The effect of different binders on freeze durability of stabilized soil

L´effet de différents liants sur la persistence quant au geldes sol traités

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ABSTRACT
This paper examine a test method to evaluate the durability of stabilised soils with respect to freeze and thaw properties. The paper also shows a methodology to evaluate the effects of different binders and their possible interactions. Further the paper indicates a need for a standardized test methodology for stabilised soils regarding frost resistance.

RÉSUMÉ
Cette communication présente une methode d´essai pour èvaluer la persistance des sols traités relativement au gel et au dégel. On présente aussi une methodologie pour évaluer les résultats de différents liants et leurs actions réciproques. Puis on met l'accent sur un besoin d´une méthologie d´essai standardisée pour les sols traités concernant la résistance au gel.

Keywords :Stabilized soil, fine-grained, freeze testing, UCS, lime, slag

1 INTRODUCTION

In this project one main goal was to test the possibility for utilising the natural soil. The soil was utilised both as foundation for roller concrete as well as for landscaping purposes. Using stabilised soil in pavement constructions is a well known technique. However, using stabilised material in landscaping in a cold environment is not well tested. Therefore the lack of experience and knowledge is obvious. In landscaping the stabilised soil is directly affected of rain (erosion) and temperature (freezing). The stabilised soil was placed in a terraced shape, se Figure 1.

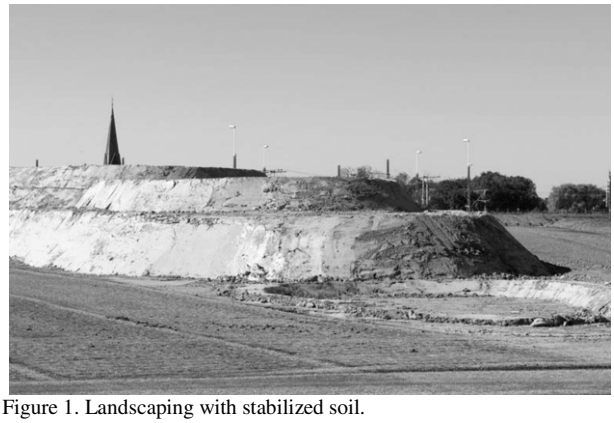

Figure 1. Landscaping with stabilized soil.

For this project hydrated lime and slag were chosen as binders for stabilising the natural soil. The natural soil consisted of clay till.

2 METHODOLOGY

Three different binders were chosen in this laboratory study; Hydrated lime, slag (GGBFS) and Polyroad. To study the effects and possible interactions a specific statistical experimental design was chosen. The design is called Central Composite Design (CCD), Montgomery (1996). In a case with three independent variables (binders) the test consists of 15 unique runs plus one extra in the centre. Since two replicates were used the total amount of cases was 32.

The effect of freezing and thawing was tested according to Swedish Standard 137244, Anon (2005). This standard is developed for hardened concrete and is not really applicable for stabilised soil. The method measured how much material that has been scaled off from the sample during 56 test cycles. Each cycle consist of a temperature variation according to Figure 2.

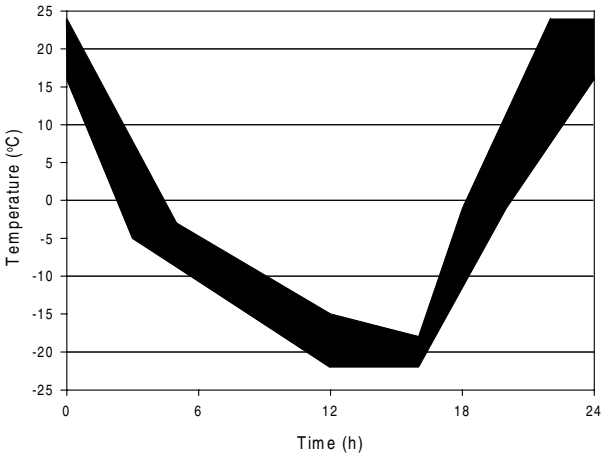

Figure 2. The black area shows the acceptable temperature range during the freeze and thaw tests.

The scaling during the freezing test is performed on samples that are covered with a rubber membrane on all sides except on the freezing surface. Then the freeze surface is submerged with water for 72 hours. Just before the freeze testing the sample is heat insulated from all sides except for the freezing surface.

Then the freezing liquid (in this case water) is placed on top of the specimen. The specimen is then placed in the freezing chamber.

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3 SAMPLE PREPARATION

The natural fine-grained till was excavated from a site in southern Sweden. In laboratory the soil was homogenised and stored in air tight containers. The soil was mixed with the binders according to the CCD. After one hour the mix was compacted in a special compaction equipment for stabilised soil, se Figure 3.

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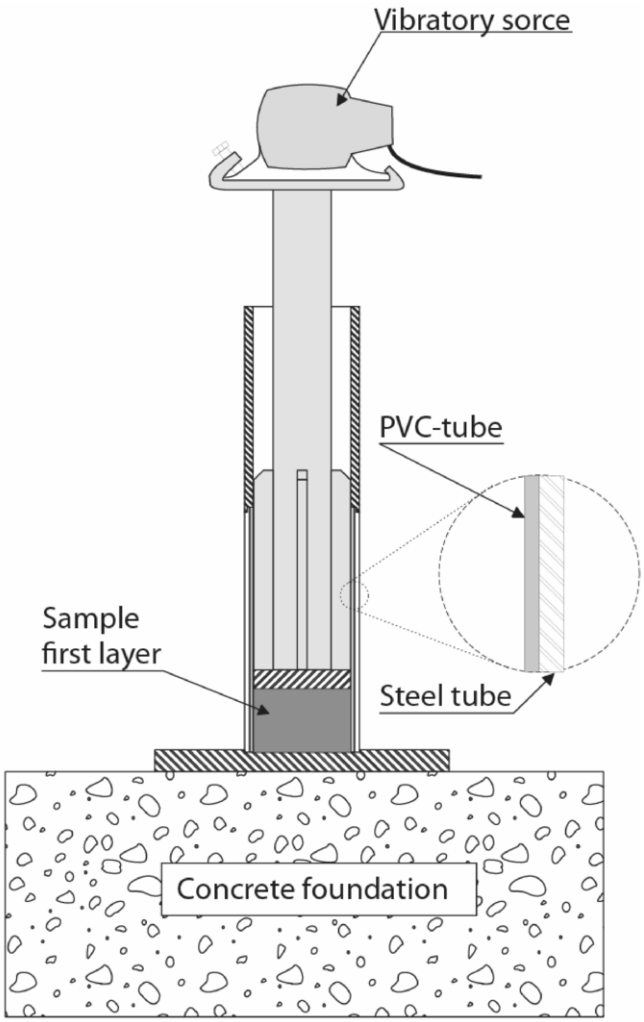

Figure 3. Compaction equipment for stabilised soil.

The specimen was compacted in three layers and the surface between each layer was scarified to ensure a good connection between the layers. Each layer consists of approximately 1600 g of stabilised soil. After compaction the specimen and the plastic tube is removed from the compaction equipment. The specimen will cure within the plastic tube to preserve the confining pressure caused by the compaction. The specimen's ends were covered with paraffin to ensure that no drying occurred.

The specimen has a height of approximately 240 mm and a diameter of 100 mm.

After sufficient curing (in this case 90-days) the specimens was cut in two pieces. One aimed for unconfined compressive strength (UCS) testing and the other for freeze and thaw testing.

4 TESTING

Three different tests were performed on the samples. Freeze test, free-free resonant column test and UCS testing The UCS were performed according to SS-EN 13286-41, Anon (2003).

The setup for the free-free resonant column test is shown in Figure 4, Ryden and Lindh (2006). In this method the sample is placed "free" on soft foam and vibrations are excited with an impact by a small steel sphere. The resulting "free" vibrations of the sample are measured with an accelerometer or microphone, and the resonant frequencies can be observed as peaks in the corresponding amplitude spectrum (FFT) of the measured signal.

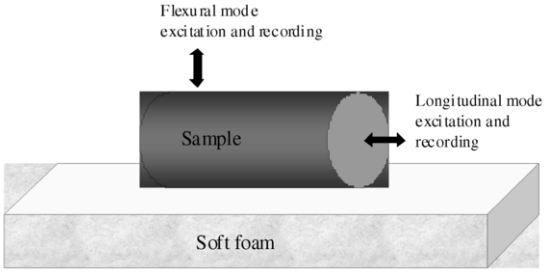

Figure 4. Free-free resonant column test set-up.

5 RESULTS

The specimen's dry density was calculated and the effects of different binders were calculated. The result shows that slag and lime have a significant effect on the dry density, se Figure 5.

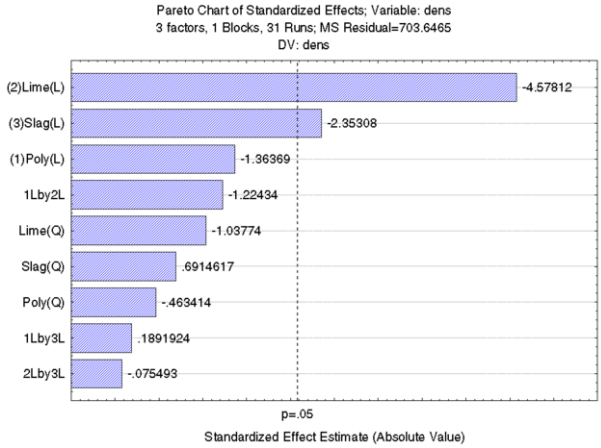

Figure 5. Pareto chart showing the effects of different binder on dry density. L in the figure means linear effect.

The (L) in the figure shows the linear effect and (Q) the quadratic effect. The red line shows the significance (p-level). A p-level of 0.05 indicates that there is a 5% probability that the relation between the variables found in the sample is a "fluke".

The figure shows that only the linear effect of lime and slag are significant on the dry density.

The results from the free-free resonant column test show similar results as for the dry density, se Figure 6. However, high density indicates high P-wave velocity and in this case lime and slag have a negative influence on density. One the other hand binder reaction causes bonding that have a higher impact on P-wave velocity than the density.

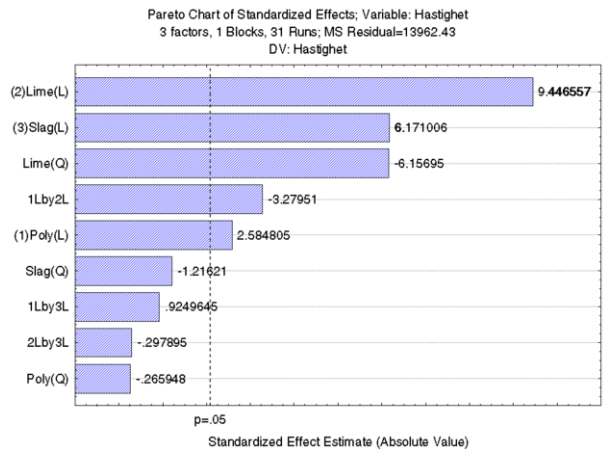

Figure 6. The effect on P-wave velocity for the different binders.

In this case the quadratic effect of lime as well as the interaction between lime and Polyroad has a negative effect on the compression velocity. The effect of Polyroad has a minor positive linear effect on the velocity.

The effect on UCS testing is shown in Figure 7.

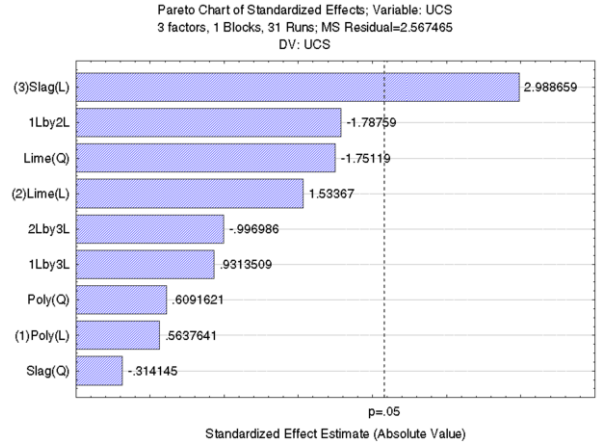

Figure 7. The effect on UCS for the different binders.

There is a clear discrepancy between the compression velocity and the UCS results. The UCS testing shows that it is only the slag component that has a significant impact on the UCS. This result was not expected. The difference was later found to be caused by problems with the impact source.

The results from the freeze testing shows that slag have a significant effect on the scaling properties, se Figure 8.

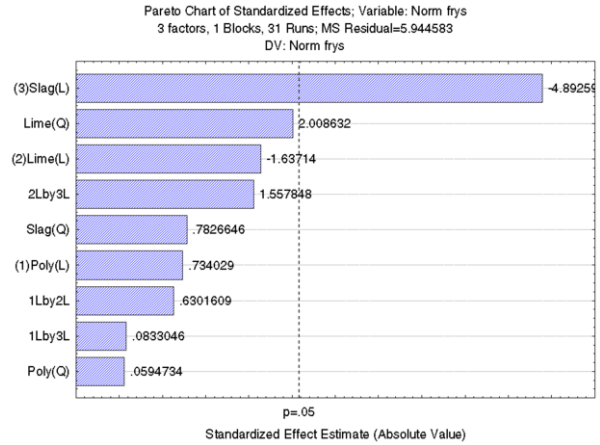

Figure 8. The effect on scaling for the different binders.

This result shows that there is a clear relation between strength and the scaling properties. This effect is expected since high compressive strength indicates high tensile strength and the tensile strength is important for the scaling properties.

In this case only one out of fifteen different binder recipes could be accepted according to the scaling at freezing test.

6 CONCLUSIONS

Stabilised soils have a lower resistance against frost compared to concrete. This means that test methods for concrete testing are not applicable for stabilised soils. Utilising stabilised soils for constructions that are directly exposed to frost needs some sort of protection against free water. The hydrophobic effect from Polyroad seems not to have any significant effect on the frost properties.

The only binder that has a significant effect on the frost properties was slag.

Seismic testing, i.e. free-free resonant column, is a very fast and accurate method for testing. However, in this study there were problems with the impact source and therefore the results was not quite as good as usual.

REFERENCES

Montgomery, D. C. 1996. Design and Analysis of Experiment. Wiley

Anon, 2003. Unbound and hydraulically bound mixtures- Part 41: Test method for the determination of the compressive strength of hydraulically bound mixtures. SS-EN 13286-41, SIS, Stockholm.

Anon 2005. Concrete testing-Hardened concrete- Scaling at freezing. SS 137244:2005, SIS, Stockholm (in Swedish).

Ryden, N. and Lindh, P. 2006. Quality Control of Cement Stabilised Soil Using Non-destructive Seismic Tests. Advanced testing of fresh cementitious materials. August 3-4, 2006.Stutgart.