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Friction Trends of Anti-Icing Chemicals on Tined Concrete

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ABSTRACT

This latest set of anti-icing chemical friction tests was conducted on a tined concrete surface. Most of the chemicals tested, in their liquid sate provided a friction equivalent to, or greater than, 0.5. Relative humidity levels between 25 to 40% caused most of the chemicals to transition through a minimum friction slurry state. During this transition a number of the chemicals produced a friction significantly below 0.5. Some of the chemicals appeared to be absorbed by the porous concrete. Others appeared to form a bond with the concrete allowing them to remain in a liquid state, even at extremely low relative humidity levels, and therefore provide a constant friction.

INTRODUCTION

Prior research into the effect of liquid ant-icing chemicals on the coefficient of friction has shown a relationship between the relative humidity, the state of the chemical, and the resultant friction on a sandblasted glass surface and a section of well traveled asphalt roadway. This latest set of tests was performed on a tined finish concrete surface, to ascertain the chemicals' effects on the friction available on a concrete roadway or bridge deck. Particular emphasis was put on the dependency of the friction on the ambient relative humidity, as it affected the chemicals' state.

To date it has been shown that the friction afforded by most anti-icing chemicals is dependant on the state the chemical is in. Whether a particular chemical will remain in its initial liquid state after application, or whether it will transition through a slurry state, into its solid state, under exposure to a low relative humidity environment, can affect the friction the chemical provides. Like the previous research on a glass and asphalt surface, this set of testing was performed to ascertain if such a humidity driven state change occurs in these chemicals on a concrete surface, and if this affects the friction provided by the chemicals on the concrete surface.

This latest set of tests was performed on a tined finish concrete surface, as presently used on new and refinished bridge decks in the province of British Columbia and other jurisdictions. Degradation of the friction tester's tire, during the prior tests on an asphalt surface prevented direct friction comparisons between anti-icing chemicals. During this testing, the drag sled's test tire condition was stringently monitored, and the tire was replaced a number of times, to ensure results which could, for the first time, be used to compare anti-icing chemicals head-to-head.

In total 15 anti-icing chemicals were tested on the concrete surface. Of these 14 were applied as a liquid. One was applied in solid crystal form. All were tested in similar fashion to ascertain their effect on the coefficient of friction between an automobile tire and a concrete roadway, and how this effect may be dependent upon the chemical's state and, hence the ambient relative humidity. While reviewing the results, the reader should keep in mind that they represent the friction between a newly finished concrete surface, in other words not traffic polished, and a new tire with little to no tread wear. Hence, these should be considered as the maximum friction attainable. A fair comparison of a chemical's friction performance is to gauge the friction results of this chemical, with the friction found on the dry, and wetted with water only, concrete surface.

PROCEDURE

All testing was performed in a climate controlled test chamber engineered and built by Forensic Dynamics Inc. The test surface was a 1.5 meter long, 0.3 meter wide, section of concrete build for the testing. The concrete mixture used for its construction, as well as the tined finish on its surface, were according to the current standards used for bridge decks in the province of British Columbia. The climate controlled test facility was used to set the test temperature at a constant 5°C, 41°F, and alter the humidity values, to permit the applied anti-icing chemicals to dehydrate, and subsequently re-hydrate on the concrete surface. Such movement, between liquid and solid states, and back to liquid form, cannot be controlled in the real world; hence, the environmental chamber was necessary to fully modulate these transitions.

The friction was measured using a drag sled, equipped with a Firestone M&S radial tire, weighing precisely 11.6 lbs. The pull force was measured using a Mettler Toledo 100 lb load cell, with a sensitivity of 0.001 lbs. The drag sled was pulled across the test surface, using a constant velocity motor, at a rate of approximately 30cm per second. This allowed for data collection of approximately 30 dynamic force measurements, as the sled was pulled over an approximate one meter distance, at a sampling rate of about 10 measurements per second.

Each set of force measurements was averaged to determine the pull force for each test run. The available friction for each test run was calculated from this average pull force and the weight of the drag sled. Importantly, the data was collected at a drag sled velocity of about 1.0 kph (0.6 mph).

Between tests, the drag sled was removed, washed, and rinsed, as was the concrete surface. To monitor the condition of the test apparatus, and in particular the tester's tire, at the start of each test, prior to the introduction of the anti-icing chemical, a set of 'dry runs' was performed, and the dry friction value of the drag sled on the concrete surface was verified. After the concrete surface had been rinsed free of the chemical, at the end of the test, 'wet with water only' runs were also performed to assure tire degradation was not affecting the test results.

For each test, the liquid anti-icing chemical was applied at a rate of 60 Liters per lane kilometer (25 gallons per lane mile), using a pump spray mister. This method of chemical application was implemented to model the chemical's distribution on an actual roadway by traffic. The single solid chemical was applied at a rate of 30 grams per square meter, or approximately, 6 lbs per 1,000 sq. feet, and the tester was dragged across the product once to distribute it. A minimal amount of water was then sprayed onto the test surface and product in an effort to simulate the product in a state where it had just been dissolved into solution. The amount of water applied was approximately 64 ml per square meter. The environmental chamber was sealed following application of the anti-icing agent, and temperature and humidity conditions set. The relative humidity was altered to allow dehydration and rehydration of the chemical. Throughout the varying humidity conditions, friction measurements were taken at 5 minute intervals.

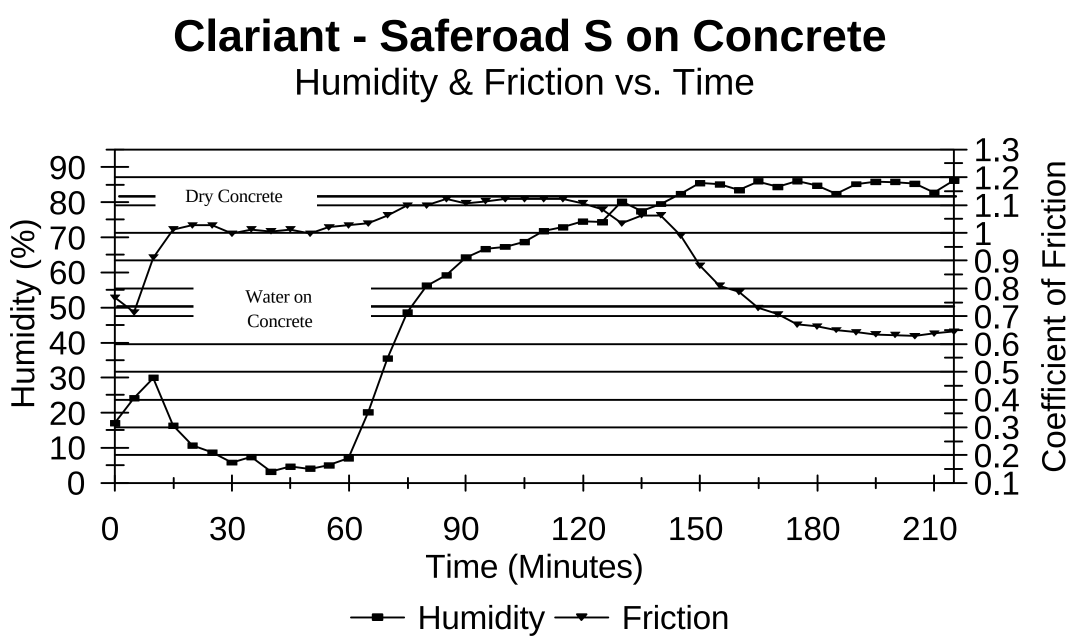
RESULTS

The following are the results of the friction testing performed on the provided 15 anti-icing chemicals. Throughout the testing, the dry and wet with water friction on the concrete test surface was monitored. The friction on the dry concrete surface was found to be 1.11 ± 0.05. Wetted with water only, the friction on the concrete test surface was 0.71 ± 0.05.

Clariant - Saferoad S

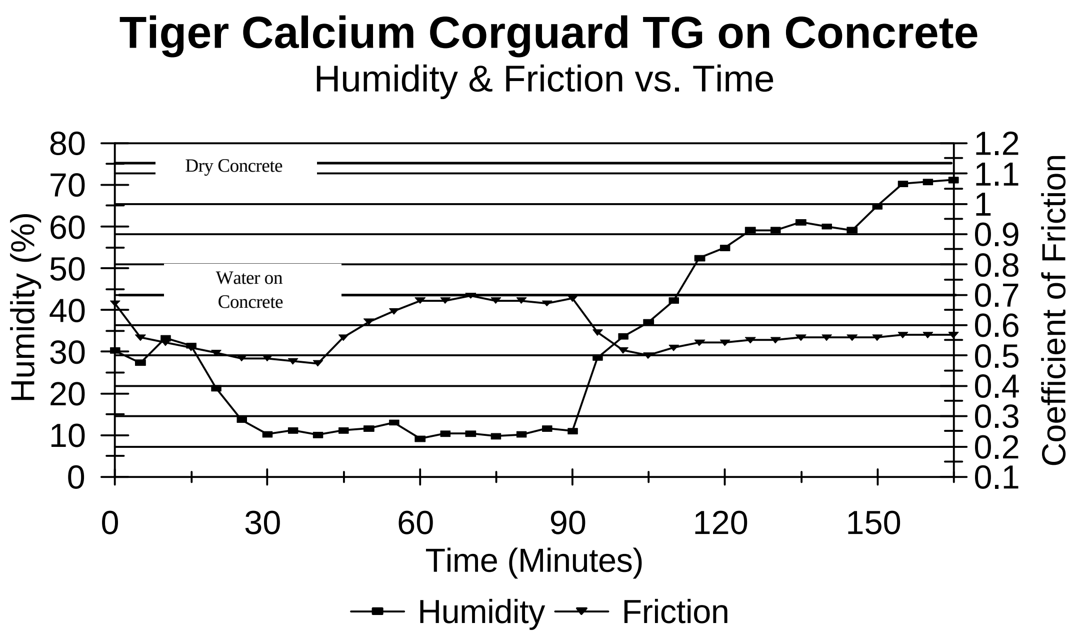
Saferoad S was the only solid anti-icing agent tested. The product was applied at the manufacturer's recommended application rate, and a number of test runs were performed to establish the friction with the solid crystals on the concrete surface. A friction of 0.98 was found.

A second friction test was run, in which the solid crystals were applied to the test surface and a minimum amount of water was sprayed onto the track, to simulate a precipitation event sufficient to put the chemical into a liquid solution. The initial friction provided by this solution was 0.77. At relative humidity levels below 30%, this solution dehydrated, until only a solid white precipitate was left on the concrete surface, which afforded a friction of 1.0. Upon introduction of humidity the friction rose to a maximum of 1.12. The agent exhibited a sufficiently hygroscopic nature to allow it to transition from a solid precipitate into a liquid solution. While transitioning to a liquid a minimum friction of 0.63 was recorded, before the chemical achieved a final liquid state friction of 0.65.



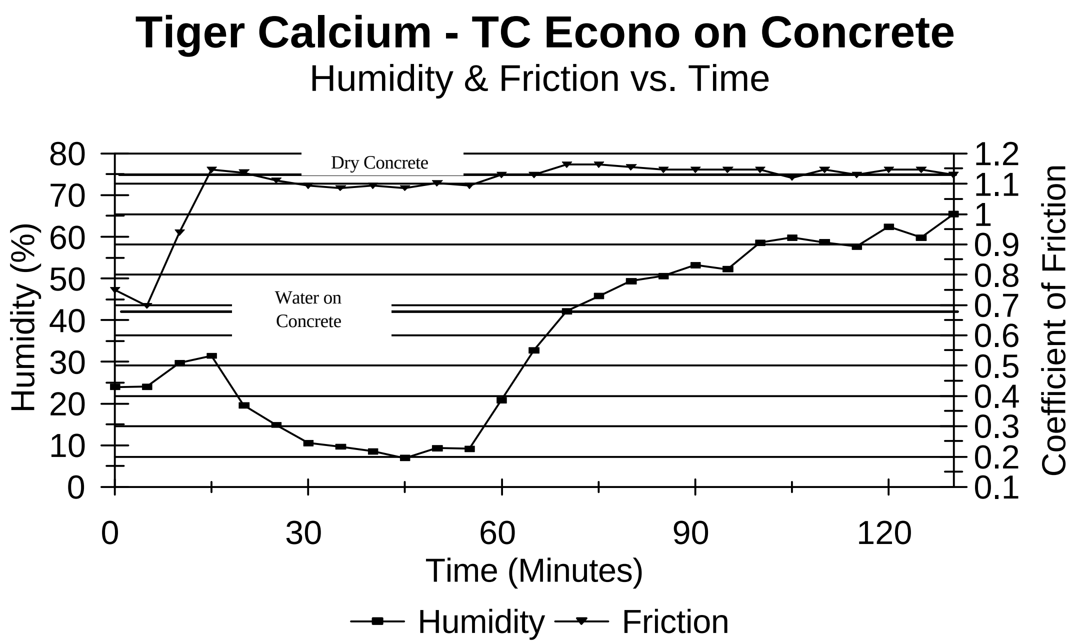
Tiger Calcium Services – Corguard TG

When in a liquid state Corguard TG produced a friction of 0.57 on the concrete surface. Exposed to relative humidity levels below 30% the chemical transitioned through a minimum friction of 0.47, before, under continued dehumidification, it achieved a maximum friction of 0.7. Upon introduction of moisture into the test chamber, the product once more approached the minimum friction value found, before returning to its liquid friction value of 0.57.



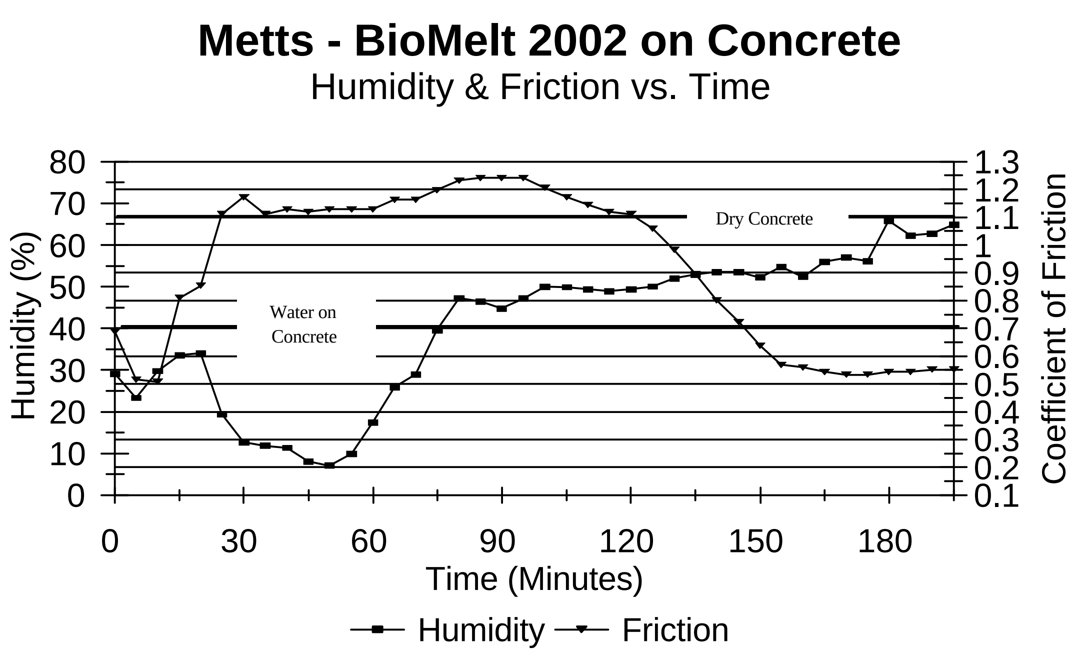
Tiger Calcium Services – TC Econo

Applied in its liquid state onto the concrete surface TC Econo produced a friction of 0.75. Exposed to an environment below 30% relative humidity this chemical appeared to dry out rapidly. After only 15 minutes the friction on the concrete surface had increased to 1.15, equivalent to the friction on the dry concrete surface. With the introduction of humidity, up to as high as 65%, only minor fluctuations in the friction were noted. On average, the friction remained equivalent to a dry surface, and the chemical did not rehydrate into a liquid state.



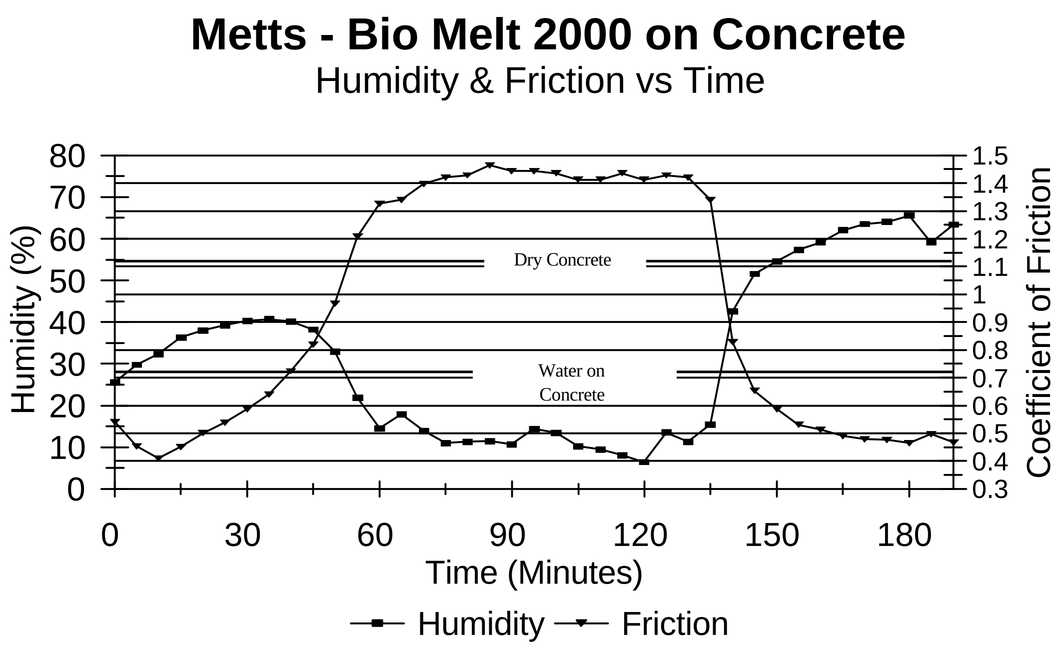
Metts – Bio Melt 2002

In a liquid state Bio Melt 2002 produced a friction of 0.55 on the concrete surface. At a relative humidity below 30% this chemical rapidly transitioned through a brief minimum friction of 0.51, before leveling out at a friction of 1.13. As humidity was introduced the friction increased to a maximum of 1.24, before the chemical completely transitioned into its liquid state. During the final transition, the friction dropped below the final liquid friction value by 0.02.



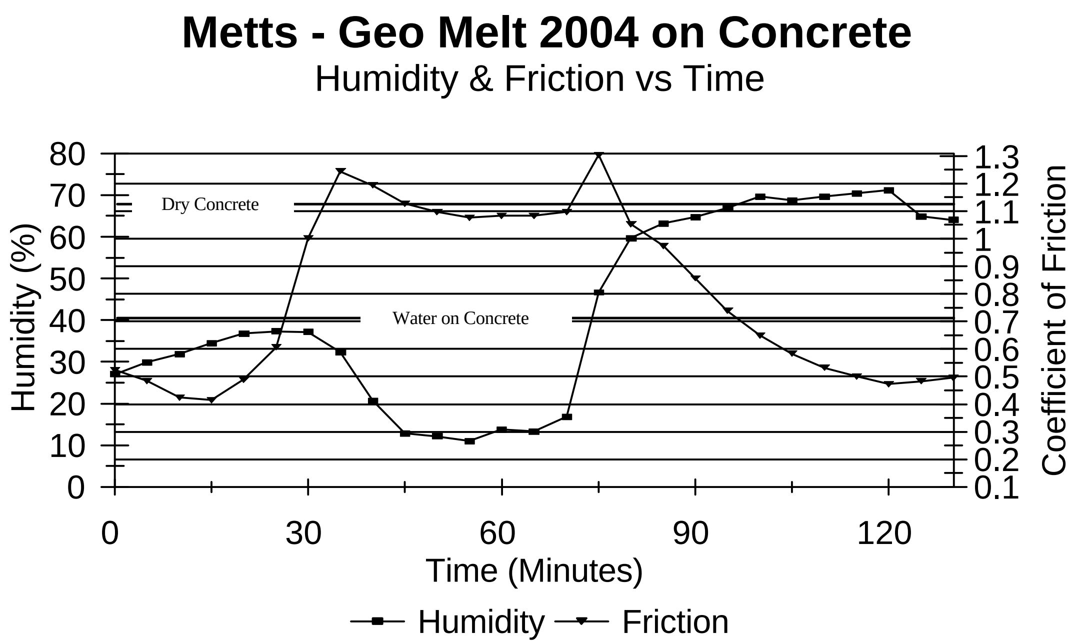
Metts – Bio Melt 2000

At relative humidity below 30%, Bio Melt 2000 achieved a minimum friction of 0.41 only 10 minutes following application as a liquid. The friction then rapidly increased to a maximum of 1.47, and remained there until humidity was re-introduced into the test chamber. Introduction of humidity caused a rapid decrease in the friction to a value of 0.47, at which point the chemical was back in its liquid state.



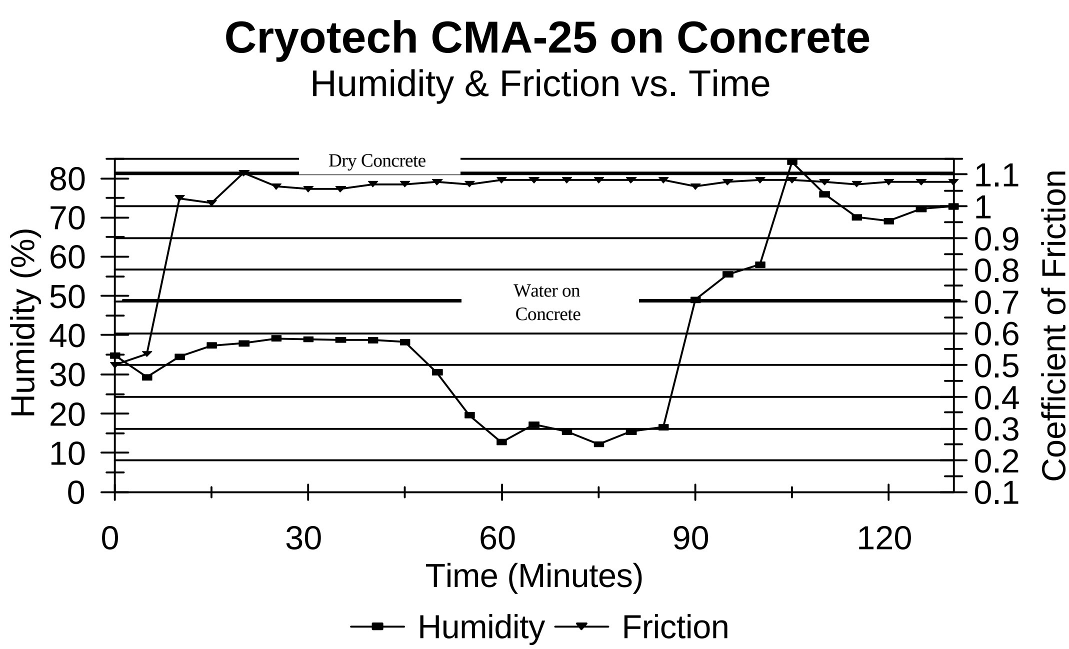
Metts – Geo Melt 2004

Applied as a liquid to the concrete surface, Geo Melt 2004 produced a friction of 0.5. Exposed to relative humidity levels below 40% the chemical transitioned through a minimum friction of 0.42, before the friction increased to a value of 1.25, following which it settled to a value of 1.08. The friction remained at this value until the humidity in the chamber was increased above 45%, which caused a maximum friction measurement of 1.3. As the humidity was increased further to 70%, the chemical transitioned back into its liquid state and a friction of 0.5.



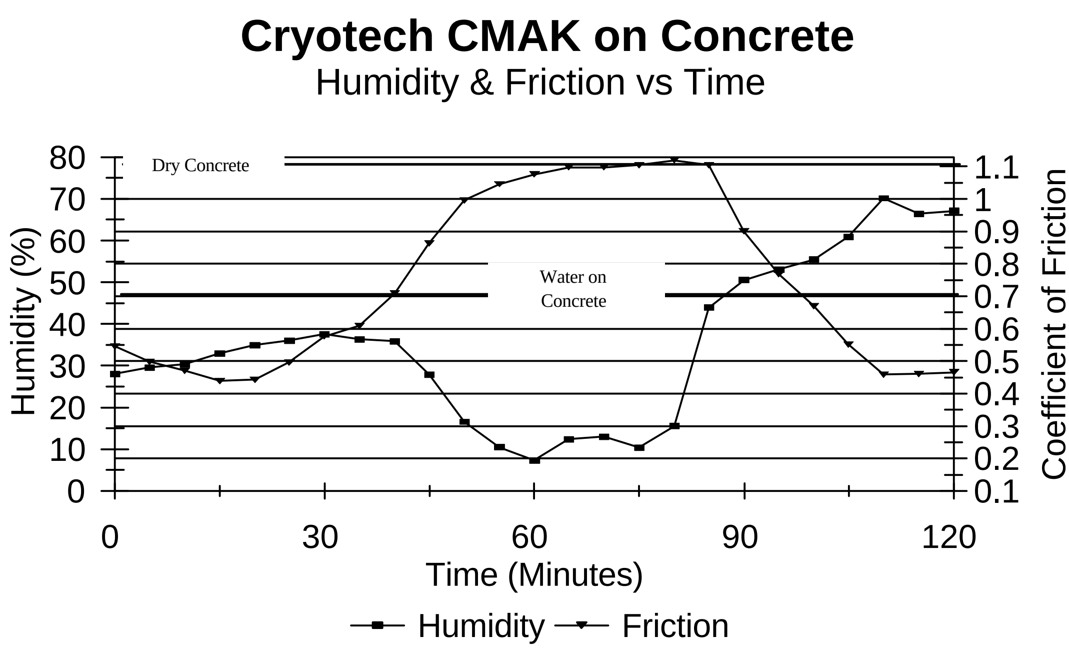
Cryotech – CMA-25

CMA-25, applied to the concrete surface in its liquid state produced a friction of 0.5. This was the lowest friction recorded with this chemical. At a relative humidity below 40% the friction produced by the chemical rapidly increased to a maximum of 1.08. Increasing the relative humidity to as high as 85% had no apparent affect on the chemical, as the friction remained at 1.08.



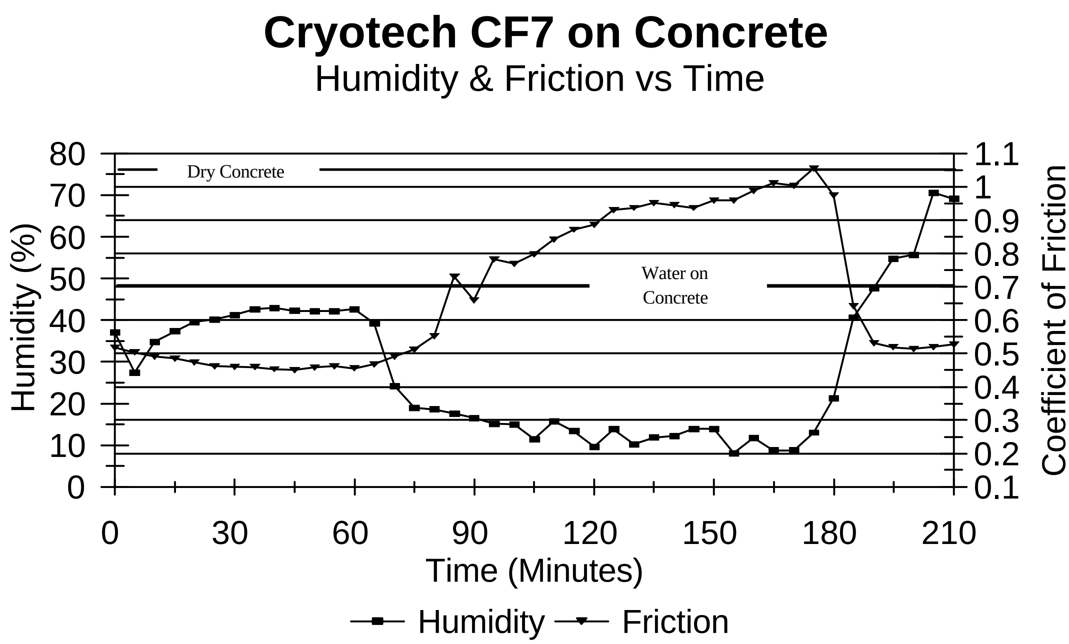
Cryotech – CMAK

As a liquid on the concrete surface, CMAK produced a friction of 0.47. Relative humidity below 30 to 40% was sufficient to cause the chemical to transition through a minimum friction of 0.44. It continued to transition until it achieved a maximum friction of 1.12, equivalent to the friction on the dry concrete surface. As humidity was introduced, the chemical transitioned back into its liquid state, with a friction of 0.47, with out going through a low friction phase.



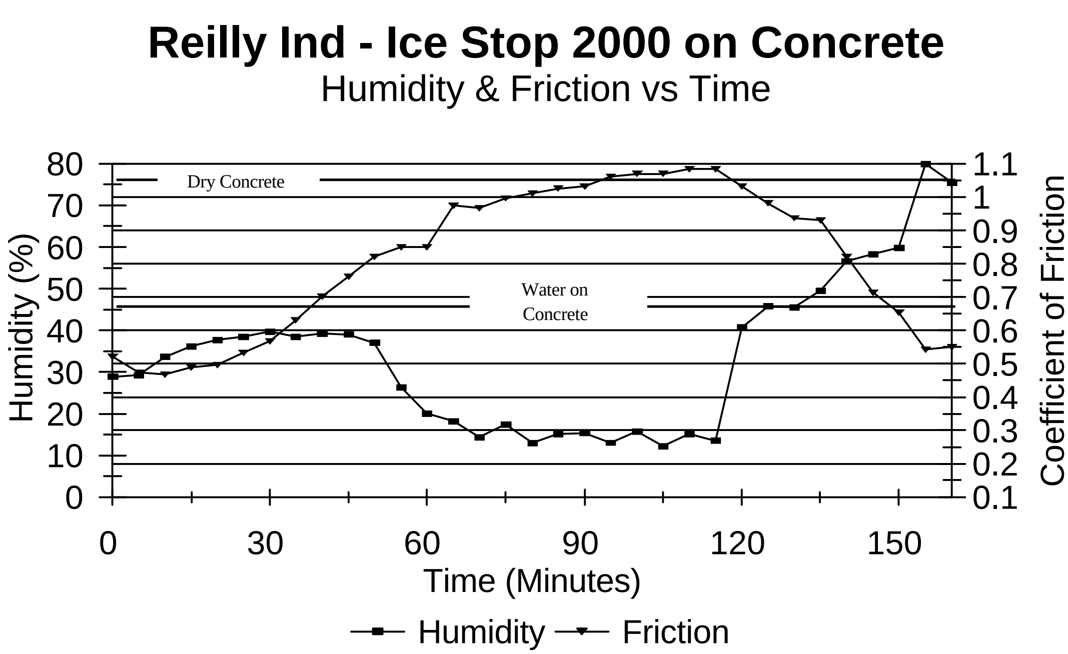
Cryotech – CF7

On application, in its liquid form, CF7 allowed for a friction of 0.53 on the concrete surface. At a relative humidity below 45% the chemical slowly transitioned through a minimum friction phase, of 0.45. As the humidity was reduced below 20% CF7 more rapidly transitioned toward a maximum friction of 1.06. Upon introduction of humidity into the test chamber, the chemical rapidly transitioned back into its liquid state, and a friction of 0.53. No significant friction drop was noted in this final transition.



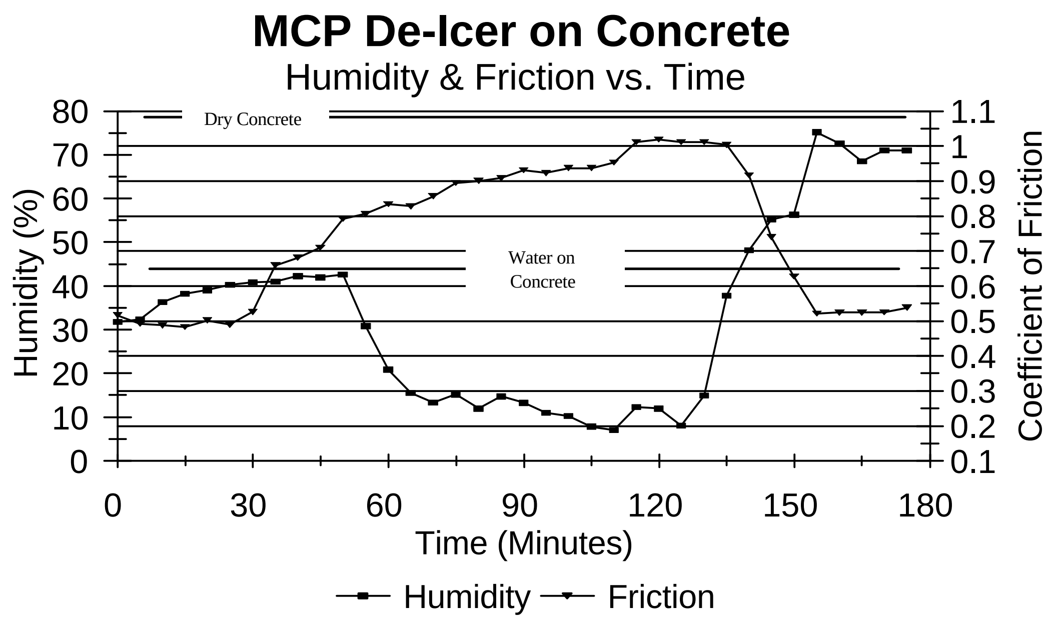
Reilly Wendover – Ice Stop 2000

In its initial liquid state on the concrete surface, Ice Stop 2000 caused a friction of 0.55. Relative humidity below 40% was sufficient to cause the chemical to transition rapidly through a brief minimum friction phase of 0.47, before achieving a maximum friction value of 1.08. Addition of humidity allowed the chemical to transition just as rapidly back into its liquid state, with out the detection of a low friction phase.



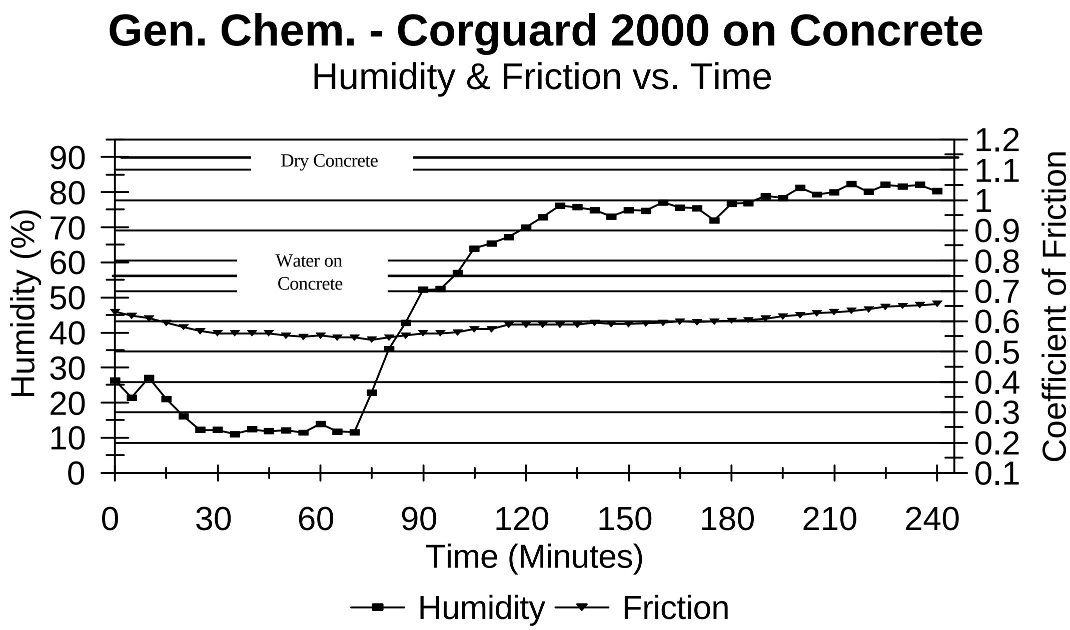
Minnesota Corn Producers – MCP De-Icer

MCP De-Icer, following application in its original liquid state, produced a friction of 0.54 on the concrete surface. At relative humidity levels below 45% the chemical remained in a liquid state for approximately 30 minutes, at a minimum friction of 0.48, before it began to transition toward a maximum friction phase of 1.02. Reduction of humidity levels below 20% did not increase the chemicals transition rate. Increasing humidity levels above 45% allowed the chemical to transition back rapidly to its liquid state, and a corresponding friction of 0.54.



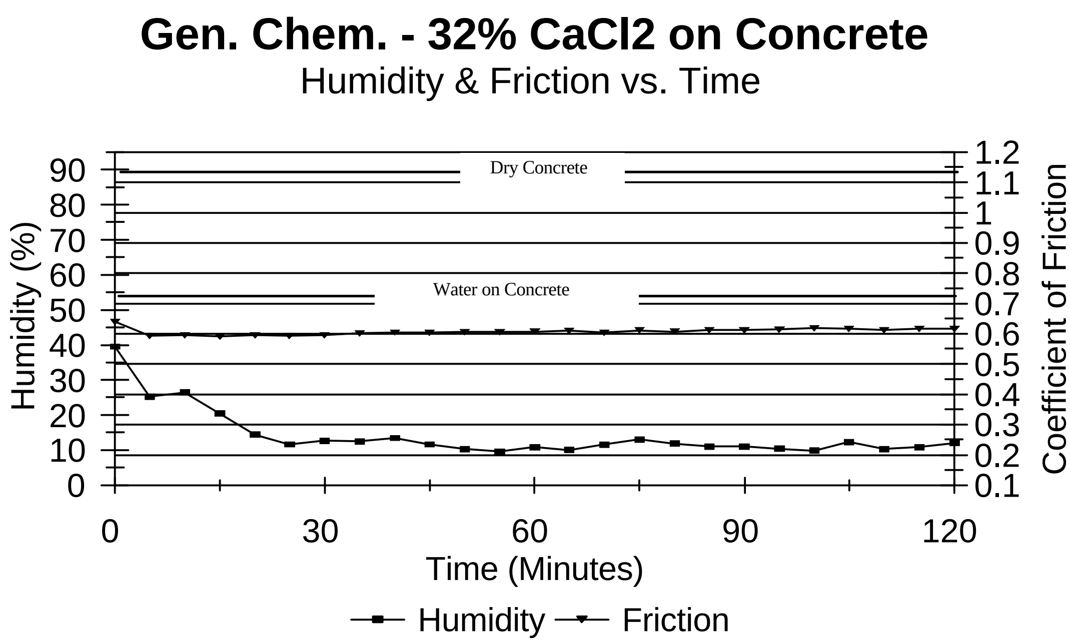
General Chemical – Corguard 2000

Corguard 2000, on the concrete surface, responded quite differently from most of the chemicals tested. Application in its liquid state resulted in a friction measurement of 0.63. Exposed to a relative humidity level of just 10%, the friction allowed by the chemical reduced to a minimum of 0.54. Introduction of humidity into the test chamber, up to levels of 70% and above, caused the friction to reach a maximum of 0.66, basically equivalent to the initial, liquid state, friction recorded.



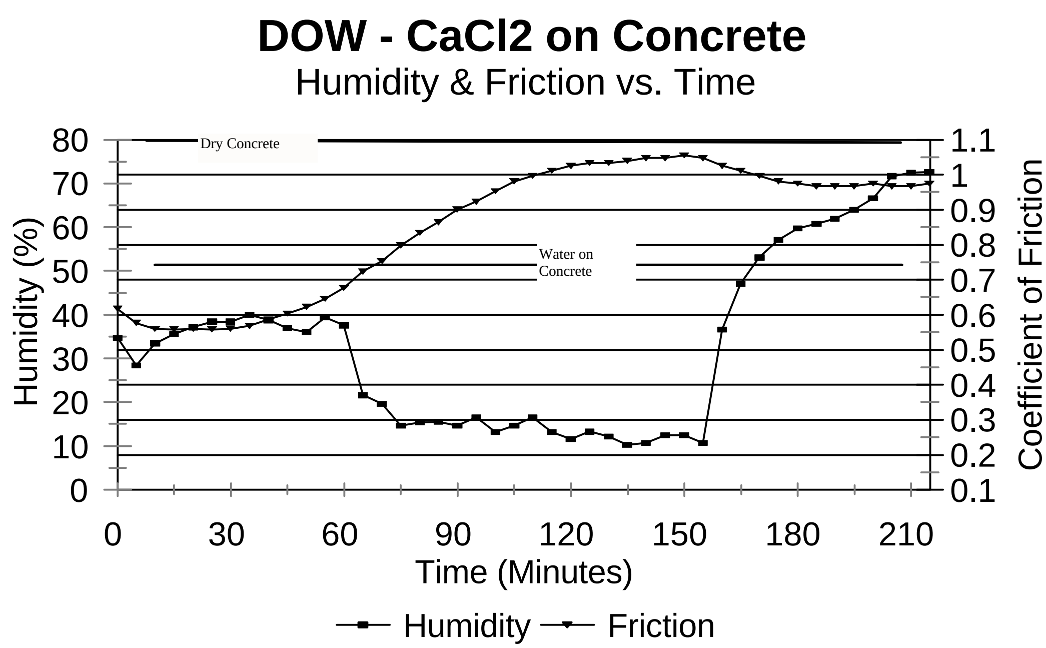
General Chemical – 32% $CaCl_2$

The 32% Calcium Chloride solution produced a friction of 0.64 upon initial application as a liquid onto the concrete surface. Reduction in relative humidity levels to as low as 10% had very little effect on the friction provided by this chemical, which appeared to remain in its liquid state throughout the testing. During testing the friction only varied slightly, reaching a low of 0.59, during the second test run, and a value of 0.62 when testing was halted.



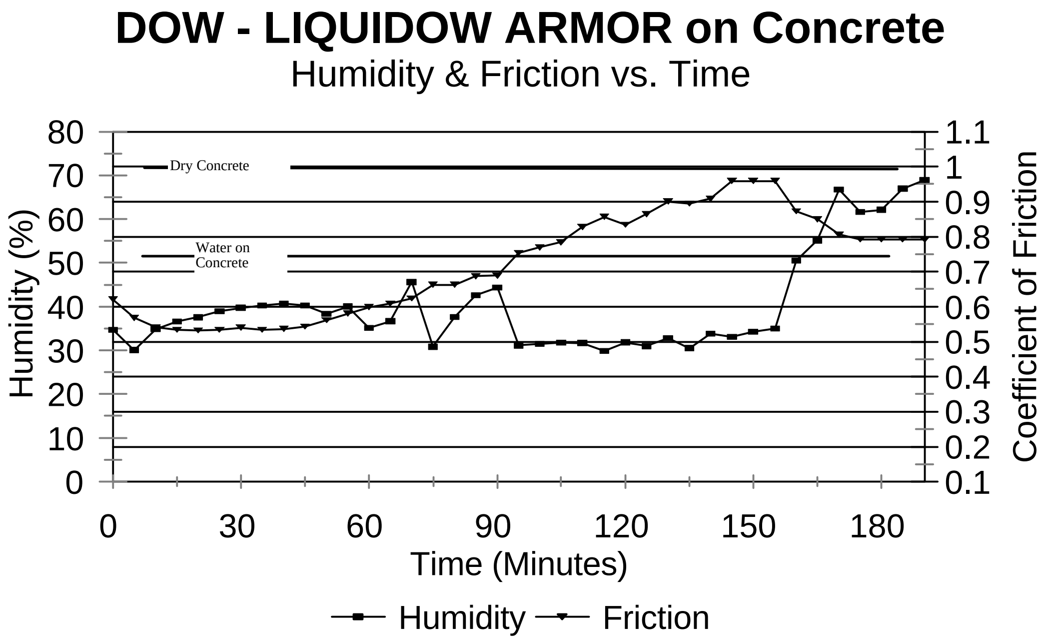
DOW - $CaCl_2$

Applied onto the concrete surface in its liquid state $CaCl_2$ produced a friction of 0.62. At relative humidity levels below 40% the chemical transitioned through a minimum friction phase of 0.56. When humidity levels were reduced below 20%, the chemical continued to transition toward a maximum friction of 1.06. Following introduction of humidity into the test chamber, the friction reduced to a constant value of 0.97, which remained unchanged, even at humidity levels above 70%.



DOW – LIQUIDOW ARMOR

LIQUDOW ARMOR allowed for a friction of 0.62 when applied to the concrete surface in its liquid state. Relative humidity levels between 30 to 40% caused the chemical to transition through a minimum friction phase of 0.53, which lasted approximately 30 minutes, before it transitioned further toward a maximum friction of 0.96. Increasing relative humidity levels to above 50% caused the friction to rapidly reduce to 0.79. Further increases in the relative humidity did not cause any change in this friction value.


DOW - LIQUIDOW ARMOR on Concrete
Humidity & Friction vs. Time
Humidity (%)
Coefficient of Friction
Dry Concrete
Water on Concrete
Time (Minutes)
0
10
20
30
40
50
60
70
80
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
0
30
60
90
120
150
180
Humidity
Friction

DISCUSSION

Prior research into the effect of liquid anti-icing chemicals on the coefficient of friction has shown that the friction provided is affected by the chemicals state, and that this state can be dependent on the ambient relative humidity. In a liquid state, most chemicals on an asphalt roadway afforded a friction slightly lower than that found with only water on the asphalt roadway. Most of these chemicals, at relative humidity levels of 30%, or below, were shown to dry out and transition into a solid state, were they produced friction levels equivalent to, or slightly lower, than that found on a dry asphalt roadway. However, during this transition, some of these chemicals exhibited a “slurry” phase, which reduced the friction on the asphalt roadway below the liquid friction values.

This latest friction testing of liquid anti-icing chemicals was performed on a tined concrete surface, representing a finished concrete bridge deck. The tined finish caused an average dry friction on the test surface of 1.1. The average friction on the concrete test surface, when wetted with water, was 0.71. Warner et al.[1] suggest a friction of 0.8 to 1.2 can be expected on a dry, new, sharp Portland cement roadway, and a friction of 0.5 to 0.8 may be found on the same roadway when wet. The tined concrete test surface used for this set of friction tests, therefore, was felt to adequately model the concrete roadways, which the average motorist may encounter.

The friction results presented in this paper must be considered a maximum. Limpert[2] has shown that friction is speed dependent, with higher friction values found at lower speeds. The friction testing was performed at a speed of approximately 1 kph, and, therefore, the recorded friction values are near the maximum possible. To assure that tire degradation would not affect test results, the present set of testing was performed with new tires. Goudie et al.[3] have shown that tire wear can affect friction test results, particular on a wet surface. Testing with new tires only, therefore, again provides friction results that must be considered a maximum. Lastly, as a concrete roadway is worn by traffic, the friction it provides to an automobile tire is reduced, and correspondingly lower than the friction results recorded on the new, and sharp concrete test surface.

All but one of the 15 chemicals tested, when in their liquid state, produced friction values on the concrete test surface lower than the value of 0.71 found with only water. The Tiger Calcium – TC Econo produced a friction of 0.75. Clariant’s Saferoad S, when allowed to dissolve into a liquid in a high humidity environment had the lowest percent reduction of 8% compared to water on the concrete surface. Both General Chemical products, as well as both DOW products, in their liquid states produced friction values within 15% of only water on the test surface. The liquid friction provided by the remaining chemicals ranged from 20 to 34% lower than the water only friction; see Table 1. It is suggested that the smaller the friction difference between a wet concrete roadway and the friction provided by the liquid anti-icing agent, the less likely application of the chemical would cause difficulties for motorists.

Manufacturer	Product	Friction			Friction Drop (%)	
		Liquid	Min.	Max.	Liq. - Min.	Liq. - Water
Cryotech	CMAK	0.47	0.44	1.12	6	34
Metts	Bio Melt 2000	0.47	0.41	1.47	13	34
Cryotech	CMA-25	0.5	0.5	1.11	0	30
Metts	Geo Melt 2004	0.5	0.42	1.3	16	30
Cryotech	CF7	0.53	0.45	1.06	15	25
MCP	MCP De-Icer	0.54	0.48	1.02	11	24
Reilly Wendover	Ice Stop 2000	0.55	0.47	1.08	15	23
Metts	Bio Melt 2002	0.55	0.51	1.24	7	23
Tiger Calcium	Corguard TG	0.57	0.47	0.7	18	20
DOW	LIQUIDOW ARMOR	0.62	0.53	0.96	15	13
DOW	CaCl2	0.62	0.56	1.06	10	13
General Chemical	32% CaCl2	0.62	0.59	0.64	5	13
General Chemical	Corguard 2000	0.63	0.54	0.66	14	11
Clariant	Saferoad S	0.65	0.63	1.12	3	8
Tiger Calcium	TC Econo	0.75	0.7	1.16	7	-6

Table 1. Liquid Friction Rankings

In the previous report, "LIQUID ANTI-ICING CHEMICALS ON ASPHALT: FRICTION TRENDS", it was suggested that maintaining a friction above 0.5 on the roadway would allow for safe motor vehicle operation. All but two of the chemicals tested, in their liquid state provided a friction of 0.5, or greater. These two, CMAK and Bio Melt 2000, had liquid friction values of 0.47, which are not significantly lower than 0.5, allowing for a test error of 0.05. All of the chemicals tested therefore meet this criterion. However, recall that these are maximum friction values, and that, therefore, on a polished concrete roadway, with worn tires, the friction provided by some of these chemicals, in their liquid state, may not produce a friction of 0.5.

Friction testing of liquid anti-icing chemicals on a glass surface revealed that most of these chemicals experience what was termed a "slurry" phase as they transitioned from a liquid to a solid state, and vice versa, depending on relative humidity conditions. This slurry phase was associated with a drop in friction levels for these chemicals below those found in their liquid state. Friction testing of these chemicals on an asphalt surface showed that this slurry phase may still cause a reduction in the available friction, even on as relatively rough a surface as asphalt. In the asphalt testing, only CMA and CMA-25 did not exhibit such a low friction state. Similarly, during this latest testing on concrete, only CMA-25 did not cause a reduction in friction, below liquid state levels. The remaining 14 chemicals all showed this friction drop in either the liquid to solid, solid to liquid, or both state transitions.

The reduction in the friction provided by these remaining 14 chemicals, compared to the friction they afforded in their liquid state, varied from 3 to 18% (Table 1). However, these drops are only significant if they reduced the friction below the safety limit of 0.5. Only Metts' Bio Melt 2000 and Geo Melt 2004, as well as Cryotech's CMAK, reduced the friction, during this slurry state, significantly below 0.5. Again, the reader should keep in mind that these are maximum friction values, and that due to tire and roadway wear, the friction provided by some of the other chemicals during the slurry state may also reach levels significantly below 0.5. The time period over which these chemicals produced a minimum friction is discussed later in the report.

Nine of the 15 chemicals tested on the concrete surface were also tested on asphalt. Unfortunately, because of degradation of the tester's tire during the asphalt testing, the absolute friction values between asphalt and concrete cannot be compared. However, a comparison of the percent reduction in friction during the slurry state, compared to the liquid state, was performed. This comparison showed a definite trend in the friction reduction caused by these chemicals. The percent friction reduction caused by each chemical on asphalt was very similar to the percent friction reduction it caused on the concrete surface. This suggests that the slurry state may only be dependent upon the chemical used, and the humidity, but is not due to an interaction between the chemical and the roadway surface.

Greater generalities between a chemicals friction performance, or its behaviour under exposure to extreme low and high humidity, on asphalt and concrete are however not possible. General Chemical's Corguard 2000 and 32% $CaCl_2$ were tested on both the asphalt and concrete surfaces. At relative humidity below 30% both chemicals, on asphalt, rapidly transitioned from a liquid, lower friction, into a solid, maximum friction, state. On concrete, neither of these two chemicals, even at relative humidity levels as low as 10%, transitioned into a maximum friction state. Specifically, Corguard 2000, at low humidity levels showed a slight slurry state with a reduced friction of 0.54. It remained in this state until the humidity in the test chamber was increased to 40% and above, at which time it returned to its liquid state and associated friction of 0.63. The 32% $CaCl_2$, at relative humidity levels around 10%, did not respond at all. The friction recorded dropped initially, as the chemical was spread out on the concrete by the first test run, and then remained at this liquid state friction of 0.62.

This unexpected behaviour of General Chemical's anti-icing agents on concrete suggests a possible interaction between the chemicals and the concrete surface. It is postulated that these chemicals may be bonding to the concrete surface. Through this bond, the chemicals are able to retain the water in their solution, and hence are not, or only slightly, affected by exposure to a low humidity environment. Further testing on concrete surfaces with smoother finishes, than the tined finish on the concrete test surface, may indicate if the theorized bonding is physical or chemical in nature. An anti-icing chemical's ability to maintain a constant friction, regardless of the ambient relative humidity, may have a number of benefits. Firstly, it would likely be easier for the average motorist to adapt their driving to the application of an anti-icing agent, if the friction produced by this agent did not vary significantly with humidity. Secondly, if the chemicals are able to bond to a tined concrete roadway, retention of the chemical on the roadway could be increased.

The friction test results of Cryotech's CMA-25, Tiger Calcium's TC Econo, and DOW's $CaCl_2$ and LIQUIDOW ARMOR raised some questions pertaining to the chemicals' retention properties on the tined concrete test surface. The CMA-25 on the concrete surface, as it did on the asphalt surface, would not transition back from a solid to a liquid state, under exposure to high humidity. On asphalt, however, even in its solid state CMA-25 showed to have an effect on the friction available. On concrete, after it rapidly dehydrated at humidity below 40%, it showed to have no significant effect on the friction, which at 1.08 was virtually identical to the friction on the dry concrete. The TC Econo behaved almost identical to the CMA-25. It also quickly dehydrated, leaving the concrete with a friction equivalent to the dry friction. This was possibly due to the significantly rougher surface of the tined concrete compared to the traffic polished surface of the asphalt. Alternatively, both of these chemicals reached a friction equivalent to the dry concrete, at humidity levels between 25 to 40%, extremely quickly, suggesting that dehydration of the chemicals was not the only mechanism causing the rapid friction increase. The chemicals penetrating the porous concrete could also have caused this rapid transition. If so, then their anti-icing ability may also have been affected by this.

DOW's $CaCl_2$ and LIQUIDOW ARMOR dehydrated much slower than the CMA-25 and TC Econo. Both reached a maximum friction, in this manner, very nearly equivalent to the friction on the dry concrete. Upon addition of humidity into the test chamber, the friction produced by both began to decrease, suggesting they were transitioning back to their liquid state, as they had on asphalt. However, the friction for $CaCl_2$ leveled out again at 0.97, as did the friction for LIQUIDOW ARMOR at 0.79. No further changes in friction occurred with increases in humidity. This suggests that not all of the chemical initially applied to the concrete remained when humidity was re-introduced into the test chamber. As a result, the remaining chemical reabsorbed less water, and hence the friction reduction was not as great as seen on the asphalt surface. Again, this is suggestive of some of the chemical having penetrated into the porous concrete, which may affect its anti-icing ability.

As found during the glass and asphalt testing, relative humidity was the factor controlling the chemicals' states and thereby the friction provided by these chemicals on the concrete test surface. All of the liquid anti-icing chemical tests were initiated at relative humidity levels between 25 to 40%. With the exception of the General Chemical agents, as discussed earlier, this relative humidity range was sufficient to cause the chemicals to dehydrate and initiate a liquid to solid state transition. Most of the chemicals passed through a slurry state, during this transition, which produced minimum friction values on the concrete surface. The tests suggest that the lower the relative humidity the faster the chemicals transitioned through this minimum friction slurry state. However, the actual transition rate appears to be directly related to the chemical being tested. For example, at a relative humidity between 30 to 40%, Metts' Geo Melt 2004 transitioned from a liquid to a maximum friction state, in approximately 30 minutes. At the same relative humidity range, and over the same ½hour time period, Reilly Wendover's Ice Stop 2000 had just passed through the minimum friction slurry state.

Humidity also played a critical part on the state transition capability of the only solid anti-icing agent tested, Clariant's Saferoad S. Initially, the chemical was diluted for testing, by misting it with sufficient water to just go into solution. At low humidity it rapidly dehydrated to a solid state with a friction of approximately 1.0. When humidity was introduced into the test chamber, the friction rose to that found on the dry concrete. Not until the relative humidity exceeded 70%, did the friction begin to drop. Therefore, after application as a solid, unless put into solution by a precipitation event, this chemical is expected to go into solution only in a high humidity environment.

CONCLUSIONS AND RECOMMENDATIONS

1. In their liquid state, most of the anti-icing chemicals tested provided a friction on the tined concrete test surface at or above the recommended safe roadway value of 0.5.

2. None but one of the chemicals in their liquid state provided a friction on the concrete surface equal to or greater than the friction of 0.71 found with only water on the tined concrete.

3. While transitioning between liquid and solid sates, at relative humidity levels between 30 to 40%, a number of the tested chemicals passed through a minimum friction slurry state, in which the friction on the concrete test surface dropped significantly below 0.5.

4. Some of the chemicals appeared to be absorbed by the porous concrete. Testing is recommended to confirm this, and if found to be so, the effect on the chemicals anti-icing capabilities on concrete may need to be verified.

5. Two of the agents tested responded differently to the same test protocol on asphalt and concrete, suggesting a physical or chemical bond between the chemicals and concrete may exist, which prevents the chemicals from dehydrating at low relative humidity levels. This may aid in the retention of the chemical on the concrete, and warrants further investigation.

6. By preventing dehydration of an anti-icing chemical, a constant friction would be achieved.

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DISCLAIMER

Any opinions, findings, and conclusions or recommendations expressed in this publication are those of Forensic Dynamics Inc. and do not necessarily reflect the view of the Pacific Northwest Snowfighters Association (PNS).

This report is the result of an impartial approach used to evaluate the co-efficient of friction of anti-icing chemicals used in snow and ice removal. The report addresses the co-efficient of friction on a specially constructed tined concrete surface and may not be representative of actual frictional values on concrete roadway surfaces after chemical application.

The data presented are believed accurate and the analyses credible. The statements made and conclusions drawn regarding the product evaluations do not, however, amount to an endorsement or approval of any of the products in general or for any particular application.