywacke/sandstone both exhibit a high degree of susceptibility to ASR. The Virginia gravel exhibited a relatively low level of alkali-silica reactivity. The Mississippi chert/gravel and Virginia diabase aggregates were also used in Phase I of AAPTP Project 5-3.

Four binders were used in Phase II of AAPTP Project 5-3: a Pg 58-28 binder, two PG 64-22 binders from different sources (called A and B in this paper); and a PG 76-22 binder modified with SBS polymer. Four DIAICs were included in Phase II testing, all as 2 % solutions in water: potassium acetate; sodium formate; sodium acetate and propylene glycol. The first three of these were chosen because they are widely used DIAICs and have been reported to cause damage to HMA [5, 6, 7, 8]. Although many airports are reducing or eliminating the use of propylene glycol as a deicing/anti-icing chemical, it is still in use at many facilities and so was included in the Phase II laboratory work.

*Experiments with the IT test*

This most important part of the laboratory testing involved three experiments, designed to further evaluate the phenomenon of DIAIC-related damage in HMA pavements using the IT test. Experiment 1 was designed to evaluate the effect of aggregates on DIAIC-related damage. The objective of Experiment 2 was to evaluate the effect of different binder types and grades on DIAIC-related damage. Experiment 3 was intended to determine if using hydrated lime and/or reducing air void content could help reduce the extent of DIAIC-related damage in susceptible HMA mixtures. The details of these three experiments are given below.

*Experiment 1: Aggregate Effects*—this experiment was designed to evaluate the effect of a variety of DIAICs on different aggregates. The study included one binder, five aggregates and four DIAICs. The Citgo PG 64-22 binder was used with five different aggregates: the Mississippi chert/gravel and Virginia diabase aggregates used in Phase I, along with three additional aggregates: a gravel susceptible to alkali-silica reactivity (ASR) from Virginia, a limestone aggregate from Virginia, and an ASR susceptible greywacke from the Pennsylvania. The four DIAICs that were used included: propylene glycol, potassium acetate, sodium acetate and sodium formate. All systems were evaluated using the IT procedure described above; therefore all aggregate/binder systems were also evaluated after immersion in water. The results of the Aggregate Effects experiment are summarized in Figure 2 below. Of the five aggregates evaluated, it appears that the only aggregate showing significant susceptibility to DIAIC-related damage is the Mississippi chert/gravel, although the damage in this case only occurred with the formate and acetate DIAICs; the propylene glycol actual increased the tensile strength of this mixture. Because the Pennsylvania greywacke sandstone is known to be highly alkali-silica reactive (ASR) and yet did not exhibit significant damage in this experiment, this suggests that the hypothesis that ASR somehow contributes to DIAIC-related damage may not be correct. The susceptibility of this aggregate—along with the Mississippi chert/gravel and the Virginia gravel—are examined in Experiment 2, discussed below.

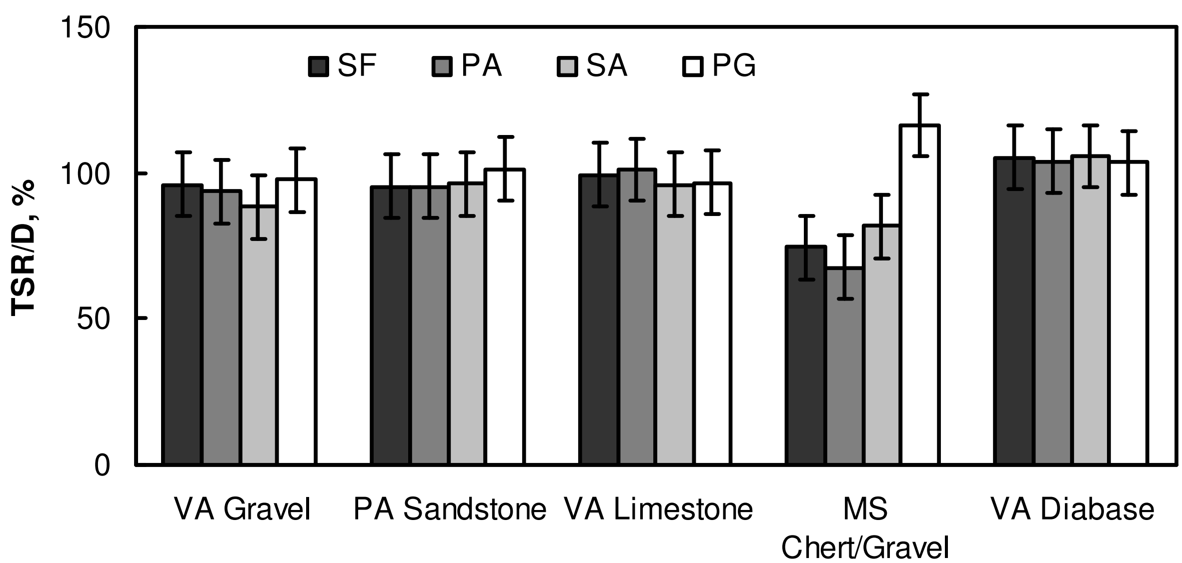


Figure 2. Results of Immersion Tension Testing on Five HMA Mixtures with PG 64-22 Binder, in Solutions of Water and Four Deicing/Anti-icing Chemicals. *Error bars show ± 2s confidence intervals for TSR/D.*

*Experiment 2: Binder Effects*—in this experiment, the effect of selected DIAICs on additional binders was evaluated using the IT procedure. Three ASR susceptible aggregates: Mississippi chert, Virginia gravel, and Pennsylvania greywacke and two DIAICs: potassium acetate and sodium acetate were selected from the materials used in experiment one, and evaluated using three additional asphalt binders: Citgo PG 58-28, Lyon PG 64-22 and Citgo polymer-modified PG 76-22. The results of Experiment 2 are summarized in Figure 3. Mixtures made using the Virginia gravel and Pennsylvania sandstone in general showed little damage. There was however a slight tendency towards greater damage with softer binders. The mixture made using the Virginia gravel and PG 58-28 binder showed some increase in damage with sodium acetate, although it is not clear if the increase is significant (88 % of the tensile strength observed with conditioning in water alone). The damage observed for mixtures made with the Mississippi chert/gravel were in general much greater, and increased with decreasing binder stiffness. This agrees with the findings of European studies that stiffer binders can help minimize DIAIC damage. This also further demonstrates that DIAIC-related damage does not necessarily occur with all siliceous aggregates, or even alkali-reactive aggregates, since the Pennsylvania sandstone is highly reactive and still seems resistant to DIAIC-related damage.

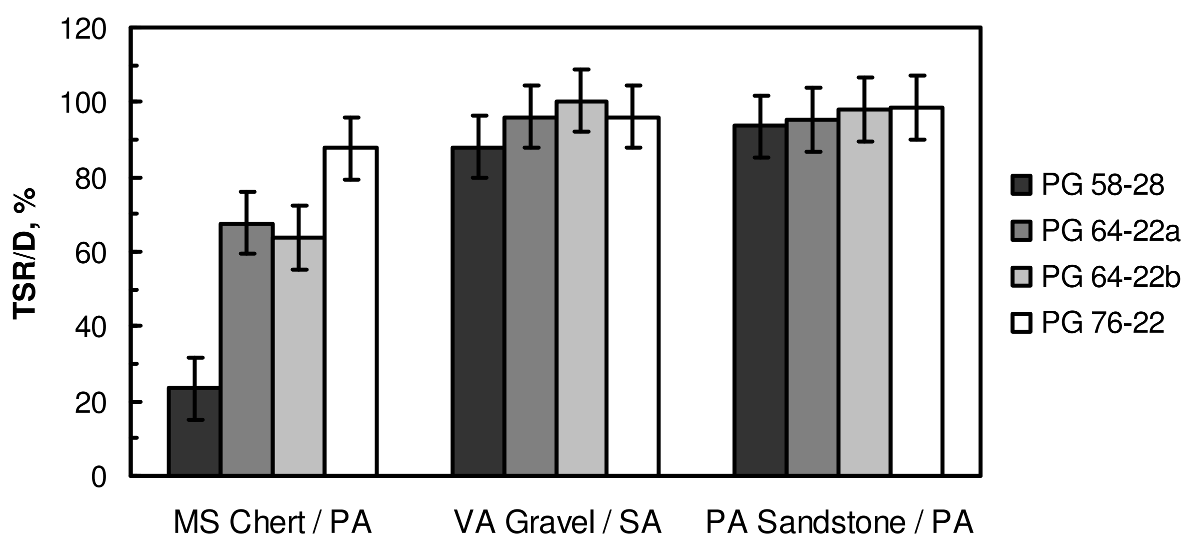


Figure 3. Results of Experiment 2 (Binders). *PA = potassium acetate; SA = sodium acetate. Error bars show ±2s confidence intervals for TSR/D.*

*Experiment 3: Air Voids and Hydrated Lime Effects*—in this experiment, the effect of lower air voids, and hydrated lime on DIAIC-related damage was investigated. Three systems (binder/aggregate/DIAIC) were selected from those previously tested: Mississippi chert with Citgo PG 64-22 binder in potassium acetate, Mississippi chert with Lion PG 64-22 in potassium acetate, and Virginia gravel with Citgo PG 58-28 in sodium acetate. Two treatments were evaluated. First, specimens were compacted to 5 % air voids, rather than the standard 7 % used in the Experiments 1 and 2. The second treatment was compaction to 7 % with inclusion of hydrated lime in the HMA as an antistrip additive.

The results of Experiment 3 (air voids/additive) are summarized in Figures 4 through 6 below. In this experiment the effect of two possible treatments for reducing DIAIC-related damage were evaluated. The first was compacting to a lower air void content—5 % rather than 7 %. The second involved treating the mixtures with 1 % hydrated lime. Hydrated lime was used as an additive rather than lithium nitrate as originally planned because the results of Experiments 1 and 2 strongly suggested that the observed DIAIC-related damage is not related to alkali-silica reactivity, but instead is most likely an accelerated form of moisture damage. Figure 4 summarizes the results of testing on the Mississippi chert/gravel/PG 58-28/potassium acetate system. In this case, both improved compaction and hydrated lime significantly reduced the amount of DIAIC-related damage, although the amount of damage measured as the percent reduction in strength relative to the strength of specimens conditioned in water with the identical treatment was still significant—45 and 26 % damage for improved compaction and hydrated lime, respectively. This result does suggest that either approach is promising for reducing DIAIC-related damage. It is possible that both treatments together would provide even better results, although there is the practical question of whether or not it is feasible to require improved compaction during construction of HMA pavements where the materials are prone to DIAIC-related damage.

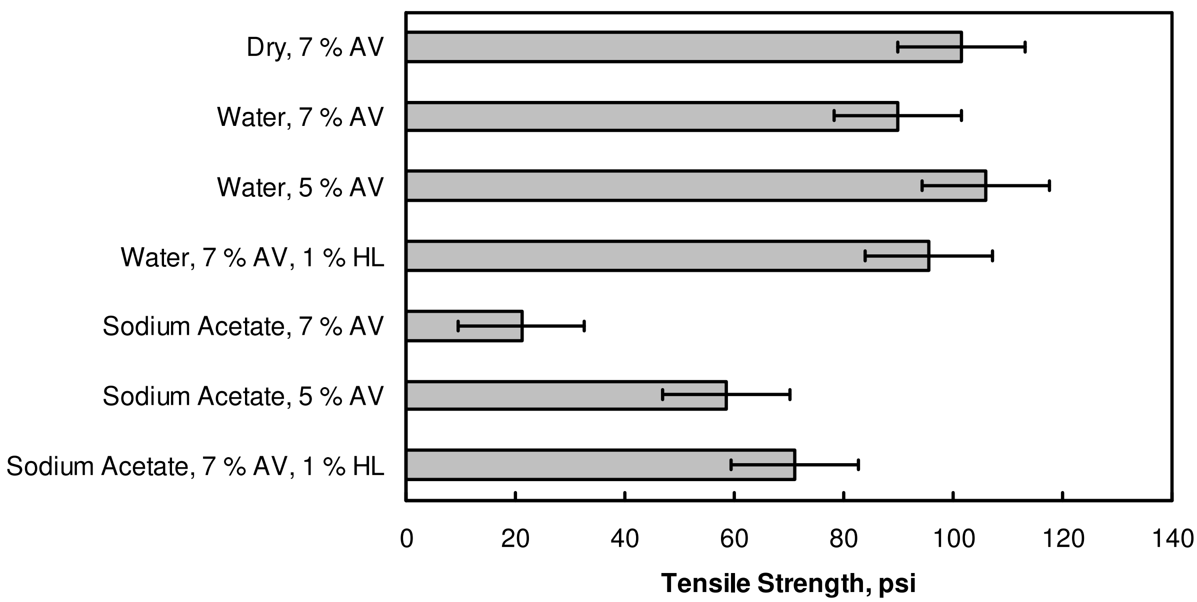


Figure 4. Indirect Tensile Strength Values for Mixture with Mississippi Chert/Gravel and PG 58-28 Binder, Subjected to Different Treatments. *Error bars show ± 2s confidence intervals for tensile strength.*

Figure 5 summarizes the results of Experiment 3 for the Mississippi chert/gravel/PG 64-22(2)/potassium acetate system. The results for this system are similar to those for the first system, although the benefits of lower air voids and hydrated lime do not appear to be as pronounced. It is likely that the effects of these ameliorative treatments—especially hydrated lime—will vary from system to system. It is also possible that other antistripping additives might prove more effective in reducing DIAIC-related damage, depending on the specific combination of aggregate and binder being used.

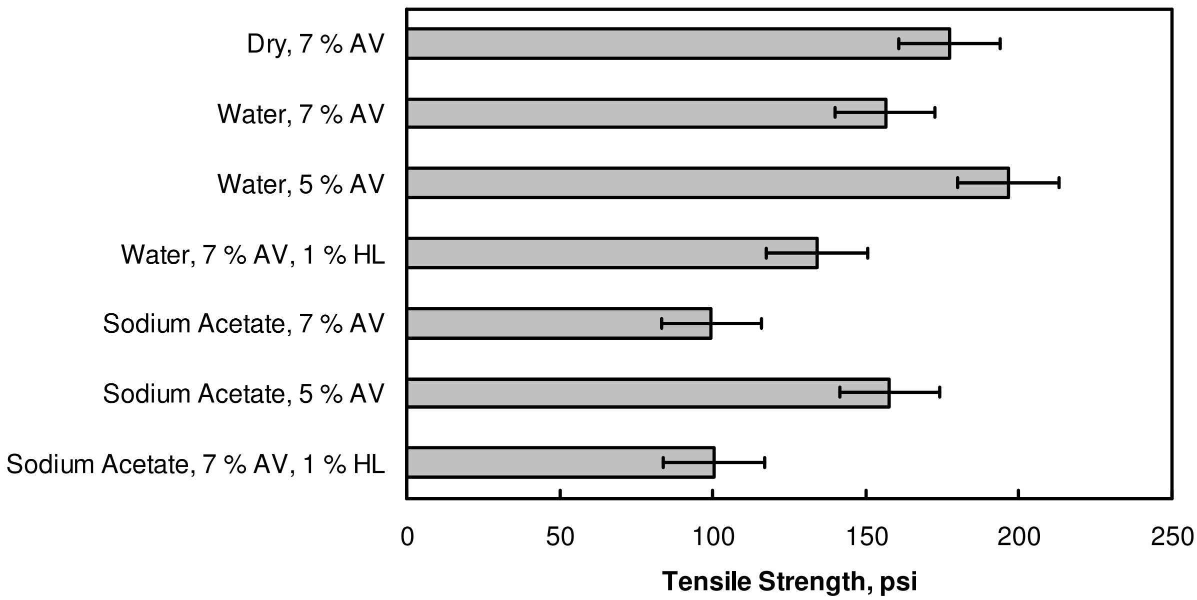


Figure 5. Indirect Tensile Strength Values for Mixtures Made with Mississippi Chert/Gravel and PG 64-22(2) Binder, Subjected to Different Treatments. *Error bars show ± 2s confidence intervals for tensile strength.*

Figure 6 summarizes the results of Experiment 3 for the Virginia gravel/PG 58-28/sodium acetate system. In this case, improving compaction and using hydrated lime both improved tensile strengths, but this increase was nearly the same for specimens conditioned in the sodium acetate solution as it was for specimens conditioned in water alone, suggesting that in this case these treatments had little effect on DIAIC-related damage. However, it must be remembered that the amount of DIAIC-related damage for this system was quite low, perhaps insignificant. This system was included primarily in the interest of including a different aggregate in Experiment 3; it is not clear in this case if there is significant DIAIC-related damage, although the fact that the tensile strength values are consistently slightly lower for specimens conditioned in sodium acetate—regardless of the treatment—indicates that this system does in fact exhibit a small amount of DIAIC-related damage.

**Surface Tension Measurements**

Nuclear Magnetic Resonance (NMR) imaging methods were used to obtain asphalt-water interfacial parameters, including contact angles and surface tensions. Details of this procedure are not included here to keep this paper brief, but are provided in the final report for the project [10]. As reported by other researchers, it was found that some of the DIAICs evaluated caused a significant reduction in asphalt-water surface tension; the largest reduction occurred with 35 % solutions of propylene glycol and sodium formate. This agrees with findings by other researchers. This lowering of surface tension possibly contributes in some cases in the accelerated moisture damage seen in some HMA mixtures subjected to DIAICs. However, it should be pointed out that there was in this case no clear correlation between the observed asphalt-water surface tension and the results of the IT test.

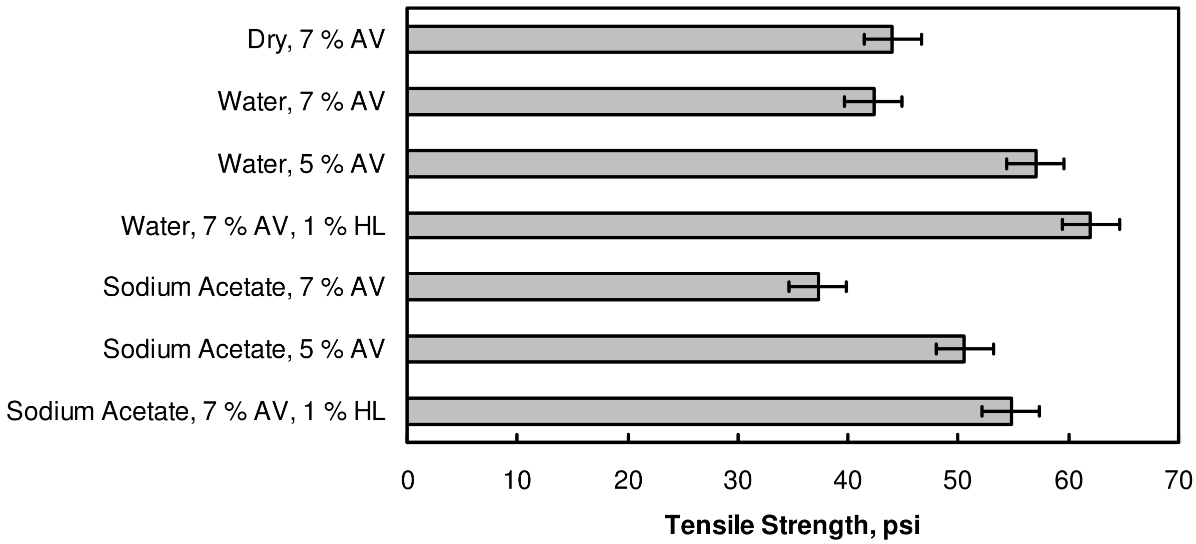


Figure 6. Indirect Tensile Strength Values for Mixture Made with Virginia Gravel and PG 58-28 Binder, Subjected to Different Treatments. *Error bars show ± 2s confidence intervals for tensile strength.*

**Field Tests**

The results of the IT tests on the field cores are summarized in Figure 7. This plot shows average IDT strength for field cores from the three airfields, including both new and old pavements at the Boston Logan airport. Because there was significant variation in bulk specific gravity within the various groups of cores, the strengths have been adjusted for variation in bulk specific gravity, based upon the results of an analysis of variance (discussed in the following paragraph). There are differences in the IT strengths among the airfields—strengths for the cores from the old Boston Logan pavement are especially high. In general, the potassium acetate treatment appears to slightly increase the IT strength. This suggests that none of these HMA mixtures are susceptible to DIAIC-related damage. An analysis of variance performed on these data confirmed that for none of the mixes was there a statistically significant difference between the tensile strength after conditioning with water and after conditioning in DIAIC solution.

## DISCUSSION OF RESULTS

Previous research on DIAIC-related damage in HMA airfield pavements has suggested that the primary cause of this distress is essentially moisture damage accelerated by the lower surface tension and relatively high density of DIAIC-solutions compared to water. The lower surface tension of the DIAIC-solutions allows them to more thoroughly wet asphalt binder surfaces in a mixture, and also allows more rapid penetration at the asphalt-aggregate interface. The higher density of DIAIC-solutions means that these will penetrate into the HMA pavement more rapidly than water, simply because of their greater density. The results of AAPTP Project 5-3 in general seem to support this hypothesis, although there may be other factors contributing to DIAIC-related damage that are not yet understood. After Phase I of AAPTP Project 5-3 it was believed that an alkali-silica reaction between DIAICs and aggregates might contribute to damage in HMA subjected to DIAICs, but the results of Phase II testing did not support this hypothesis.

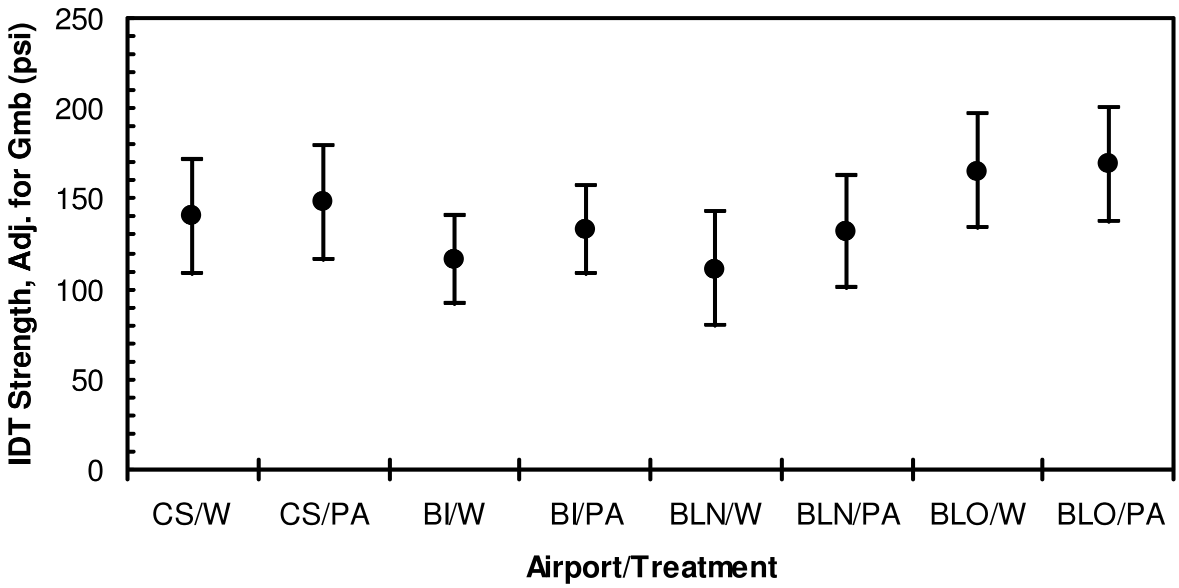


Figure 7. Results of IT Test for HMA Cores Taken at Four Airfields: Colorado Springs (CS); Boise, Idaho (BI); Boston Logan/New (BLN); and Boston Logan/Old (BLO). *W = water, PA = potassium acetate solution. Error bars represent two standard-deviation confidence limits for the average strength.*

In cases where DIAIC-related damage is a problem, solutions are relatively straightforward. It should for the most part be treated as a type of moisture induced damage. Changing binders and/or aggregate may reduce or even eliminate the problem. If this is not economical, anti-strip additives might reduce the susceptibility to DIAIC-related damage to an acceptable level. Using harder binders—especially PG 76-22 polymer modified binders—tends to greatly reduce the extent of DIAIC-related damage.

The IT test developed during AAPTP Project 5-3 is potentially a useful tool for identifying HMA mixtures susceptible to DIAIC-related damage. It is simple, quick and can be run by any laboratory familiar with AASHTO T-283 and related procedures. It was effective in identifying one aggregate—the Mississippi chert/gravel—as producing HMA mixtures prone to DIAIC-related damage. However, it cannot be concluded that the test is highly effective in identifying mixes prone to HMA damage. This is because it was not possible during this study to locate a significant number of HMA mixtures prone to DIAIC-related damage that could then be subjected to the IT procedure to determine if this test would correctly identify their poor resistance to deicer-related damage. Cores from airfield pavements tested during this study represented material that was possibly subject to DIAIC-related damage—it was not certain that these cores represented HMA prone to this type of distress. Therefore, prior to full implementation of this test procedure, additional evaluation of its effectiveness in identifying DIAIC-related damage is warranted. Such an evaluation should ideally consist of testing a number of different HMA mixtures, including a number known to be susceptible to DIAIC-related damage. Such samples could possibly be procured from laboratories in Finland and other parts of Scandinavia where this problem is apparently more widespread.

## CONCLUSIONS AND RECOMMENDATIONS

The conclusions listed below are based in part upon the literature review conducted during Phase I of the project, and also upon the results of laboratory testing performed during Project 05-03. The most important of these laboratory tests involved the immersion tension (IT) test, a procedure similar to AASHTO T 283 which appears to be very promising in identifying deicer/anti-icing chemical-related damage in HMA pavements. The IT test procedure was used to investigate the effects of various factors on DIAIC-related damage: DIAIC type, aggregate type, binder grade, air void content, and the addition of hydrated lime to the mixture. In most cases, the results of these laboratory tests agreed with findings made by other researchers as summarized in the literature review. Work performed as part of AAPTP Project 05-03 has resulted in 12 important findings:

1. Certain deicer/anti-icing chemicals (DIAICs) appear to increase the extent of moisture-induced damage in some HMA mixtures. This should not be considered a unique form of distress, but an accelerated type of moisture damage. For this reason it should be called DIAIC-related damage.
2. DIAIC-related damage in HMA mixtures does not appear to be common. It appears to be limited to HMA mixtures containing significant amounts of siliceous aggregate. However, many siliceous aggregates may not exhibit significant DIAIC-related damage.
3. This research indicated that temperatures of 60°C are high enough to cause damage in HMA exposed to acetate- and formate-based DIAICs.
4. DIAIC-related damage is generally more severe for HMA made with softer binders. Conversely, using stiffer binders, especially PG 76-22 polymer modified binders, will tend to minimize DIAIC-related damage in susceptible mixes.
5. DIAIC-related damage increases in severity with increasing in-place air void content. Therefore, when an HMA is suspected of being susceptible to DIAIC-related damage special care should be taken to ensure that pavements constructed with the mixture are properly compacted.
6. The addition of hydrated lime may decrease the severity of DIAIC-related damage in susceptible mixes. Although not evaluated as part of this study, it is possible that other anti-stripping additives might also be effective in reducing the extent of DIAIC-related damage.

7. The IT test is a promising test for the laboratory evaluation of HMA for susceptibility to DIAIC-related damage. However, the procedure needs to be evaluated on a much wider range of HMA mixtures, including several with a known history of susceptibility to DIAIC-related damage.

## REFERENCES


1. USEPA, *Preliminary Data Analysis, Airport Deicing Operations (Revised),* Report No. EPA-821-R-00-016, United States Environmental Protection Agency, August 2000.
2. Nilsson, F., *Durability Problems on Nordic Airfields- The Influence of Deicing Agents on Asphalt Concrete,* Proceedings of the XXIInd PIARC World Road Congress, October 2003.
3. Air Force, *Pro-Act Fact Sheet—Deicing/Anti-icing,* Air Force, July 2002.
4. Edwards, Y., J. Rollén, G. Lange, J. Aurstad and T. Nilsen, *Durability Problems on Nordic Airfields—the Influence of De-Icing Agents on Asphalt Concrete Pavements*, VTI Notat 24A-1999, Linköping, Sweden: The Swedish National Road and Transport Institute (VTI), 1999, 54 pp.
5. Ekblad, J. and Y. Edwards, *Precision of LFV Method 2-98: Effect of De-Icing Fluid on the Surface Tensile Strength of Asphalt Concrete for Airfields—Adhesion Test*, Research Report TRITA-VT AR 05:01, Stockholm, Sweden: AVD För Vägteknik, May 2001, 26 pp.
6. Hassan, Y., A.O. Abd El Halim, A.G. Razaqpur, M. Farha, *Laboratory Investigation of Effect of Deicing Chemicals on Airfield Asphalt Concrete Pavement Materials,* Proceedings, 2nd International Conference on Engineering Materials, August 2001.
7. Farha, M.H., Y. Hassan, A.O. Abd El Halim, A.G. Razaqpur, El-Desouky, A. Mostafa, *Effects of New Deicing Alternatives on Airfield Asphalt Concrete Pavements,* Federal Aviation Administration Technology Transfer Conference, 2002.
8. Alatyppo, V., *Conclusions- Finnish Deicing Project,* Helsinki University of Technology, Laboratory of Highway Engineering, 2005.
9. Christensen, D. W., J. Mallela, D. Hein, M Farrar, E. Kalberer and R. Bonaquist, *Airfield Asphalt Pavement Technology Program Project 05-03:Effect of Deicing Chemicals on HMA Airfield Pavements, Revised Final Report*, September 2009, 43 pp.
10. Massachusetts Port Authority, May, 2005, *Standard Protocol for Evaluation of Existing Hot Mixture Asphalt Pavements at Logan International Airport.*