Executive Summary

Evaluation of Safecote de-icer (Phases 1 and 2)

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(Phases 1 and 2)

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The Highway Agency's Environmental Strategy for England's Main Roads (HA, 1998) and the UK Environment Agency's policy encourage best practice and the use of products that reduce the input of pollutants such as chloride into the natural environment. The use of more environmentally friendly de-icer products could also help to provide a cost-effective solution to mitigate structural damage.

Safecote Ltd, a UK-based de-icer company, has introduced a new de-icer product (Safecote) based upon extensive experience of application in the USA, which has the potential to help reduce chemical contamination of the environment. In 2000, TRL Limited was commissioned to investigate the effect of this de-icer product as an additive or pre-wetting agent for salt products. As a pre-wetting agent to salt, the primary aims are to reduce the chloride component of the treatment in order to mitigate against the damaging effects of salt and to reduce the level of damage that occurs to both concrete and steel when chloride-based de-icers are used for winter maintenance.

The study was carried out in the two Phases and the findings have been reported.

Phase 1

- Freeze/thaw damage to concrete (TRL Report PR/IS/86/2000)
- Skid resistance and binder stripping of asphalt surfacings (TRL Report PR/IS/87/2000)
- Corrosion of steel and aluminium coupons (TRL Report PR/IS/88/2000)
- Environmental impact (TRL Report PR/IS/89/2000).

Phase 2 - (TRL Report PR/IS/13/02)

- Freezing Point Temperature (FPT) depression.
- Environmental assessment – highway runoff and leaching.
- Skid resistance of asphalt surfacings.
- Application and spreading characteristics.
- Ice melt, ice penetration and ice undercutting.

This report summarises the findings from the two Phases of the study. For further details, it is necessary to refer to the individual reports as indicated above.

2 DE-ICING FORMULATIONS

In general the following formulations were evaluated but, at the request of the client, not all the formulations were considered in every phase of the work.

S1 – Safecote added as a pre-wetting agent/admixture to solid rock salt (NaCl). 33.3litres of Safecote to 1000kg of rock salt.

S2 - Safecote added as a pre-wetting agent/admixture to rock salt (NaCl). 22.2 litres of Safecote to 1000kg of rock salt.

C32 – A Safecote/Calcium Chloride de-icing liquid. A 32% solution of Calcium Chloride ($CaCl_2$) (by weight) added to Safecote in a 1:1 ratio (by volume).

M30 - A Safecote/Magnesium Chloride ($MgCl_2$) de-icing liquid.

A 30% solution of Magnesium Chloride (by weight) added to Safecote in a 1:1 ratio (by volume).

Safecote – The undiluted product

Also, where requested by the client, they were compared to the effects of various other de-icers which included rock salt, Urea, ApClear KA1 (Potassium Acetate), Ethylene Glycol, Pre-wetted salt (Rock salt with a Calcium Chloride pre-wetting agent) and Magnesium Chloride.

3 SUMMARY OF THE RESULTS

3.1 FREEZE/THAW DAMAGE TO CONCRETE

The effect of the M30 and C32 formulations on the level of freeze/thaw damage to concrete mixes was assessed and compared to the effect of rock salt. The tests were carried out on two types of Pavement Quality Concrete (PQC), one for use on highways and one for use at airports using the test method given in prEN 1338 (BSI, 1993).

After a 28-day period of 24-hour freeze/thaw cycles using five per cent solutions of the various de-icers, the specimens were assessed visually and by collection of loose material from the concrete test surface. The Safecote based formulations cause no visual damage to either of the concrete mixes whereas damage was caused by rock salt. Loose material was collected from the surface of the majority of the specimens, but in the case of M30 and C32 it did not appear to be concrete.

3.2 SKID RESISTANCE AND BINDER STRIPPING OF ASPHALT SURFACINGS

In Phase 1, the effect on the skid resistance of asphalt surfacing materials was investigated using a Portable Skid Resistance Tester. Two different materials were used - a fine-textured and an open-textured asphalt surfacing, and the effects of the de-icers were evaluated for a range of concentrations.

At all the concentrations tested, the S1 formulation had no detrimental effect on the Skid Resistance Value (SRV) but the undiluted C32 and M30 formulations reduced the SRV. As a consequence, their use may not be suitable as a precautionary de-icer on surfaces close to the minimum permitted skid resistance. Their use might be acceptable where immediate dilution of the product can be expected (i.e. when used on snow and ice already present on the road surface) or on surfaces with an SRV well above the minimum permitted skid resistance.

In Phase 2, skid resistance tests were carried out using the S2 formulation. The effective skid resistance of the S2 formulation was compared to rock salt on the same test surface using the TRL SCRIM machine (British Standards Institution, 1999). S2 formulation and salt (grade 6.3mm) were applied with a typical spreader at rates of $10g/m^2$ and $20g/m^2$.

Under dry conditions, consistent high values were obtained for the S2 formulation and for rock salt at both spread rates. The S1 and S2 formulations showed no detrimental effect on the skid resistance of the road surfaces tested.

Tests in Phase 1 were undertaken to investigate whether or not the S1 formulation would lead to binder stripping of the aggregate in asphalt surfacing materials. The method employed was as given in MoD Specification 040, Appendix B (Defence Estate Organisation, 1998). There was no evidence of binder stripping for the aggregate/binder combination tested.

3.3 CORROSION OF STEEL AND ALUMINIUM COUPONS

The effect of a range of Safecote and non Safecote-based de-icing chemicals on the corrosion of steel and aluminium coupons was investigated using a modified version of the neutral salt spray test as given in BS 7479 (BSI, 1991).

Under the test conditions employed, the M30 Safecote-based de-icing formulation caused less corrosion on mild steel samples than all the other de-icing chemicals that were tested. The C32 formulation was marginally worse, but was still less corrosive than the remainder. The S1 formulation only caused 55 per cent of the corrosion seen with rock salt and was approximately comparable with ApClear KA1 and Urea. As a further comparison, pre-wetted salt caused 127 per cent of the corrosion seen with rock salt alone.

In the case of the aluminium samples, Safecote caused significantly less corrosion than the rock salt. It did cause slightly more corrosion than ApClear KA1, but the difference was minimal. Pre-wetted salt was not tested on aluminium samples.

3.4 FREEZING POINT TEMPERATURE (FPT) DEPRESSION

Tests were undertaken in a climate chamber to determine the FPT depression of an S2 formulation as a de-icer. The S2 formulation was compared with solutions of rock salt, a 23.3 per cent saturated solution of brine, undiluted Safecote and Safecote with brine. De-ionised water was used as a control. The test data were transformed into graphs of cooling curves. At other points on the curves, the data were extrapolated to obtain the FPTs.

The results showed that for 3 per cent and 5 per cent solutions of the S2 formulation, the FPTs were at least as good as rock salt alone. There is no evidence however that the addition of Safecote improves the FPT.

3.5 ENVIRONMENTAL IMPACT

Based on the chemical analysis of the Safecote product and information supplied by the client an assessment of the environmental effects of using Safecote-based de-icers was carried out.

In Phase 1, it was determined that the Safecote product has a high Biological Oxygen Demand (BOD), appreciable amounts of various heavy metals and may have a high Phosphorus content. As a consequence, the use of large amounts of Safecote over a winter maintenance period could have significant negative impact on the environment. However, Safecote is primarily intended for use in conjunction with rock salt or other de-icers for UK highway applications. Therefore, to determine the overall environmental effect of using a Safecote-based de-icer, further evaluation was carried out in Phase 2.

3.5.1 Highway runoff

Guidelines from the Design Manual for Roads and Bridges (Department of Transport, 1998) suggest a basic methodology for calculating dilution factors and subsequent contribution as a concentration to the downstream watercourse. Calculations were made for two theoretical Scenarios – A and B, for a stream along a 1km length of carriageway comprising four lanes with no camber. Scenario A had high dilution, a high runoff rate and rapid discharge into watercourses and Scenario B had low dilution, less precipitation and a smaller runoff rate.

The S2 formulation complies with the UK Water Quality Standard and the current UK Environment Agency Standards for highway runoff for heavy metals and other chemicals.

The results showed that, as an additive to rock salt, Safecote is likely to be far less damaging to the environment than rock salt alone. Safecote may be best suited to highway de-icing when used at a recommended application ratio of 3 per cent weight for weight to rock salt.

3.5.2 Leaching

The addition of Safecote to salt should not be a leachate problem at highway depots that are adhering to environmental standards for storage facilities and proper management of stockpiles.

3.6 APPLICATION AND SPREADING CHARACTERISTICS

Spreading trials were carried out to compare the performance of the S2 formulation with virgin 6.3mm rock salt in order to assess whether the addition of Safecote to rock salt enhances the spreading performance and whether it improves the distribution of rock salt into the desired target spread area.

Spreading trials of the S2 formulation compared with virgin 6.3mm rock salt were undertaken using a Foden dual spinner spreader at the TRL Research Track. The experiment comprised eight runs at 50km/h along a simulated 3-lane motorway in accordance with BS 1622 (British Standards Institution, 1989). This combination was designed to deliver salt to three lanes and the hard shoulder. The S2 formulation (ratio of 22.2 litres per tonne of rock salt) was applied at spread rates of $10g/m^2$ and $20g/m^2$.

The mean results of the $10g/m^2$ spread showed that more salt was spread into the target zone with the S2 formulation than with rock salt. The target spread was achieved in most of the hard shoulder, lanes 1 and 2 and the nearside of lane 3. Under spreading occurred in lane 3 although this was also true for rock salt. Over spreading beyond the target zone also occurred but this was less for the S2 formulation than the rock salt suggesting that the addition of Safecote to rock salt gives improved salt control. The mean results of the $20g/m^2$ spread indicated that the S2 formulation gave similar improved performance in the target area.

Environmental concerns might be raised with respect to the spread of grains beyond the hard shoulder and lane 3 into the verge and central reservation, especially for rock salt alone. It is thought however that the spread patterns observed during the tests reported here are likely to be a function of the particular spreader employed and hence not necessarily typical of all spreaders.

Dry spreading normally results in longitudinal snaking effects with non-uniform spread patterns whereas pre-wetted salt spreading normally tends to reduce this effect. The addition of the S2 formulation to the rock salt also reduced the longitudinal snaking effect.

3.7 SHRP TESTS – ICE MELT, ICE PENETRATION AND ICE UNDERCUTTING

The S2 formulation was tested against the Strategic Highway Research Program (SHRP) methods for evaluating chemical and solid de-icers (SHRP, 1992). The S2 formulation was dissolved in de-mineralised water to give a 25 per cent solution by weight. For comparison, the same tests were also carried out on 25 per cent solution of dry rock salt.

The following SHRP set of tests were specified for the S2 formulation and rock salt:

SHRP H-205. I Test method for ice melting of solid de-icing chemicals
SHRP H-205.3 Test method for ice penetration of solid deicing chemicals
SHRP H-205.5 Test method for ice undercutting by solid deicing chemicals

The results of the tests have shown that similar properties are demonstrated by both products in an initial 30 minute period during the ice melt and ice penetration processes for the solutions tested at the test temperatures of -2°C, -6°C and -10°C. However, the S2 formulation is slightly more effective than salt over the one-hour test period.

The S2 formulation is slightly more effective in the ice undercutting process at test temperatures of -2°C, -6°C and -10°C than rock salt for the solution concentrations tested.

4 CONCLUSIONS

With its good corrosion inhibitor properties, its non-stripping properties of binders from asphalt surfacings and its reduced concrete spalling to structures compared to rock salt, Safecote has the potential to be used as a pre-wetting agent for wetted salt treatments. Hence, this could reduce the adverse effects on the environment and transport structures and the quantity of salt used.

5 RECOMMENDATIONS

A cost benefit analysis for the use of Safecote formulations should be carried out to determine whether real monetary gains could be realised for the de-icing of UK roads. This is particularly relevant in demonstrating the 'holdover' times of Safecote formulations in order to reduce the number of applications required.

The long-term benefits offered by Safecote formulations to the environment, through reduced chloride content, should be compared to salt products. The component benefits to highway runoff, soil contamination, corrosion of steel reinforcement and aluminium and spalling of concrete structures should be fully quantified.

The long-term cost reduction as a consequence of mitigation of infrastructure damage due to chloride attack, although clear from the test results of concrete, asphalt and corrosion damage mitigation, cannot be financially quantified at this stage and will vary according to regional infrastructure characteristics and climatic conditions. It is therefore recommended that winter maintenance practitioners take a view as to how they might quantify the possible benefits based on their own operational experience, and the type and nature of their infrastructure assets.

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