



ROADEX III
NORTHERN PERIPHERY



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Treatment of Moisture Susceptible Aggregates

Executive Summary

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EXECUTIVE SUMMARY
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PREFACE

The report that follows is an executive summary of the 2005 ROADEX II report "Material Treatment" by Pauli Kolisoja and Nuutti Vuorimies of Tampere University of Technology.

It aims to be a working manual, concentrating on the testing methods and practices that should be carried out for low volume roads suffering from moisture susceptible material problems related to seasonal changes, especially spring thaw weakening.

The report is not intended to replace the reference works available on the subject but it is hoped that the summaries outlined will give the reader a greater understanding of the issues and solutions for this problem.

The report was written by Nuutti Vuorimies and Pauli Kolisoja from Tampere University of Technology, Finland. Sanni Pitkäranta from Tampere University of Technology translated it into English. Ron Munro, project manager of the Roadex III Project, checked the language. Mika Pyhähuhta of Laboratorio Uleåborg designed the report layout.

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Chapter 1. Introduction

1.1 THE ROADEX PROJECT

The ROADEX Project is a technical co-operation between roads organisations across northern Europe that aims to share roads related information and research between the partners.

The Project was started in 1998 as a 3 year pilot co-operation between the roads districts of Finnish Lapland, Troms County of Norway, the Northern Region of Sweden and The Highland Council of Scotland and this was later followed up with a second project, ROADEX II, from 2002 to 2005.

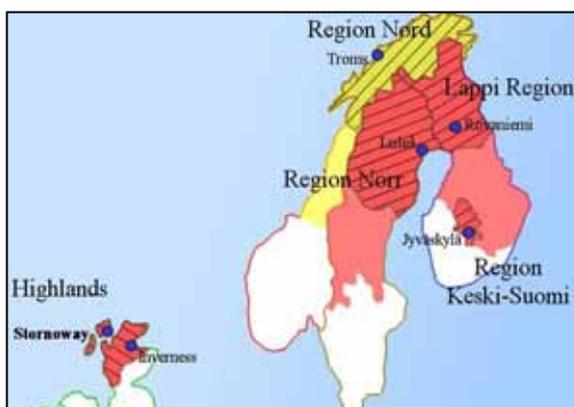


Figure 1: The Northern Periphery Area and Roadex II partners

The partners in the ROADEX II Project comprised public road administrations, forestry organisations, forest companies and haulage organizations from regions in the Northern Periphery. These were The Highland Council, Forest Enterprise & The Western Isles Council from Scotland. The Region Nord of The Norwegian Public Roads Administration and The Norwegian Road Haulage Association, The Northern Region of The Swedish Road Administration and The Lappi and Keski-Suomi Regions of The Finnish National Roads Administration. (These latter Finnish Regions also received aid from their local forest industry organisations of Metsähallitus, Lapin Metsäkeskus, Metsäliitto & Stora-Enso.)

The goal of the project was to develop ways for interactive and innovative road condition management of low traffic volume roads integrating the needs of local industry, society and roads organisations. Eight formal reports were published together with a project DVD and full copies of all reports are available for download at the ROADEX web site at www.roadex.org.

This Executive Summary report is one of 8 summaries that have been prepared under the direction of the ROADEX III project (2006-2007), a new Project where the named project Partners above were joined by the additional Northern Periphery Partners of the Municipality of Sisimiut, Greenland, The Iceland Public Roads Administration and the Finnish Road Administration Region of Savo-Karjala.

1.2 TREATMENT OF MOISTURE SUSCEPTIBLE AGGREGATES

Seasonal changes and freeze-thaw cycles are the most significant factors that contribute to the loss of bearing capacity of moisture susceptible materials in cold climates. The deterioration is caused by excess water that has accumulated in the road structure and cannot escape from the layers as the structure thaws. As a result, the road may quickly be damaged by heavy traffic.

Material treatment of the road structure can be used to keep water away from the moisture susceptible materials. If water is scarce in the structural layer before and during the freezing period, the layer does not usually create ice lenses. Even during the thawing period in the spring the layer will work as designed and spread the load across a wider area so that the road will have a better durability against traffic loads.

Traditional stabilisers, such as bitumen and cement, are generally used to make a significant improvement to the strength and stiffness of the treated layers. However, these techniques require large quantities of stabilisation agents to be used and thus the treatment methods are usually uneconomical on low volume roads. New types of stabilisation agents have been developed to reduce the moisture susceptibility and to improve the low bearing capacities due to seasonal changes. These new agents, usually called non-traditional stabilisation agents, are aimed for road materials whose bearing capacity and strength are sufficient, except for the short-term, but nevertheless significant, losses of bearing capacity related to seasonal changes.

This report concentrates in presenting the types of information and investigations that are needed when using stabilisation agents to reduce the moisture susceptibility of the materials in the structural layers of the road. An essential part of the report is to clarify and even simplify the process of how information can be used and utilized. Since the research project concentrates primarily on low volume roads in the Northern Periphery of the European Union, the report aims to focus on cost-effective investigation and information gathering methods.

When reading the report one should bear in mind that a complex combination of factors affects the water flow and its impact in different aggregates and weather conditions. The mixing of stabilisation agents will complicate the situation so that they may be used in inappropriate places if their combined behaviour is not known well enough. Especially important is research on non-traditional stabilisation agents since until now there is no reliable information available about their long-term performance in road structures.

This report is based on Roadex II project report "Material Treatment" (Kolisoja and Vuorimies 2005) and on a Finnish report on new material treatment techniques for unbound, moisture susceptible road materials "Sitomattomien väylämateriaalien

kosteustilaherkkyttä vähentävät uudet käsittelytekniikat” (Vuorimies and Kolisoja 2005) which is a report from a project mainly financed by Tekes (Finnish Funding Agency for Technology and Innovation). Test experiences from the Finnish Road Administration’s strategic research project S14 in 2006 have also provided information to this report.



Figure 1.2. Treatment of wearing/base course with a stabilisation agent

Chapter 2. Treatment of Moisture Susceptible Aggregates – Short Description

2.1 TRADITIONAL STABILISATION AGENTS

Bitumen and cement are the most common stabilisation agents for bearing capacity improvements on road structures. Bitumen has also been used for the material treatment of moisture susceptible materials in the areas of seasonal frost. For traditional stabilisation agents there are generally reliable guidelines, based on long-term experience and research. In Finland the Road Administration's Stabilisation Instructions have been in test use since 2002. In addition to bitumen and cement the Stabilisation Instructions also cover the use of blast furnace slag and combined products in the stabilisation process. In combined stabilisation two or more binding agents are used to combine the good properties of both soft and hard binding agents (Finnish Road Administration 2002).

On low volume roads the use of traditional stabilisation agents is usually hindered by its high cost. Furthermore, in cold areas they can only be used for materials with a maximum 12% fines content.

2.2 NON-TRADITIONAL STABILISATION AGENTS

There is no established classification for non-traditional stabilisation agents. The Roadex II subproject "Material Treatment" describes new treatment agents and their influence mechanisms. In this section the new techniques are presented only briefly. In most cases the non-traditional stabilisation agents can be categorized into one of the following five classes:

- 1) polymers
- 2) enzymes
- 3) ionic treatment agents
- 4) lignins and
- 5) resins

Polymers are available in several different types. Some of the most efficient new stabilisation agents for coarse grained moisture susceptible road materials are polymers. Most of the polymer products are in the form of emulsion but there are also powdered polymers available.

Enzymes and ionic treatment agents work well for materials with a high fines content. Therefore they are unlikely to be applicable for the treatment of coarse grained materials in cold climate countries where a low fines content of the road aggregates is pursued.

Lignins are often by-products from the forest industry and, due to their biodegradability, they have mainly been used as dust suppressants. Resins are usually made of natural products or oils and thus they normally have only short-term effects. On the other hand, with oil resins a small risk of environmental contamination does exist.



Figure 2.1. Different stabilisation agents.

Chapter 3. Gathering Information to Assess the Effectiveness of the Treatment

3.1 BASIC ROAD INFORMATION

Every road has its history and road improvements or repairs always have a cause. If the road construction and maintenance processes are well-documented and properly stored, it is possible to acquire valuable information about the materials that were used or planned to be used in the road structure, and also about the sites that have been repaired. If no information is to be found in the archives, experienced workers or local residents can be interviewed. With supplementary research made, e.g. by using a ground penetrating radar, the basic road information can be updated before the repair.

The following basic information categories are helpful in evaluating whether the material treatment of the structural layers is useful in improving the road performance:

- the thicknesses of the structural layers
- the materials used in road construction
- previous repair procedures
- previous maintenance procedures
- damages observed on the road
- the condition of the ditches and the distance of free water from the road structures
- the amount of (especially heavy) traffic
- previous experience from similar materials
- availability of suitable equipment for the treatment of road materials

The evaluation also requires information or prognoses about factors that may limit the use of some repair techniques. The following questions will reveal the most essential aspects for method or treatment agent selection:

- how important is the road and how large is the traffic load?
- will the road be paved?
- how large is the budget?

Based on these facts it should be possible to make an evaluation of whether the material treatment of the structural layers is sensible. It should be remembered, however, that the amount and precision of the information may vary significantly from

one case to another. At the same time it should be estimated how sampling and other studies can benefit the future repairs.

3.2 SAMPLING FOR LABORATORY TESTS

The amount and location of samples should be carefully considered before the actual sampling. The material used in the structural layers may vary according to changes in construction dates or extraction sites. In this case samples should be taken from several points. The amount of sampling points and their distances from one another should be determined by the length of the road to be treated and by the reliability of previously gathered basic information. It is recommended that samples be taken from at least 2-4 points from each layer to be treated. It can then be visually estimated if the samples from different places are of the same material. The samples should be placed in a plastic bag or box so that water cannot evaporate during transportation.

Today it is natural to register the layer thicknesses observed in sampling points by taking at least one good picture, for example with a digital camera, to back up the memory and observations.

Enough sample material should be taken from the analysed layer in the first place. The minimum amount is about 80 kg of each material. If laboratory tests are taken in order to compare several different stabilisation agents or other alternative improvement solutions, the amount of sample material has to be increased.

3.3 LABORATORY TESTS FOR UNTREATED MATERIALS

Enough time should always be reserved for laboratory tests since some of them require long testing times. Ideally the laboratory tests for untreated materials should be performed in three stages if the design schedule allows it. This is especially important when it is uncertain that the road damage is caused by moisture susceptibility problems.

The basic idea in the first stage is to run the most simple and cost effective tests first. These results will be useful in designing the road repair. Based on the first stage tests a preliminary estimation of the moisture susceptibility of the analysed material can also be made. The first stage laboratory tests consist of determinations of:

- water content
- the particle size distribution curve, and
- organic material content

The uniformity of different road structures and the homogeneity of road materials can be estimated from water content values from different points in the road. The particle

size distribution should be carried out by wet sieving. If the fines content in the wet sieving is 10% or higher, the particle size distribution of the fines should also be determined. The fines content and the shape of the particle size distribution curve will have an influence on what treatment agents can be used. When producing the particle size distribution curve it is usual to determine the organic material content as well. High organic material content can cause moisture susceptibility which may influence the treatment agent selection.

The second stage laboratory tests verify the moisture susceptibility of the material using the Tube Suction test. The test is usually done for materials smaller than 20 mm maximum grain size. A more detailed description of the test method is given in the report by Saarenketo (2000) and in the test method description by Texas Department of Transportation (2003). In Tube Suction tests the bottom of the dried sample is placed in distilled water. Dielectricity and conductivity are then measured in relation to time with a measuring device from the top of the sample. The magnitude and growth rate of the dielectric value will reveal how much and how fast water rises to the top of the sample by capillary forces. A classification of unbound granular materials based on dielectric values is given in Table 3.1 according to Saarenketo (2000). Some examples of Tube Suction test results are given in the Roadex II project report "Material Treatment".

Table 3.1. Quality classification of unbound granular materials based on Tube Suction test results (Saarenketo 2000).

Dielectric value	CLASSIFICATION
< 10	Good-quality base course material
10-16	Questionable as base course material
> 16	Inappropriate as base course material

In Finland the dielectric value 9 has also been used as the maximum value in classifications of good quality base course material.

In the second stage the determination of the specific surface area and the water adsorption index will help in finding out why the material is performing poorly and the results will probably verify the Tube Suction test results. Specific surface area indicates the amount of surface area in the fines. The larger it is, the higher is the likelihood of water retention on the material particles. The water adsorption index indicates the ability of the fines to bind moisture on the surface of the particles in 100% relative air humidity, so it is also an indicator of how active the interaction is between the material and water. If the fines content is small (less than 4%) and the water adsorption index modest, it is very unlikely that the analysed material is moisture susceptible or the cause of road damages. When interpreting the test results, it should be kept in mind that the samples from the road structures may have traces of, for example, dust suppressant salts.

If the first two stages of laboratory testing indicate that the material is moisture susceptible and material treatment with stabilisation agents is possible, the third stage should consist of performing a Proctor test on the untreated material. The Proctor test gives an indication of the compatibility of the material with varying water contents and the best compaction occurs with optimum water content. Compaction and mixing of most treatment agents on site are carried out near the optimum water content of the material, and for this reason Proctor tests give important preliminary information for materials to be treated with stabilisation agents.

3.4 INFORMATION ON NON-TRADITIONAL STABILISATION AGENTS

Preliminary information on the suitability of various types of non-traditional stabilisation agents can best be obtained from the suppliers. Generally the range of the particle size distribution curve, or at least the suitable fines content for the stabilisation agent, is known. The material safety data sheet should also be requested in order for information on the transport, handling and storage of the stabilisation agent. This document will also indicate if the stabilisation agent contains potentially hazardous substances.

The requirements for weather conditions for the work on site and any traffic limitations after compaction should be identified at this time.

With the above information, together with the delivered costs of the possible treatment agents and any published research, it should be possible to limit the number of candidate stabilisation agents down to a few 'most promising' products for laboratory testing.

3.5 LABORATORY TESTS FOR MATERIALS TREATED WITH NON-TRADITIONAL STABILISATION AGENTS

The suitability of the treatment agent for the planned work should be verified with laboratory tests and, in this, the most appropriate method to compare the benefits of the treatment agent is through Tube Suction tests on both untreated and treated samples. In the base course the Tube Suction test dielectric value should be as small as recommended for a good quality base course aggregate in Table 3.1. This can be further supplemented by a frost heave test to check that frost heave does not occur in the treated material. It is essential in these tests that the tests are carried out on test samples with dry density values that can be achieved on site.

There are no long-term experiences at present on using Tube Suction test results for the planning of non-traditional stabilisations in cold climates where materials have been subjected to prolonged freezing and several freeze-thaw cycles. Because of this it has to be kept in mind that a single test parameter can never provide sufficient information for design purposes and common sense will always be required to combine laboratory test results so that they can be applied effectively in practice.

The effect that 'moisture susceptibility decreasing' non-traditional stabilisation agents have on bearing capacity can be checked with a number of tests, such as CBR tests, if necessary. However, the primary requirement is that materials for treatment must have a sufficient insitu bearing capacity before treatment, when dry, so that their properties can be preserved when water access can be prevented.

Leaching can be an issue in stabilisation works and if there is no previous experience of the selected non-traditional stabilisation agents, leaching tests should be performed in order to identify if any compounds will migrate from the material. In this case the untreated material should similarly be tested for solubility so that comparisons can be made.

Chapter 4. An example of test site and treatment agent selection

4.1 BACKGROUND

Financing for the construction of the test site and the related research was provided by Finnish Road Administration's strategic research project S14 (Economic Maintenance of Low-volume Roads). Local road districts also participated in finding suitable test sites to test the effects of two different stabilisation agents in improving the performance of the moisture susceptible material. Based on previous studies (Vuorimies & Kolisoja 2005 and Kolisoja & Vuorimies 2005) three agents were selected for the suitability tests.

4.2 TARGET: LOCAL ROAD 13581

Local road 13581 is a thinly-paved road whose condition was designed to be improved with bitumen stabilisation. As an alternative to bitumen stabilisation, moisture susceptibility decreasing non-traditional stabilisation agents were considered for a test site where the water level was relatively close to the road surface. Figure 4.1 illustrates a test pit in the affected road section. The base course thickness was 20-25 cm in the sampling points and decreased towards the ditches. Water content in the base course was 3.8%. The fines content of the material was found to be 7% by wet sieving.



Figure 4.1. Sampling on the local road 13581.

Tube Suction tests were performed for both untreated and treated materials using two parallel samples. The samples were compacted with standard effort in 5.5% moisture content and the achieved dry densities of the samples were 22.3 – 22.8 kN/m³. Figure 4.2 shows the dielectric value changes in relation to time when the samples were placed in water after being dried in a 40-45 °C oven. The maximum dielectric values of the untreated samples were 8.9 and 9.9 during the first ten days, after which the values ascended slightly. The dielectric values of the treated samples were smaller. The conductivity values measured from the untreated samples were below 15 µS/cm.

After consideration of these test results, and since the Tube Suction test dielectric values of the untreated samples did not clearly exceed the limit value (9-10), it was decided to find a more suitable test site target.

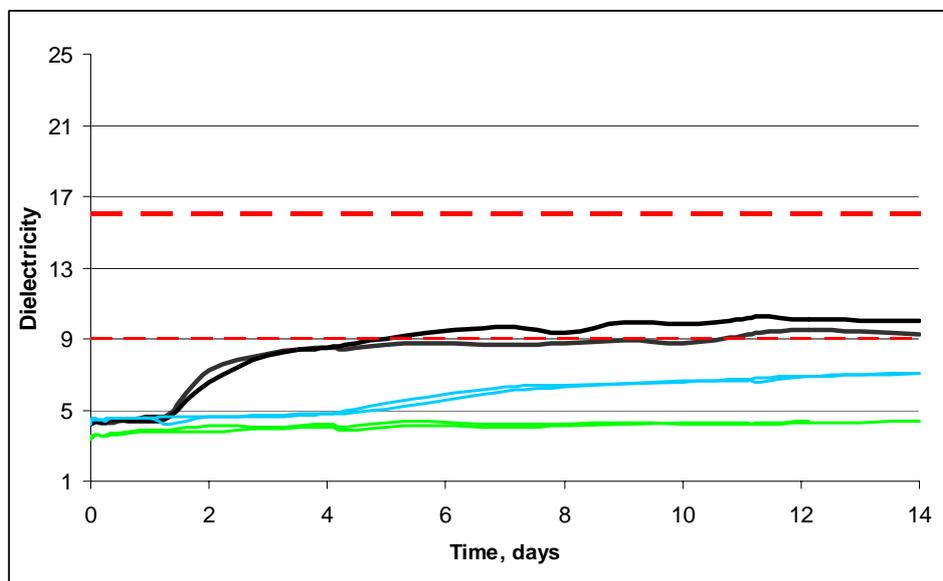


Figure 4.2. Tube Suction test dielectricity graphs for untreated (black) and treated (coloured) aggregate from the local road 13581.

4.3 TARGET: LOCAL ROAD 19735

Local gravel road 19735 had a history of suffering from surface thaw weakening in the spring. Ditches had been repaired in autumn 2005. Within the road a section situated on soft soil was selected to be a suitable test target for 'moisture susceptibility decreasing' non-traditional stabilisation agents. Figure 4.3 shows two pictures of the road section taken in spring 2005. The photograph on the left shows the ditches clogged with vegetation and the photograph on the right shows a 20 cm deep test pit through the road structural layers. The fines content of the road material from a wet sieved particle size distribution curve was above 7%. The water content of the sample was 3.5%.

Tube Suction tests were performed for both untreated and treated materials with two parallel samples. The samples were compacted with standard effort in 5.5% moisture content and the dry densities achieved were 21.8 – 22.2 kN/m³. Figure 4.4 shows the dielectric value changes in relation to time when the samples were placed in water after being oven-dried. The dielectric values of the untreated samples finally reached values of 40-50. The values of the treated samples were significantly smaller at between 20 and 25. (It should be noted here the dielectric values were high even at the start of the test as the water content was approximately 2% after drying.) The conductivity values measured from the untreated samples were 200-800 μ S/cm. The corresponding maximum values in the treated materials were about 50 μ S/cm. The high conductivity rates recorded probably derive from the dust suppressants used in the wearing course and the uneven dispersion of these compounds leads to differences between the parallel samples.



Figure 4.3. Sampling on local road pt 19735. (photographs: Jani Riihiniemi)

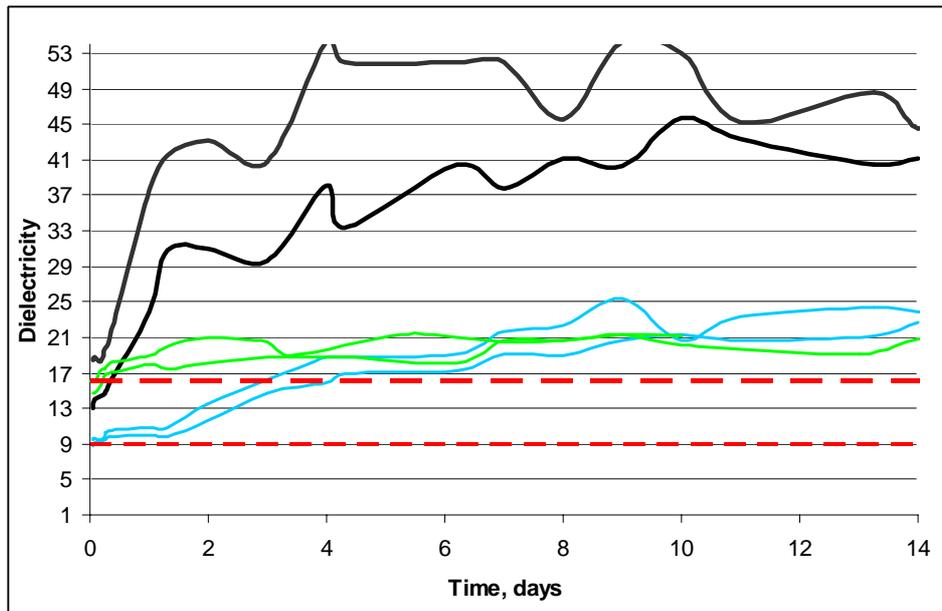


Image 4.4. Tube Suction test dielectricity graphs for untreated (black) and treated (coloured) aggregate from the local road 19735.

Based on these test results it was concluded that the test road appeared suitable for testing improvement using a non-traditional stabilisation agent since the Tube Suction tests showed that the untreated material was very susceptible to moisture and the stabilisation agents clearly decreased the moisture susceptibility in the tests. Before the final decision was made however, a frost heave test was performed on one of the two parallel Tube Suction samples. During three days of frost heave testing no frost heaving was detected in the treated samples. Almost a 7 mm (4%) frost heave developed in the untreated sample.

It was therefore concluded that based on the Tube Suction and frost heave tests the non-traditional stabilisation agents would work with the studied material. Before finally accepting the site as a test road however the specimen was tested for maximum solubility since there was no previous experience of using the non-traditional stabilisation agent in similar areas. Based on the leaching tests it was found that the treated materials would not cause a risk to the environment.

4.4 EXPERIENCES

To date there has been little experience of using low-cost treatment agents on the low-volume roads of the Northern Periphery of Europe. Current experience is limited to a few applications on test sites and to laboratory tests. Of these, experience is limited to approximately one year only, so there is little information on the long-term experience of how non traditional treatment agents function in actual road structures.

Despite this it still appears to be possible to draft a procedure to select a suitable treatment agent that will deliver the required performance in the road. A diagram of a draft procedure is presented in Appendix 1.

When considering the use of non traditional stabilisation agents in road improvements it is essential to have a good base of investigation results as a basis for design as well as sufficient time to carry out, revise and correct the data from treatment trials. This is especially important for non-traditional stabilisation agents which, at present, are rarely used and generally manufactured at significant distances from the road improvement sites, sometimes even involving shipping by sea.

At present the generally available stabilisation equipment has been designed mainly for bitumen or cement stabilisation. The new, non-traditional, stabilisation agents can be expected to differ from these traditional additives, and their dosage and mixing into the layers to be treated may require to be amended from the design values as a project develops. In this case clients and contractors should be prepared initially for slower operational rates and greater monitoring until experience is developed.

In practice it is likely that a relatively small number of low-volume roads will be improved with non-traditional stabilisation agents in the short term until enough experience from worksites has been gathered.

Chapter 5. Discussion

This report examines the use of the new 'non-traditional' stabilizing agents for moisture susceptible materials on those occasions when bitumen and cement stabilisation are considered too expensive and material coarsening is not possible. These new forms of stabilization are an important consideration for the improvement of bearing capacity of moisture susceptible soils in the Northern Periphery of Europe and especially for dealing with the weakening of roads during the spring thawing period when moisture contents of the road structural layers are at their greatest.

Practical experiences of treatments of moisture susceptible materials are very limited however and because of this absence of real knowledge this summary report has concentrated in describing what should be studied in trying to find alternative solutions to the prevention of seasonal bearing capacity degradation. The design procedure proposed looks promising as the laboratory tests required are relatively inexpensive and simple to perform. Furthermore, with wider practical experience the technique should become more definitive.

The greatest concern for many engineers intending to use the system may be the relatively new 'Tube Suction Test' method and how the selection of a stabilisation agent can be based on Tube Suction results. This is particularly important if the person interpreting the results has no previous experience about the test. This is understood and the following reports and articles are offered in support of the potential and applicability of the Tube Suction test:

- In comparative tests, for example in the USA, the Tube Suction test has been confirmed as the most appropriate method for estimating the frost susceptibility of unbound materials in the road structure (Saeed et al. 2001).
- The test has been improved and clarified for sampling and sample storing in the Tube Suction 'round robin' test results by Saarenketo (2000).
- The standardisation process has been improved further in Texas where a draft proposal has been issued (2003) and Barbu and Scullion have studied the repeatability and reproducibility of the Tube Suction Test method (2006).
- Guthrie (2001) has discovered that Tube Suction tests have good repeatability.
- The Tube Suction test is currently being used as a test criterion in the trials of the Finnish road administration's stabilisation instructions (2002) for monitoring bitumen and cement content on site.
- In Texas, Scullion and Harris (1998) have discovered that the Tube Suction test results explain the rapid damaging of cement stabilised roads.

It will only be however through monitoring test results on sites involving moisture susceptible materials that the criteria for the use of Tube Suction test will become

clearer. Until then, the proposed procedure within the report should be used carefully, and with common sense.

Finally as with all construction alternatives, even where the method for stabilisation agent selection is sound, it will only be truly needed when the overall costs are competitive with other rehabilitation methods.

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