Efficiency of runway de-icing chemicals in practice

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ABSTRACT

Solid urea was used over a decade as a de-icing chemical at the airports. Due to urea's negative impact on the environment, new chemicals were adopted to facilitate the anti-skid treatment. These new chemicals, acetates and formates, are currently widely used all over the world. One supporting thing for their use is that they have a wider temperature range (about -15 ºC) than urea, which is around -5 ºC. This could also be considered as a safety related property. The upcoming question is how we have managed to keep runways in a proper condition over a decade before these new chemicals.

Due to the well-known corrosion issues (significant safety magnitude) acetates and formates are causing to airplanes, the Finnish Air Force is now abandoning the use of these chemicals in Finland. Swedish Air Force has already abandoned the use of acetates and formates. New possible non-corrosive runway de-icing chemicals have been investigated in Finland. One very promising chemical is found to be betaine (trimethylglycine, manufactured in Finland by Danisco Animal Nutrition, patent [5]). Betaine's de-icing and corrosion properties have been investigated since 2003. After many different types of laboratory and field tests, betaine has now been used in two airfields in Finland during the last two winter seasons. In winter season 2007-2008 betaine is in use at three airports in Finland.

The laboratory test results indicated that the ice melting capacity of betaine is lower than that of acetates or formates. However, the results from the first field test encouraged to continue the research work. The runway surface friction (in Finland 0.40) is the most important requirement of the anti-skid treatment. The latest results from the analysis of practical use indicate that the demanded friction level could be easily achieved also by using betaine, and it is a reliable runway de-icing chemical as well. This is challenging the general understanding of the high ice melting capacity being the only criterion when listing chemicals in order of superiority.

1. INTRODUCTION

Solid urea was used over a decade as a de-icing chemical at the airports. Due to urea's negative impact on the environment, new chemicals were adopted to facilitate the anti-skid treatment. These new chemicals, acetates and formates, are now widely used all over the world. One supporting thing for their use is that they have a wider temperature range (somewhat -15 ºC) than urea, which is around -5 ºC. This could also be considered as a safety related property. The upcoming question is, how we have managed to keep runways in a proper condition over a decade before these new chemicals.

This article deals with the dilemma between the high theoretical melting capacity and the capacity which is needed in practice. The hypothesis of this dilemma comes from the successful use of urea: Before knowing acetates and formates, the aviation safety on runways was kept on a high level with the use of solid urea only. At the moment both types of chemicals, solid and liquid, are needed when giving anti-skid treatments to runways.

This article will show how significant research work a totally new de-icing chemical will need before it is ready for market. This new chemical is known as betaine (trimethylglysine), which is manufactured in Finland by Danisco Animal Nutrition. [5] The need for the new chemical comes from the aviation industry, where they are struggling with heavy corrosion in airplanes caused by acetates and formates. Aviation industry is now focusing more on corrosion inspection and prevention in their maintenance program.

Due to the well-known corrosion issues (significant safety magnitude) acetates and formates are causing in airplanes, the Finnish Air Force is now abandoning the use of these chemicals in Finland. Swedish Air Force has already abandoned the use of acetates and formates. New possible non-corrosive runway de-icing chemicals have been investigated in Finland. One very promising chemical is found to be betaine. Betaine's de-icing and corrosion properties have been investigated since 2003. After many different types of laboratory and field tests, betaine has now been used with success in two airfields in Finland during the previous two winter seasons. In this winter season (2007-2008) betaine is used in three airfields in Finland.

2. MELTING CAPACITY COMPARISON IN LABORATORY

Several laboratory tests were made to ensure the melting capacity of betaine. All the tests were made in the Laboratory of Highway Engineering of Helsinki University of Technology. [1] [2]

Betaine and other chemicals as reference were tested with well-known standardized tests, SHRP H-205.1 (plate test) and H-205.3 (penetration test). These tests are in general use in the aviation industry, and it is not important to introduce them in this article. The test series included a new type of test developed in the Laboratory of Highway Engineering. This test combines the plate test and the penetration test.

Normally, the practical anti-skid treatment (and especially de-icing) is done when the temperature is between 0…-5 °C. These tests were conducted at -2 and -6 °C. When analysing the de-icing efficiency of betaine in laboratory, the de-icing efficiency of potassium formate was concluded to be about double and that of solid sodium chloride about four times the de-icing efficiency of betaine (Figure 1). [2]

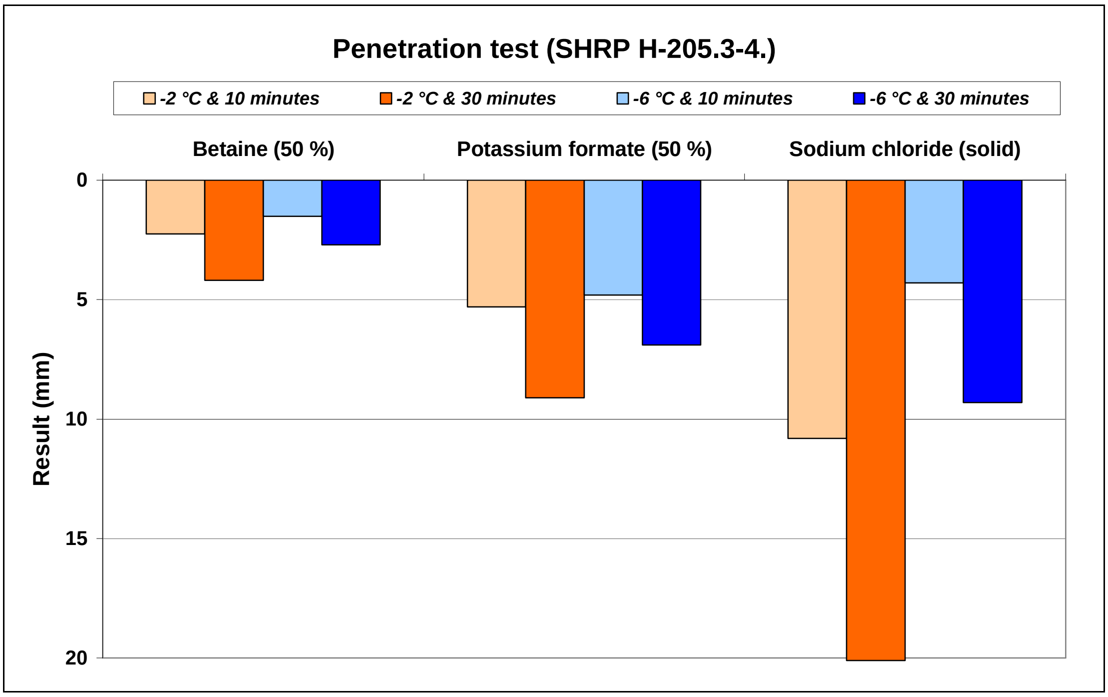

Figure 1 - Results of the penetration test made on betaine, potassium formate and sodium chloride.[1] [2]

3. RESULTS OF THE FIELD TESTS

Based on the results obtained from laboratory tests, it was decided to investigate the de-icing efficiency of these agents with field tests. These tests analysed how the ice thickness varies with different de-icers (de-icing capacity) and how the friction of icy asphalt surface varies under the influence of de-icers. In the tests measuring the de-icing efficiency, the de-icers were dispersed over ice 50 g/m^2, which in practical de-icing is the upper limit of the amount of agent applicable. According to laboratory tests, this amount of substance melts ice by only about 0.1 to 0.3 millimetres when the de-icing time is 30 minutes and the test temperature is about -6 °C. During the field tests, temperatures stayed in ranges from -5 to -7 °C. In the test the thickness of the ice was measured before spreading the agents and after 30 minutes of de-icing and brushing. The purpose of the brushing was to remove the de-icer from the ice surface in order to enable repeated testing on the same ice surface. Brushing did not reduce ice thickness. [3]

Based on the results of a field test measuring de-icing efficiency no differences were found between the de-icing efficiency of betaine and that of potassium formate, i.e. the results of the field tests correlate in no way with the results obtained from the laboratory tests. Figure 2 shows cumulative results of the field tests for different agents. The method of measuring the ice thickness was inaccurate, and for some measurements, the ice thickness had increased. However, enough measurements of ice thickness were gathered to facilitate statistical analysis of the results. The most important interpretation of Figure 2 is that in half of the measurements i.e. the mean change in ice thickness is about 0.5 mm for all agents. The achieved result is significant, since about twice the amount of ice had melted compared to theoretical values. In addition, betaine and potassium formate appear to have equal de-icing efficiency. [3]

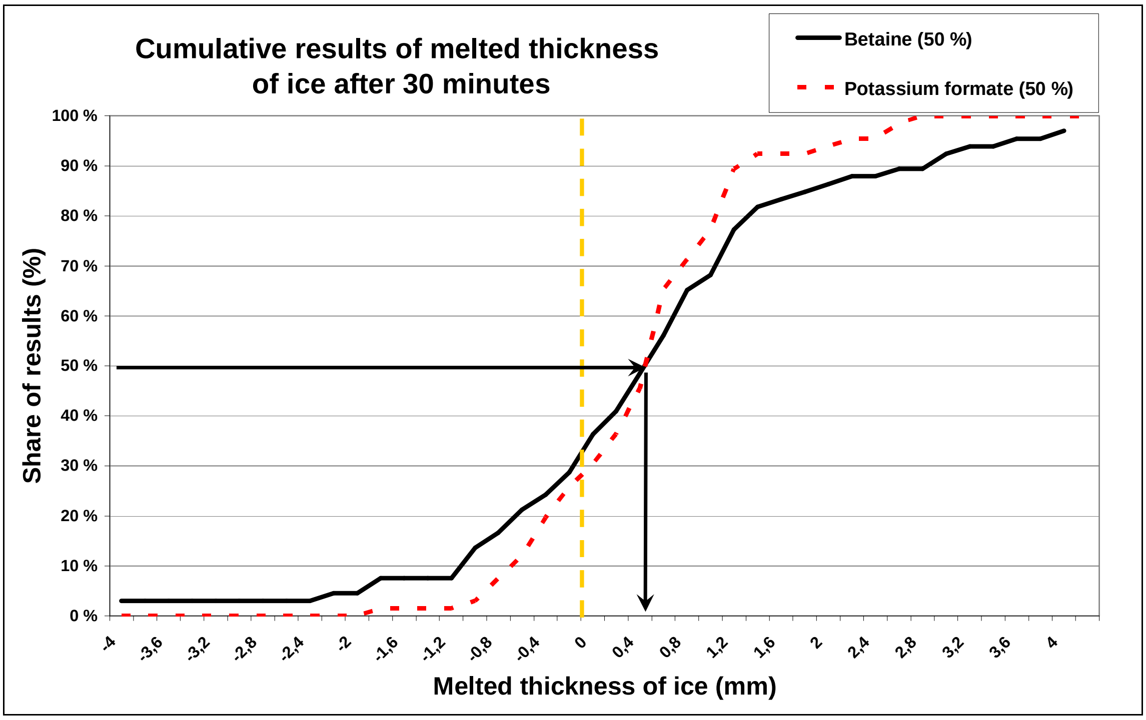

Figure 2 - Cumulative results of field tests measuring de-icing efficiency of different agents. No deviations were found in the efficiencies of these agents. [3]

Another field test was also performed on these agents to establish whether any differences could be seen in the runway friction values between different substances. The minimum friction value of airfield runways is 0.4, and if falling below this value, de-icing measures must be taken. These friction tests did not result either in any differences between betaine and potassium formate (Figure 3). [3]

The betaine was tested in the winter season of 2004–2005. Then potassium formate was used as a reference agent. The purpose of the test use was to carry out regular de-icing arrangements on airfield taxiways with the agents. The functionality of the agents was defined based on experience and using friction measurements. Both chemical passed the friction requirement level. [3]

Based on the results from the field tests, betaine and potassium formate show no differences in de-icing efficiency. These test results brought up the problem: Do laboratory tests describe the actual operating efficiency of de-icers, or is it necessary to establish the de-icing efficiency of these agents outdoors in as natural conditions as possible? If the efficiency of an applicable de-icer is evaluated by laboratory tests, what is the threshold value of de-icing efficiency that - when being exceeded - the product can be considered efficient enough? Literature has no reference to the threshold value of sufficient efficiency and, based on this research, inserting such value to current laboratory tests is questionable. Can it be deduced that this research makes the reliability and the significance of the results of laboratory tests uncertain compared to the practical de-icing activity?

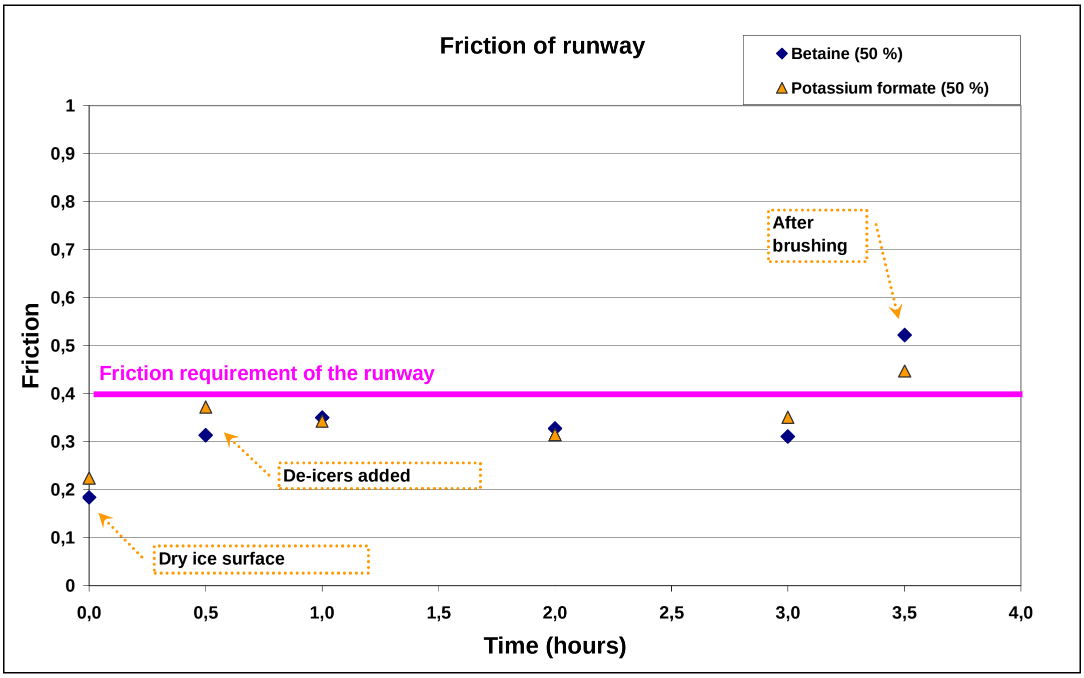

Figure 3 - Friction test results. The effect of brushing on friction is clearly visible in the results. However, no differences between these agents were recognized; both chemicals passed the requirement. [3]

4. USING BETAINE IN TWO AIRFIELDS – ANALYSIS OF PRACTICAL USE

When the field test results were published in 2004, the Finnish Air Force was struggling with heavy corrosion problems especially with their Hawk fleet. Corrosion was clearly caused by acetates and formates which were used in every airfield in Finland. The Finnish Air Force was informed of this totally new chemical, betaine, and they took interest in it. After negotiations with Finavia (former Finnish Civil Aviation Administration, managing airports), two airfields in Finland started to use betaine as their anti-skid treatment chemical in the autumn of 2005. These two airfields were Tampere-Pirkkala (civil & military) and Kauhava (military), which are both located in the Central Finland. [4]

Since this was the first time to use betaine in practice, the airport management personnel were advised to be on the alert. Consequently, this was the first and unique event to investigate the performance of betaine in practice. All the runway friction measurements and inspections were made with caution and the management personnel were informed to retain a special diary of the use of betaine. [4]

Based on these measurements and observations the Laboratory of Highway Engineering made an analysis research of the usefulness of betaine as a de-icing chemical. Data from the use of urea (years 1993-1999) in these two airfields were also included in this research project. [4]

The data was divided in four different temperature areas (+2…-2, -2,1…-4, -4,1…-6 and under -6 °C), since more than a half of the anti-skid treatments in Finland is being performed, when the temperature is between +2…-2 °C. The research included a total of 134 anti-skid treatments, and 76 of these belonged to the warmest temperature area (Figure 4). [4]

Results show that betaine is working well as a de-icing agent. Figure 5 shows the results in temperature area +2…-2 °C. Results include 95 % confidence intervals (black line bars). The lowest bar of each chemical group indicates the friction level when the runway is slippery, the bar in the middle indicates the friction level after anti-skid treatment and the upmost bar indicates long-term durability of the situation. When reading Figure 5, exact results should not be taken literally – conditions are not comparable between each treatment and chemical. Therefore the following conclusions could only be made with certain accuracy.

The friction level before anti-skid treatment is about the same with each chemical (betaine, formate or acetate and urea; Figure 5). When using betaine the friction level increases some 30 units (from 30 to 60 - from blue bar to yellow bar) and when using formate or acetate the increase is some 40 and with urea the increase is around 25 units. [4]

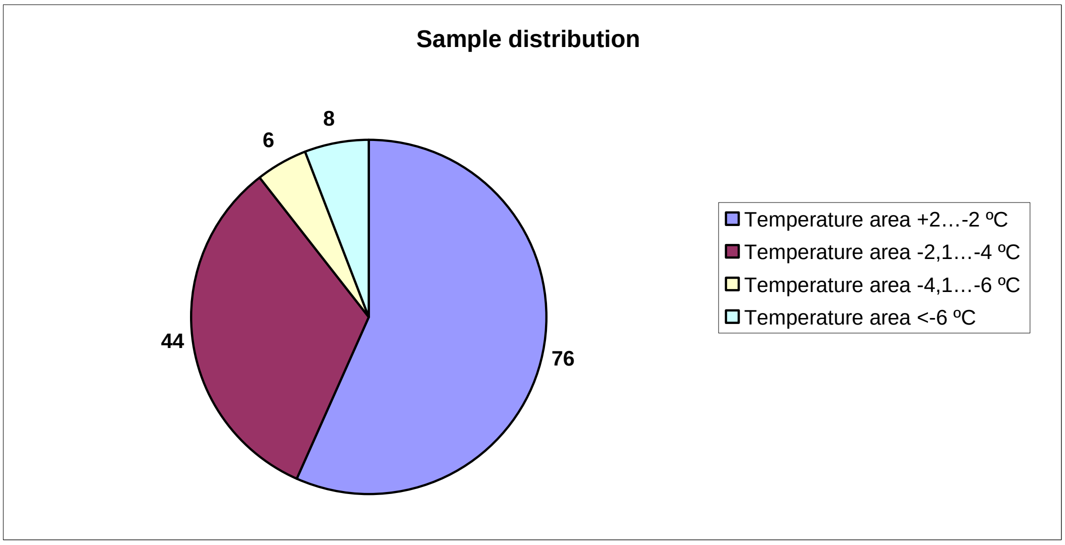

Figure 4 – Sample distribution in different temperature areas. [4]

Requirement of acceptable friction of runway is 40 (or 0,40) in Finland. With all these three chemicals, the requirement is clearly passed (Figure 5), when the temperature is around zero degrees of Celsius, which is the most important and most general temperature for anti-skid treatment. But, on the other hand, when comparing laboratory results of betaine and formate to these friction results, it seems that even though the melting efficiency of formates is about double compared to that of betaine; the same kind of difference could not be seen in the friction results. What is the point of high melting capacity in practice?

Some statistical analysis was also performed of the data. Results show (T-test) that formates and acetates are working rather better than betaine and urea. And betaine's performance is better than that of urea. Different statistical tests show that the probability of a successful anti-skid treatment (when the required friction level is passed) is 99.9994 % when using urea, with betaine it is 99.99995 % and with formate or acetate 99.9999994 %. These values are remarkably high, and it could be said that it is very safe to use these chemicals for anti-skid treatments on runways. [4]

The airport maintenance personnel have also been satisfied with the performance of betaine. Certainly, when starting to use a totally new chemical, the personnel has to learn how this chemical acts on the runway. It was the same, when acetates or formates came to the market.

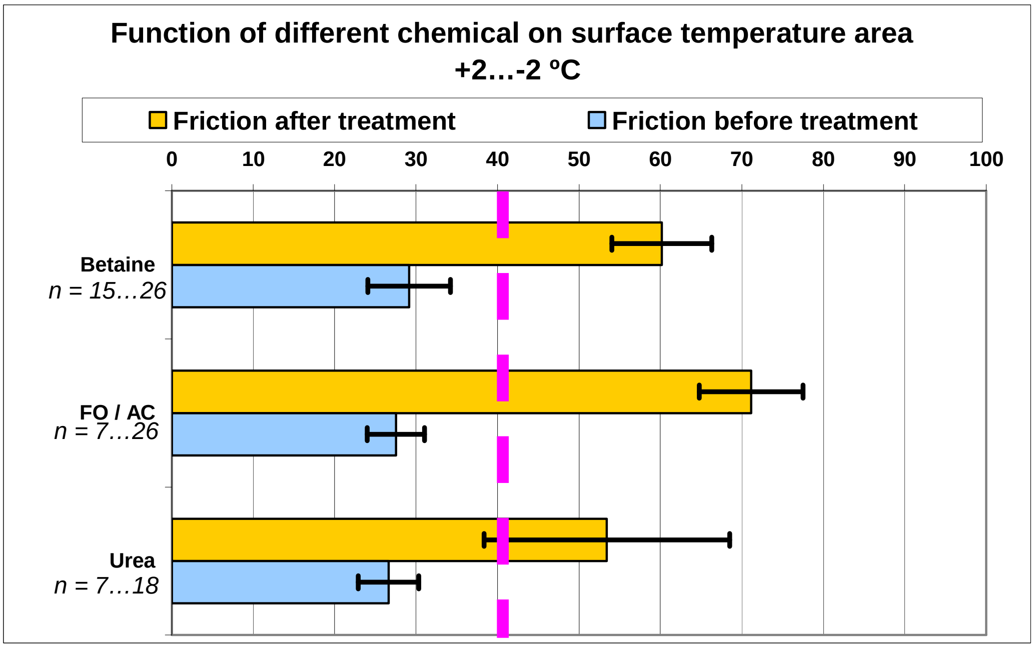

Figure 5 – Friction levels with 95 % confidence intervals of different chemicals when anti-skid treatment is being performed. Friction requirement of the runway is 40 in Finland. [4]

5. CONCLUSIONS

Before acetates and formates, urea was used as an anti-icing or de-icing chemical on runways. Due to urea's negative impact on the environment, new chemicals were adopted about ten years ago to facilitate the anti-skid treatment. These new chemicals, acetates and formates, are now widely used all over the world. Due to the well-known corrosion issues (significant safety magnitude) acetates and formates are causing to airplanes, a totally new and non-corrosive chemical was clearly needed.

This article deals with the dilemma between the high ice melting efficiency and the needed practical efficiency. This question arose, when this totally new de-icing chemical, betaine, and its practical properties were being investigated. Betaine (trimethylglysine, [5]), which is manufactured in Finland by Danisco Animal Nutrition, has been found to be a non-corrosive chemical, but its ice melting efficiency (in the laboratory) is not on the same level as that of acetates or formates.

After several laboratory and field tests, betaine has now been used successfully in two Finnish airfields for three winter seasons. Results of practice data analysis show that although betaine has lower ice melting efficiency than acetates or formates, it can easily function as a de-icing chemical in practice. The same conclusion holds true also for urea. So, what explains that the high ice melting efficiency is the only property required of a good de-icing chemical?

It is very strange that chemical users do not focus on the corrosion properties of the chemical, although several aviation accidents have taken place due to corrosion issues. For the safety of the aviation, corrosion properties should have a more important role than the ice melting efficiency of the chemical.

REFERENCES

1. Alatyppö V. & Valtonen J. Testing and comparing ice melting effectiveness of different de-icers. Vol T127. pp 41. Helsinki University of Technology. Laboratory of Highway Engineering. Helsinki. 2003

2. Alatyppö V. & Valtonen J. Testing ice melting effectiveness of Betafrost-deicer. Vol T132 & 133. pp 35&34. Helsinki University of Technology. Laboratory of Highway Engineering. Helsinki. 2003.

3. Alatyppö V. & Valtonen J. Field test of ice melting effectiveness of Betafrost-deicer. Vol T138 & 143. pp 54 & 13. Helsinki University of Technology. Laboratory of Highway Engineering. Helsinki. 2004.

4. Alatyppö V. De-icing efficiency of betaine in practice – experiments from two winter seasons. Vol T184. pp 17. Helsinki University of Technology. Laboratory of Highway Engineering. Helsinki. 2007.

5. Koskinen J. et al. Patent EP 1034231. Method for the regeneration of aqueous liquids containing trimethyl glycine. 2006.