

Frost heave in lime-stabilized Danish clay till

Arthur Kraglund Stès

Geo and Aarhus University, Department of civil and architectural Engineering, Aarhus, Denmark, aks@geo.dk

Patrick Strandgaard Laursen

Aarhus University, Department of civil and architectural Engineering, Aarhus, Denmark

Rasmus Clement Bødtker

CG Jensen and Aarhus University, Department of civil and architectural Engineering, Aarhus, Denmark

ABSTRACT: The scarcity of sand and gravel resources combined with the increasing sustainability demands have intensified interest in lime-stabilized clay till as a possible substitute for conventional sub-base materials in Denmark. However, the frost resistance of such materials remains insufficiently documented, particularly under Danish conditions. This study investigates the frost susceptibility of a Danish clay till through a laboratory programme including California Bearing Ratio (CBR), capillary rise, and frost heave testing, all performed at various curing intervals. The capillary rise tests, modified from standards intended for granular soils, showed limited variability across different lime contents and curing times. This raises concerns about their suitability and reproducibility when applied to cohesive, stabilized soils. In contrast, the frost heave tests, conducted in accordance with BS 812-124:2009, demonstrated a clear reduction in frost heave with increased curing times and lime content. After 91 days of curing, samples treated with 2% lime exhibited frost heave levels comparable to those of sub-base gravel classified as frost-resistant in Denmark. No conclusive correlation could be established between capillary rise and frost heave, highlighting the need for standardized methods tailored to lime-stabilized cohesive soils. The results suggest that the specific Danish clay till can meet frost resistance requirements, provided sufficient curing time and lime dosage are applied. This indicates its potential as a more sustainable alternative to sub-base gravel in infrastructure applications. The study advocates for the development of national guidelines to classify frost-resistant soils and to evaluate alternative sub-base materials in a consistent and sustainable manner.

KEYWORDS: Frost heave, lime-stabilization, capillary rise, sub-base materials, laboratory test.

1 INTRODUCTION

Sand and gravel resources in Denmark have become increasingly scarce in recent decades, due to rising demand in the construction sector and stricter environmental regulations regarding the extraction of sand and gravel. Disposing of unwanted soil is costly, both economically and in terms of CO₂ emissions.

In response to these challenges, lime-stabilization is a potential method for reusing locally available cohesive soils of lesser grade. Lime-stabilization enables more sustainable use of existing soils, reducing the need to source sand and gravel from distant sand and gravel pits. Despite these benefits, the frost susceptibility of Danish lime-stabilized clay till remains insufficiently documented, particularly under conditions representative of the Danish climate.

In Denmark, capillary rise is one of the primary parameters used to assess whether a lime-stabilized soil can be considered frost-resistant. This practice, however, raises questions, as there is no standardized method for conducting capillary rise tests on lime-stabilized, cohesive soils. The absence of such a standard challenges the validity and reproducibility of the results and highlights the need for further investigation of the topic.

To supplement the capillary rise test, the frost heave test (BS 812-124:2019) provides direct insight into the behaviour of lime-stabilized specimens under freezing conditions. By simulating freezing conditions, the test enables measurement of the vertical displacement caused by the formation of ice lenses. Despite being an established method in the United Kingdom, frost heave testing is not currently carried out commercially in Denmark, thereby limiting its application in practice.

As part of the project “Frostsikkerhed i kalkstabiliseret moræneler” (Frost susceptibility in lime-stabilized clay till) a literature review was conducted. The review focused particularly on testing and theoretical models used to assess frost susceptibility.

Frost heave is generally understood as the combined effect of ice lens formation and migration of unfrozen water towards the freezing front. The water migration is driven by a combination of capillary forces and cryosuction, which refers to suction generated by the curved ice–water interface and by thermal gradients in partially frozen soils. Cryosuction is typically more pronounced in fine-grained soils because of their small pore sizes and high capillary suction. However, Tabbiche et al. (2025) has shown that similar water redistribution can also occur in coarse-grained materials under appropriate hydraulic and thermal conditions.

Roesen (2019) raised questions about frost resistance in lime-stabilized soils and highlighted the need for a more consistent approach to testing.

Chamberlain (1981) conducted a comprehensive review of index tests for evaluating the frost susceptibility of soils. In his work, he introduced the capillary rise theory as an important indicator of frost susceptibility. This theory links frost heave potential to parameters such as the rate of heat removal, pore size, and hydraulic conductivity of the unfrozen soil. He noted that the particle size distribution was the most frequently used method, due to its simplicity and minimal testing requirements. Chamberlain’s review was proved inconclusive, as no definitive test method was identified, emphasizing the need for further investigation in this area.

JUN Hejlesen & Hansen (2023) conducted a test programme involving four different types of Danish clay tills. The soils were stabilized with 1% lime and subjected to curing periods of either 28 or 90 days. In this procedure, the specimens were extracted from the moulds after compaction, subsequently air-dried, and then wrapped in plastic film. Capillary rise was determined through a visual assessment, which is independent of the moisture content. The assessment involved measuring the vertical distance from the free water surface to the visibly saturated front within the specimen using a ruler. The results

demonstrated relatively low capillary rise values, ranging from 70 to 85 mm, indicating a reduced frost susceptibility under these stabilization conditions.

Building on these findings, this study aims to explore whether capillary rise is a reliable measure for frost susceptibility in lime-stabilized clay till.

It is hypothesized that a correlation exists between the capillary rise and frost heave in lime-stabilized clay till. If the material absorbs less water through capillary action, it should be less prone to frost-induced expansion. By testing and comparing both test methods across a range of lime dosages and curing times, this study seeks to evaluate whether Danish lime-stabilized clay till can be classified as frost-resistant, and whether the capillary rise remains a meaningful predictor, despite the lack of standardization.

The introduction of frost heave testing in Denmark may support the use of lime-stabilized clay till as an alternative to conventional sub-base layers of gravel. This could improve the sustainability of road construction by reducing the demand for natural aggregates and associated transport.

2 MATERIALS AND METHODS



Figure 1. Map of Denmark showing the location of Faxe.

The investigated Danish clay till originates from Faxe, located south of Copenhagen, Denmark (shown in Figure 1). Based on a combination of hydrometer analysis and dry sieving, the soil was classified as containing approximately 17% clay, 28% silt, and 40% sand, with 45.7% of the fines retained on the 0.063 mm sieve. The measured plasticity index (PI) was 8.6%, indicating low to intermediate plasticity. The Standard Proctor tests determined an optimum water content of 10.5% and a corresponding maximum dry density of 2,020 kg/m³. The natural water content was measured to be approximately 13.5%. Using guidelines from Galsgaard et al (2021), a geologist described the soil as a sandy, low plasticity clay (CL).

The clay till used in the present study is sampled in an area intended for extraction and lime-stabilization by a major Danish contractor. The aim is to market the stabilized material as a commercial alternative to traditional gravel used in sub-base layers.

2.1 Experimental program & procedures

The experimental program for the present study included several laboratory tests; however, only those relevant to the scope of this study are presented in this section. The full test programme is presented in Table 1. The laboratory tests were primarily conducted at Aarhus University, Denmark; however, the frost heave tests were performed in Bangor, Wales.

The California Bearing Ratio (CBR) tests were performed according to the standard of DS/EN 13286-47:2021. The CBR tests varied in lime percentages (0-2% added lime) and curing times (7-140 days). The CBR tests were carried out to verify that the required subgrade modulus were achieved in accordance with Danish standards.

The capillary rise tests were carried out with reference to DS/EN 1097-10:2014, a standard intended for granular soils. As the standard is not directly applicable to lime-stabilized cohesive soils, necessary modifications were made to accommodate the cohesive soil. Specifically, the standard procedure specifies the use of a wooden dowel for compaction, which is highly ineffective for lime-stabilized soils. Furthermore, the standard requires compaction in four layers, each layer subjected to 10 blows. Due to these limitations, the capillary rise specimens were instead prepared following the same parameter variations as those used in the CBR tests, including variations in lime content and curing duration. The specimens were compacted using a Proctor compaction hammer in PVC cylinders with a diameter of 150 mm and a height of 300 mm. Compaction was carried out in five layers of approximately 5 cm each, applying 56 blows per layer. The Proctor compaction hammer had a drop height of 304.8 mm (305 ± 1 mm) and a mass of 2.495 kg (2.500 ± 0.01 kg), in accordance with standard specifications. In deviation from the standard, which prescribes the use of transparent cylinders to visually observe the water front, PVC cylinders were used due to practical considerations. Following compaction, the specimens were subjected to the designated curing period. During the curing period, the specimens were kept at room temperature, which was continuously monitored using temperature loggers. After the curing period, the specimens were placed in a plastic container with water filled to a predefined level, illustrated in Figure 2.

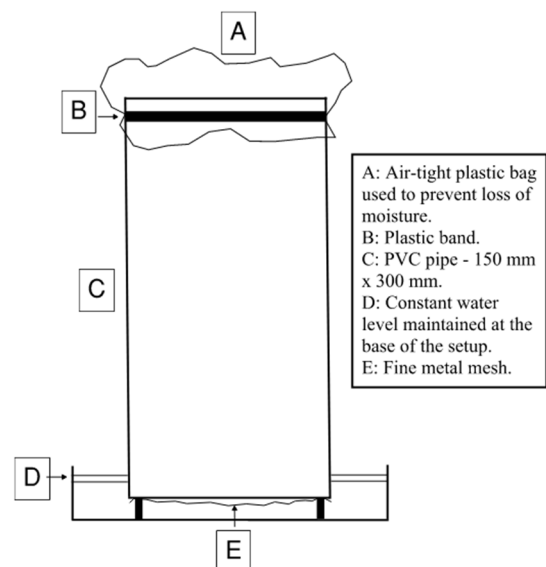


Figure 2. Capillary rise test setup.

To prevent erosion, each specimen was placed on four plastic spacers, with a fine metal mesh on top, allowing capillary suction of water. This setup deviates from the standard, which prescribes the inclusion of small holes in the bottom of the

Table 1. Test programme. The numbers indicate the number of tests per test condition.

Curing time	CBR			Capillary rise			Frost heave				
	0%	1%	2%	0%	1%	2%	0%	1%	2%	1% + 2% cement	1% + 4% cement
0 days	4			3			3				
7 days		4	4		2	2		3	3	3	3
14 days		4	4		2	2		3	3		
28 days		4	4		2	2		3	3		
91 days		2	2		2	2		3	3		
140 days		2	2		2	2					

specimen cylinder. Instead, a single larger opening was used in combination with the supporting mesh to ensure stability and uniform water access. A plastic bag was secured over the top of the specimen to minimise evaporation. The bottom of the specimens were soaked for seven days, during which the water level was maintained at a constant level. After the soaking period, the specimens were cut into 2 cm vertical increments, and the water content was determined for each increment. The underlying assumption of this test method is that the capillary rise can be estimated for the entire specimen by measuring the water content across each increment.

The frost heave tests were conducted by Celtest in Bangor, Wales, in accordance with BS 812-124:2009. The principle of the test method is based on creating a temperature gradient by exposing the sample to -17 °C air at the top while maintaining the base in contact with water at 4 °C. The resulting temperature gradient draws unfrozen water toward the freezing front through capillary suction and cryosuction, potentially leading to the formation of ice lenses. The development of ice lenses increases the height of the sample and results in frost heave. This setup allows the frost-heave behavior of the material to be quantified under controlled thermal and hydraulic conditions.

To enable this test setup, the clay till was first prepared in accordance with BS 812-124:2019. A minimum of 20 kg of bulk soil was dried in a ventilated oven at 110 °C (110 ± 5 °C) to achieve constant mass. After drying, the material was processed and passed through a 40 mm sieve to remove oversized particles.

Following this, the mixing process was initiated. Water was added to the dried soil to reach the optimal water content of 10.5%. This standardized preparation was chosen to minimise variability between samples and ensure reproducible test conditions. The prepared test samples measured 100 mm in diameter and approximately 150 mm in height, following the standard sample dimensions used in BS 812-124:2019 testing.

When preparing the soil specimens for testing, 3% water for each 1% lime was added to ensure adequate water was available for the reaction and to maintain a consistent water content across all samples, independent of the lime content.

With all test samples prepared according to the same procedure, the test programme included variations in lime percentages (0-2%) and curing periods ranging from seven to 91 days. The curing times were selected based on the following considerations:

- 7 and 14 days: Included to evaluate short-term effects.
- 28 days: Selected due to its established use in previous stabilization studies, with a timeframe allowing pozzolanic reactions to develop.
- 91 days: Adopted with reference to standard curing practices in concrete technology, where peak compressive strength is assessed.

Extended curing times beyond 28 days may result in additional changes to the material properties, which are relevant

for evaluating long-term frost-resistance performance and durability of the treated material.

In addition to the mixtures solely with lime added, the test programme also included samples stabilized with a combination of 1% lime and 2-4% cement, cured for seven days. This configuration was incorporated based on established UK practice for improving the frost resistance of cohesive soils. Including this combination allowed for comparison with other commonly used stabilization approaches. It also provided some insight into alternative methods that may be relevant under Danish conditions, particularly for short curing times.

3 LABORATORY TEST RESULTS

The obtained laboratory test results are presented in the following sections: CBR tests in Section 3.1, capillary rise tests in Section 3.2 and frost heave tests in Section 3.3.

3.1 California Bearing Ratio

Due to varying curing periods ranging from seven to 140 days, the CBR tests were conducted over an extended timeframe. The obtained subgrade modulus is presented in Figure 3.

The two horizontal green dotted lines serve as reference values, representing the typical upper limits for sub-base gravel (150 MPa) and base gravel (300 MPa) used in Denmark. After 28 days of curing, all the specimens exceeded the sub-base gravel reference, regardless of the amount of added lime. After 140 days of curing, the two samples with 2% lime obtained a subgrade modulus exceeding the base gravel reference. Notably, the 2% bottom sample achieved this after 91 days.

As illustrated in Figure 3, variation was observed in the maximum obtained subgrade modulus. The 2% bottom sample reached 407 MPa, while the 1% bottom sample deviated significantly from the overall trend, most likely due to visible defects observed during testing.

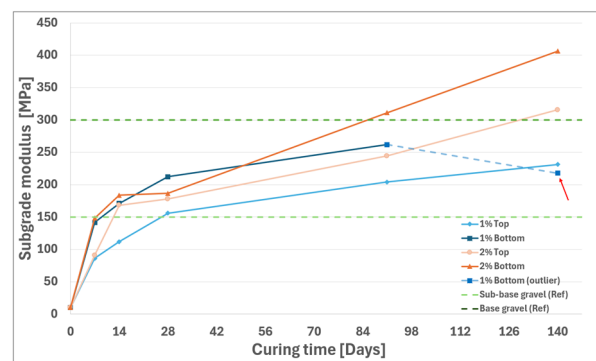


Figure 3. CBR test results.

3.2 Capillary rise

The results obtained from the capillary rise tests are presented in Figure 4. A reference value of 80 mm, established by JUN Hejlesen & Hansen (2023) on similar soil materials, is included for comparison.

As shown in Figure 4, the capillary rise remained relatively constant throughout the test period. It was anticipated that the untreated samples (0% lime) would achieve full capillary rise, reaching the top of the sample (+250 mm), and that the capillary rise gradually would decrease with increasing curing time.

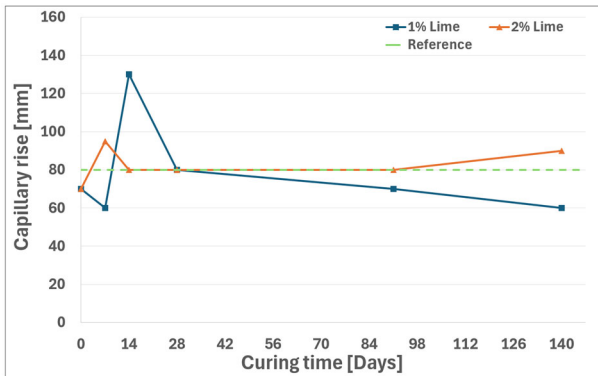


Figure 4. Capillary rise test results.

The tests without added lime were repeated multiple times, thereby providing a basis for comparing the results with the theoretical assumptions. These repeated tests yielded a result of 70 mm, confirming the initial findings. The corresponding data point is shown in Figure 4 for zero days of curing.

The majority of the results were close to the reference value; however, several outliers are evident in Figure 4 – most notably the 1% sample with a curing time of 14 days. All reported values represent the mean of two samples, a limitation imposed by the project's timeframe. In this case, the two measurements differed significantly (70 mm and 190 mm), raising concerns about the reliability of using the average as a representative value.

3.3 Frost heave

The frost heave tests were carried out by Celtest in Bangor, Wales. The results, presented in Figure 5, illustrate the progression of frost heave with increasing curing times. A reference value of 3.2 mm of heave was selected, based on Danish literature (Roesen, 2019). This reference value was obtained through tests on sub-base gravel, which is considered frost resistant in Denmark.

The untreated samples exhibited a mean frost heave of 15.5 mm. Samples with curing times of 7 and 14 days achieved nearly identical values, with frost heave ranging between 15.0 and 15.8 mm. This limited variation may reflect the insufficient development of pozzolanic reactions during the early curing stages, thereby resulting in minimal structural change in the treated soil.

With a curing time of 28 days, the 1% lime-stabilized specimen exhibited lower frost heave than the 2% specimen. A possible explanation for this behaviour is the addition of 3% water per 1% added lime. At 28 days of curing, the pozzolanic reactions are still ongoing, so part of the added water may not yet have been consumed. Consequently, the 2% specimen may have retained a higher water content than the 1% specimen, which may have contributed to the increased frost heave.

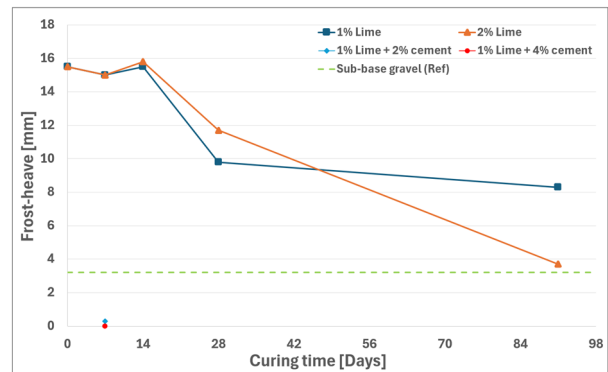


Figure 5. Frost heave results according to BS 812-124:2009.

Following 91 days of curing, a different trend was observed. The 1% sample exhibited a frost heave of 8.3 mm, while the 2% sample showed a significantly lower frost heave of 3.7 mm. At this point of curing, the majority of the added lime and water is expected to have reacted, leading to a denser and more stable soil structure in the 2% sample. These results indicate that, given sufficient curing time, higher lime content contributes more effectively to frost resistance. The 2% sample, after a curing period of 91 days, achieved a frost heave performance comparable to that of the frost-resistant sub-base gravel used as reference in the present study.



Figure 6. Ice lens formation in samples cured for 91 days after frost heave testing. The sample with 1% lime is on the left; 2% on the right. The ice lenses are highlighted by the red markers.

This improvement is likely due to the advanced pozzolanic reaction, resulting in the formation of stable cementitious compounds, which enhances soil bonding and reduces susceptibility to ice lens formation. The results after 91 days of curing provide a more representative assessment of the long-term durability of the lime-treated material, reflecting its frost resistance under extended, realistic environmental exposure. This is essential for determining its applicability in real-world geotechnical contexts.

The two samples treated with a lime-cement combination exhibited frost heave values of 0.0 mm and 0.3 mm, respectively. From a perspective of frost susceptibility, these results are technically promising, offering insight into the material's potential. Compared to the samples stabilized with lime only, these results highlight the effect of combining binders, particularly in relation to short-term performance. The findings provide a point of comparison within the broader test programme.

4 DISCUSSION

The findings from both the capillary rise and frost heave tests provide valuable insight into the frost resistance of lime-stabilized clay till. However, several aspects of the test procedures and interpretation of results warrant a discussion.

Contrary to expectations, the capillary rise remained relatively constant across all samples, regardless of lime content and curing time. This outcome raises concerns regarding the test setup, adapted from standards originally developed for granular soils (DS/EN 1097-10). The method was selected as a practical approach to estimate potential water uptake. However, the low variation between samples, combined with the discrepancy between replicates at 14 days, indicates potential limitations in reproducibility and precision under the given conditions. It is therefore reasonable to question whether this test is suitable for assessing capillary rise in lime-stabilized cohesive soils.

Figure 7 shows the water content profile for four different capillary rise samples. This example illustrates that the water content varied by only a few percentage points throughout the entire height of the samples. This variation may be attributed to the natural variation in the moisture content of clay till rather than a clear capillary rise. This minimal variation made it difficult to determine the exact height of capillary rise. Consequently, the exact capillary rise remains somewhat uncertain, which further highlights the challenges of using this test method on cohesive, lime-stabilized soils.

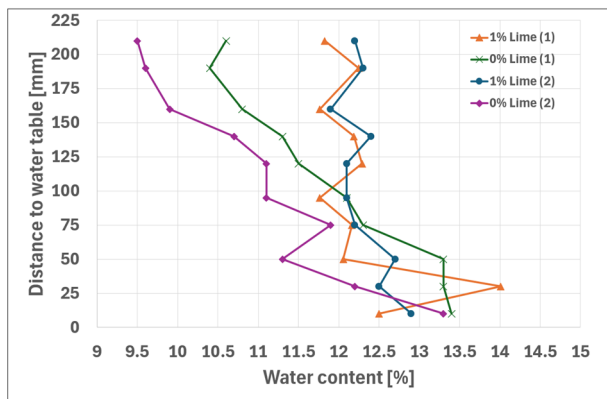


Figure 7. Capillary rise graphs with seven days of curing.

One of the primary aims of the study was to investigate a potential correlation between capillary rise and frost heave. However, the limited variation in the capillary rise results between tests complicates direct comparison. This contrast is apparent when compared with the consistent reductions in frost heave observed with increased curing time. In theory, reduced capillary rise may lead to decreased frost heave, as a lower availability of water limits the formation and growth of ice lenses. This mechanism is expectedly more pronounced in fine-grained soils, where water movement through capillary suction plays a key role in frost heave development. However, recent MRI-based research on sandy soils has shown that coarse-grained materials may also exhibit water redistribution and frost-heave behaviour (Tabbiche et al., 2025). This occurs when adequate water supply and freezing gradients drive migration towards the freezing front. In the present study, such a relationship between capillary rise and frost heave was not evident in the experimental data, and no conclusive correlation could be established within the tested timeframe and methodology.

The frost heave tests revealed a significant reduction in vertical displacement with increasing curing time. The sample with 2% added lime showed a frost heave of 3.7 mm after 91

days of curing, approaching the benchmark of the frost-resistant sub-base gravel (3.2 mm heave). These findings highlight the importance of allowing sufficient curing time for the pozzolanic reactions to fully develop, which impacts the soil's resistance to frost heave. However, the practical implementation of a 91-day curing period may prove logistically challenging, particularly within the constraints of standard construction timelines. As an alternative, a maturity model, similar to those used in concrete engineering, could be developed. This would allow laboratory results to serve as a basis for predicting the field performance of lime-stabilized soils, thereby reducing the need for prolonged in situ curing prior to quality assessment. While field verification would still be required, a maturity-based approach may improve the efficiency and feasibility of quality control in large-scale infrastructure projects.

Currently, Denmark lacks clear, standardized thresholds for classifying a soil as frost-resistant. The absence of precise guidelines creates significant challenges in defining the criteria for frost resistance in soil materials. Without well-defined standards, it becomes more difficult to replace the traditional sub-base layer of gravel with lime-stabilized soil, despite the potential environmental benefits of such substitutions.

In contrast, the United Kingdom has established more defined categories, distinguishing between frost susceptible and non-frost susceptible. According to UK standards, a soil material is considered non-frost susceptible if its frost heave does not exceed 15 mm, providing a benchmark for frost-related performance.

In discussions with specialists from the Danish Road Directorate (Vejdirektoratet), it was suggested that a potential frost heave of up to 10 mm may be acceptable for construction purposes. However, this would require the heave to be uniform, without resulting in differential settlement or deformation. This perspective suggests that the performance threshold for determining the frost resistance of stabilized materials in Denmark could be reconsidered.

While the technical performance of cement-stabilization is well documented, its widespread implementation in Denmark is constrained by the cement contents typically required (2-4%). Such binder contents are associated with a higher carbon footprint. In contrast, lime-stabilization generally requires about 1% lime, which reduces the binder demand per unit volume of treated soil. This demand for higher binder content poses a challenge in Denmark, where infrastructure policies are shaped by climate and sustainability targets.

Cement-stabilized clay till demonstrated low frost heave in this study's frost heave tests, with values as low as 0.0 mm and 0.3 mm observed after seven days of curing. However, these results must be carefully weighed against the associated environmental costs. They confirm that cement-stabilized soils can achieve near-complete frost resistance, which is advantageous from a durability and performance perspective.

In Denmark, cement-stabilization is typically used only for friction materials in infrastructure projects. Therefore, the low frost heave observed in the cohesive soil indicates a potential use in frost-exposed subgrades. However, realizing this potential on a broader scale would require careful consideration of its carbon footprint.

Although the number of test specimens was limited, the results provide insight into the material's behaviour under the tested conditions. All reported values are based on at least two measurements, and while additional replicates would increase statistical confidence, the current dataset allows meaningful interpretation. This is particularly relevant for the capillary rise tests, where some variation was observed between samples. Future studies should include a larger number of replicates to

enable more detailed statistical analysis and to strengthen the evidence in the observed trends.

5 CONCLUSION

This study investigated the frost susceptibility of lime-stabilized Danish clay till through laboratory tests, including capillary rise and frost heave measurements. The findings contribute to a better understanding of the conditions under which stabilized cohesive soils, such as the tested material, can be considered frost-resistant.

Contrary to theoretical expectations, the experimental data showed that no clear correlation could be established between capillary rise and frost heave within the constraints of the applied test methodology. Although a reduction in capillary rise was anticipated with increasing curing time and lime content, the measured values remained approximately uniform, independent of these variables. This raises questions about whether the capillary rise test method, which was originally developed for granular soils, is appropriate for assessing cohesive stabilized soils. A standardized and reproducible method tailored specifically to cohesive, lime-stabilized materials is needed to improve the reliability of such measurements.

In contrast to this, the frost heave tests showed a consistent trend: increased curing time and higher lime content reduced vertical displacement. At 91 days of curing, the sample stabilized with 2% lime demonstrated frost heave levels comparable to those observed in the sub-base gravel recognized as frost-resistant in Danish practice. Furthermore, the use of lime-cement combinations yielded frost heave values close to zero after just seven days of curing. This highlights the potential of binder-stabilized soils in frost-prone environments. However, the use of cement must be balanced against environmental considerations, particularly in light of Denmark's climate policies.

Currently, there is no clearly defined frost heave threshold in Denmark for classifying soil as frost-resistant. The establishment of national standards for frost heave testing and performance assessment would enhance the ability to evaluate alternative sub-base materials, such as lime-stabilized clay till, on a consistent and objective basis. Similarly, a standardized method for assessing capillary rise in stabilized soils would aid future studies and design practices.

In conclusion, while no direct link was found between capillary rise and frost heave, the results strongly indicate that the Danish clay till investigated in the current project can be considered frost-resistant with the appropriate lime content and curing time. These insights may support the development of more sustainable construction practices, provided that technical performance, practical feasibility, and environmental impact are weighed in balance.

6 ACKNOWLEDGEMENTS

The authors would like to acknowledge the support from COWIfonden and Geo. Special thanks to Bent Grønsvov Jensen (Aarhus University), Bjørn Staghøj Roesen (COWI), Kristian Rosted Brødbæk (Geo), and Michael Rosenlund Lodahl (Geo), whose valuable insights and contributions helped shape the direction and outcome of the project.

The authors would also like to acknowledge Ole Sørensen from SR Gruppen for his assistance in acquiring the soil used in the study.

The authors also wish to acknowledge Ewen McKay and Neil Hughes from Celtest for carrying out the frost heave tests and sharing their practical experience.

7 REFERENCES

- BS 812-124. (2009). Part 124: Method for determination of frost heave. British Standards Institute.
- Chamberlain, E.J. (1981). Frost susceptibility of soil – Review of index tests.
- DS/EN 1097-10, 2nd edition. (2014). Tests for mechanical and physical properties of aggregates – Part 10: Determination of water suction height. Danish Standard.
- DS/EN 13286-47, 2nd edition (2021). Unbound and hydraulically bound mixtures – Part 47: Test method for the determination of California Bearing Ratio, immediate bearing index and linear swelling. Danish Standard.
- DS/EN 17892-4, 2nd edition (2016). Geotechnical investigation and testing, Laboratory testing of soil – Part 4: Determination of particle size distribution. Danish Standard.
- Galsgaard, J., Fredericia, J., Frederiksen, J., Jakobsen, L., Okkels, N., Stockmarr, P., Sørensen, J. (2021). A guide to engineering geological soil description - DGF Bulletin No. 1. Danish Geotechnical Society.
- JUN Hejlesen & Hansen (2023). Kalkstabiliseret lerjord i fjernvarmeledningsgrav, Revision 2.0. JUN Hejlesen & Hansen.
- Roesen, B. S. (2019). Frostkategori for kalkstabiliseret lerjord. COWI.
- Stès, A.K., Laursen, P.S., Bødtker, R.C. (2024). Frostsikkerhed i kalkstabiliseret moræner. Aarhus University.
- Tabbiche, C., Roca, J., Sidi-Boulenouar, R., Maillet, B., Pereira, J., Chabot, B., Bornert, M., Aïmedieu, P., Tang, A. (2025). Magnetic Resonance Imaging as a tool for investigating frost heave dynamics: a new experimental setup and application. *Canadian Geotechnical Journal*. 62:1-19.