UNCONFINED COMPRESSIVE STRENGTH PROPERTIES OF CEMENT STABILIZED PEAT

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ABSTRACT

Peaty soil is viewed as a weak subgrade with poor bearing capacity and high compressibility. This study presents cement stabilization of peat to improve its engineering properties. Soil samples for laboratory experiments were collected in Riga Region, Garkalne municipality, near the Riga-Pskov road, in the place where a fen is formed by the peat of up to 5 meters in thickness.

Unconfined compression tests were performed for stabilized peat specimens (cured in laboratory, soaked in water) to evaluate an increase in bearing capacity for three different Portland cement dosages- 200kg/m^3, 250kg/m^3 and 300kg/m^3; and three different surcharge rates-0kPa, 6kPa and 18kPa; in 7, 14 and 28 days. Surcharge rates were varied in order to evaluate the effect of stabilization in different depth and under additional axial loading during the process.

Laboratory tests showed that not only the unconfined compressive strength, but also stiffness and compressibility of the peat were remarkably improved when mixed with cement. It was found that the effect of stabilization is strongly related to binder dosage, surcharge rate and curing time. The unconfined compression strength increase reached even 20 times the strength of the natural untreated and stabilized peat with 300kg/m^3 cement dosage and 18kPa surcharge after 28 days curing and soaking in water.

Key words: peat, cement stabilization, hydraulically bound mixtures, unconfined compressive strength

INTRODUCTION

There are certain extents of the prospective construction areas consisting of soil layers with reduced physical and mechanical properties. In the areas with peat layers in the base, the accessibility during the construction phase and ability to construct safe, stable and serviceable structures of civil engineering projects may be greatly reduced due to the poor bearing capacity, high compressibility, and high water content.

Peat usually forms on water saturated land that is poor in oxygen and thus hinders the decomposition of dead plant matter by natural microorganisms. In these circumstances, the dying vegetation accumulates year after year in the form of a peat layer. To ensure the peat land preservation, water input must keep up with water loss.

The main aim of using stabilizers is to increase the bearing capacity and with that the compressibility and stability of the treated soil layers. The most common stabilizing agent for peats is Portland cement, although there are also other binder and additive types.

When cement reacts with water in peat, it forms calcium silicate hydrate ($3CaO \cdot 2SiO_2 \cdot 3H_2O$) gel, which acts as glue that binds and holds the soil particles together. It is well recognized that organic soils can retard or prevent the proper hydration of binders such as cement in binder-soil mixtures (Hebib, Farrell, 2003). Normally peat has a relatively low content of pozzolans that can enter into secondary cementation reactions. Subsequently, the interaction between hydrated lime $Ca(OH)_2$ and the soil yields less effect in the secondary stabilization reactions. Therefore, no significant strength gain can be achieved from peat stabilization by cement unless cement is added to the soil in a large dosage. However, peat can be a highly variable material and the engineering properties of a peat deposit will be a result of the formation and morphology of the peat. For example, low pH<4.8 values usually characterize fibrous peats (raised bog), while amorphous-granular peats are rather neutral with a pH between 4.8 and 6.4 (Silamiķele, 2010). Consequently, lower pH values will negatively affect the reaction rate of the binder, resulting in a slower strength gain in peat and vice versa.

Directly after mixing the soil with a binder, 0.5-1.0m of fill (approximately 9-18kPa) is normally laid out on top of the stabilized mass in order to create a more homogeneous stabilized mass. In addition, the fill/embankment ensures a trafficable bed for the continuous stabilization of adjacent areas. The initial preloading, applied shortly after mixing the soil with the binder, can be expected to improve the strength of the stabilized peat (Ahnberg et al., 2001).

The use of cement in peat stabilization has been studied for a long time, and in many countries codes of practice are available. In Latvia, the laboratory mechanical performance of the hydraulically bound mixtures of cement and soil is classified according to LVS EN 14227-10. Normative references to other documents applied in the study, such as LVS EN 13286-41, are also included.

The objective of this study is to evaluate the effect of the binder dosage, different surcharge rates, and also unconfined strength development in time at the laboratory. Unconfined compression tests were performed for stabilized peat specimens, cured in the laboratory and water soaked, to evaluate an increase in bearing capacity for three different Portland cement dosages - 200kg/m^3, 250kg/m^3 and 300kg/m^3; and three different surcharge rates - 0kPa, 6kPa and 18kPa; in 7, 14 and 28 days.

MATERIALS AND METHODS

It is noted that peat can be a highly variable material depending on the formation and morphology. At one end of the scale, fibrous peats will have a visible plant structure with little humification, while amorphous peats, at the other end of the scale, will have a highly decayed structure.

The most distinctive characteristic of a peat deposit is its high water content, which generally ranges from 500% to 2000%, but can reach as high as 2500% for some coarse fibrous peats (Munro, 2004). Many of the geotechnical characteristics of peat result from this basic property.

The ash content (or non-organic content) is normally somewhere between 2% and 20% of its insitu volume and this range of ash contents can be an indicator of this type of peat (Munro, 2004).

Amorphous granular peats can have insitu undrained bulk densities of up to 1200 kg/m^3 whilst for very woody fibrous peats it can be 600 kg/m^3. Dry densities of peat can typically vary between 60 kg/m^3 to 120 kg/m^3. The specific gravity of peat typically varies from 1.5 to 1.8 with the higher ranges again reflecting a higher mineral content (Munro, 2004).

The void ratio of peat varies with the type of peat and moisture content. For example, peat with a moisture content of 1000% is likely to have a void ratio of approximately 18. Void ratios as high as 25 can be found in fibrous peats and void ratios as low as 9 are possible for the denser amorphous granular peats (Munro, 2004).

The permeability of peat in the field is highly variable and reduces dramatically when subjected to loading. The permeability of virgin peat usually ranges from 10^{-2} to 10^{-4} cm/sec, but when loaded with a low embankment it can quickly reduce to 10^{-6} cm/sec and with a higher embankment construction to as low as 10^{-8} to 10^{-9} cm/sec (Munro, 2004).

The peat samples were taken in Riga Region, Garkalne municipality, near the Riga-Pskov road by the edge of the WESS Motors Auto Bergi, in the place where a fen is formed by peat of up to 5 meter in thickness (see Figure 1). The cement stabilization of this soil was studied at the laboratories of the Riga Technical University (RTU).

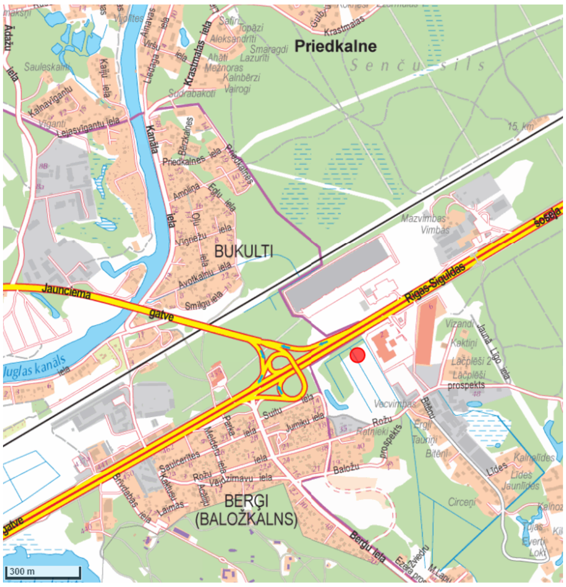

Figure 1. Map of Garkalne municipality, area by the Riga-Pskov road near the edge of WESS Motors Auto Bergi. The location is indicated with a red circle (SIA "Karšu izdevniecība Jāņa sēta"...)

The field area is mostly flat or slightly curved in such a way that that the center of the bog does not rise above the surrounding mineral ground, which is typical for fens that receive water from melting snow or from seepage flows. Fens have a tendency to contain peats that have a higher mineral content, lower water content and which are more humified than in raised bogs. According to typical fen formation as well as previous laboratory testing (Testēšanas pārskats Nr. 614-08…), sampled peat soil can be described as amourphos-granular peat with physical and chemical properties given in Table 1.

Table 1

Physical and chemical properties of natural peat

Properties	Natural peat tested
Natural water content (%)	690
Organic content (%)	91
Ash content (%)	9
Van Post classification (Hn)	H8-H10
pH	5.3

The KUNDA NORDIC CEM I 42.5N ordinary Portland cement was used for the soil stabilization in laboratory. Binder was mixed with soil in three different dosages 200kg/m^3, 250kg/m^3 and 300kg/m^3 using mixer KELAR EM2-1500E-2 (2000W) until the mixture was homogenous (approx. 10min). Then the soil-cement mixtures were placed by hand in plastic tubes with an inner diameter of 46mm.

Three special loading conditions for each of the different binder dosages were tested. Surcharge of 18kPa and 6kPa were put on samples filled in 200mm long plastic tubes shortly after mixing the soil, while surcharge was not put on samples filled in 100mm long plastic tubes. All the test samples were stored in a water container ensuring that water could interact with the stabilized soil at room temperature, i.e., about 20°C (see Figure 2).

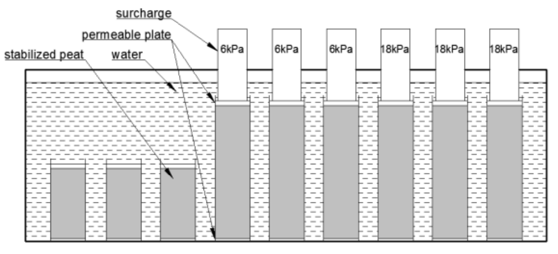

Figure 2. General design of test samples storage box

Unconfined compression tests were performed to evaluate the strength of stabilized peat samples after 7, 14 and finally 28 days stored in a water container with three different loading rates. All the test specimens were stored and then tested in triple tests, i.e., there were three equal samples for the same binder dosage and surcharge rate.

Prior to testing, the stabilized soil samples were prepared with a constant height to diameter ratio of 2. The samples were cut and smoothed to form parallel end surfaces. An unconfined compression test was performed with the electromechanical apparatus Zwick Z100 in accordance with LVS EN 13286-41.

RESULTS

It was observed during laboratory testing that the unconfined compression strength (UCS) of stabilized peat increased remarkably already after 7 days curing in water container and it enlarged continuously.

The quantitative UCS values of stabilized peat samples are plotted as a function of time in Figures 3 to Figure 8. The stabilized peat with binder dosage of 200kg/m^3 and without surcharge showed 73.2kPa, 90.5kPa, and 113.0kPa strength in average after 7, 14, and 28 days curing, respectively. While the stabilized peat with binder dosage of 300kg/m^3 and 18kPa surcharge showed 242.9kPa, 305.0kPa, and 355.8kPa strength in average after 7, 14, and 28 days curing, respectively. This is the range of experimental data, i.e., between 73.2kPa and 355.8kPa.

It was approximately estimated that natural peat does not accomplish even UCS of about 15kPa. Therefore, the strength gain for stabilized peat was observed to be more than 20 times the strength of the natural peat and stabilized peat with 300kg/m^3 Portland cement dosage and 18kPa surcharge.

The strength gain of stabilized peat was evaluated as a function of binder dosage and also surcharge rate. It is essential to compare the effect of these different factors.

Effect of binder dosage on the strength of stabilized peat

The unconfined compression test results of stabilized peat with three different binder dosage rates and constant surcharge rate can be seen in Figure 3, Figure 4 and Figure 5 as a function of time.

It was determined that the higher the binder dosage, the higher the predictable UCS value. Strength of stabilized peat after 7 days curing under the identical preloading with binder dosage of 250kg/m^3 increased 43% and with binder dosage of 300kg/m^3 increased 124% more than with binder dosage of 200kg/m^3 in average. Furthermore, strength increase after 14 and 28 days with a binder dosage of 300kg/m^3 continued to rise 17% faster than with dosage of 200kg/m^3 and 250kg/m^3 in average. This is an indication of the optimal Portland cement content in the mixture in order to ensure a continuous stabilization process.

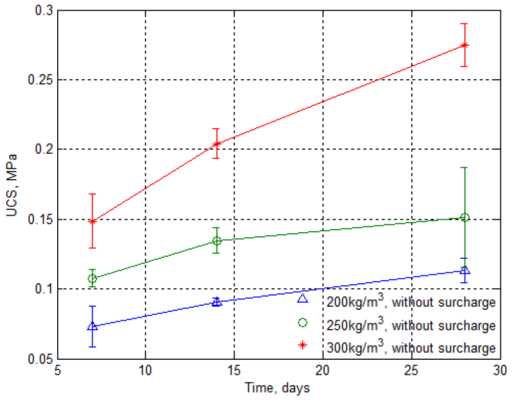

Figure 3. UCS values as a function of time for different binder dosages and without surcharge

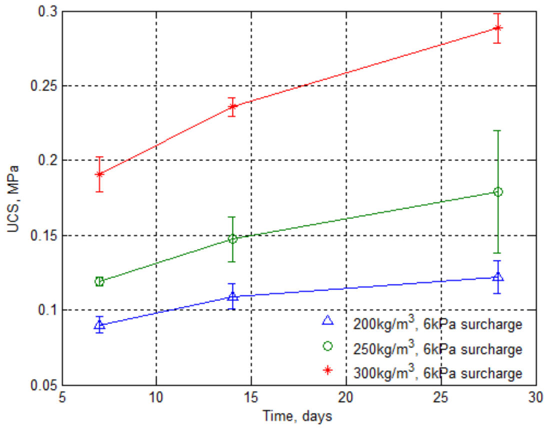

Figure 4. UCS values as a function of time for different binder dosages and with 6kPa surcharge

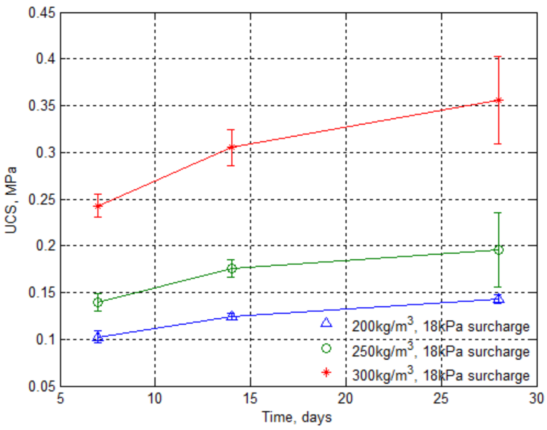

Figure 5. UCS values as a function of time for different binder dosages and with 18kPa surcharge

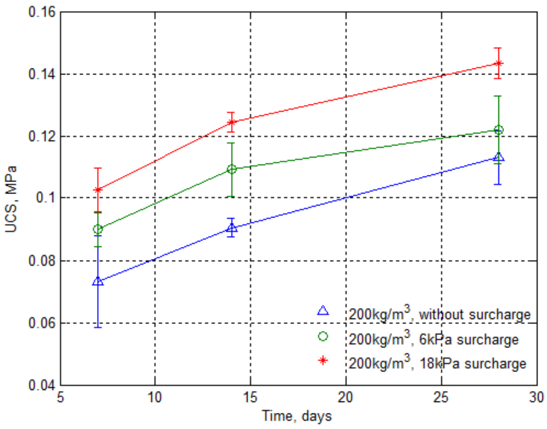

Figure 6. UCS values as a function of time for different surcharge rates and with 200kg/m^3 binder dosage

Effect of preloading on the strength of stabilized peat

The unconfined compression test results of stabilized peat with three different surcharge rates and constant binder dosage can be seen in Figure 6, Figure 7 and Figure 8 as a function of time.

It was found that there is a visible UCS increase when a surcharge is applied for all three different binder dosage rates after 7 days curing. However, both the character and the UCS increase after 14 and 28 days stayed the same in the range of the standard deviation. We can say that there is a remarkable effect of surcharge in the early stage of stabilization, while stabilization effectiveness in the later stage is determined generally by the binder dosage rate. This also might be because the surcharge rate was relatively low, i.e., only 6kPa and 18kPa.

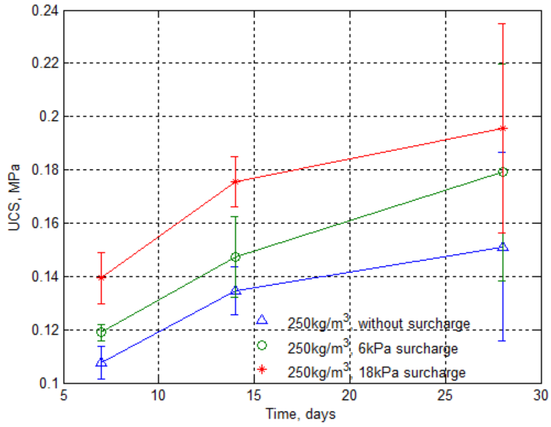

Figure 7. UCS values as a function of time for different surcharge rates and with 250kg/m^3 binder dosage

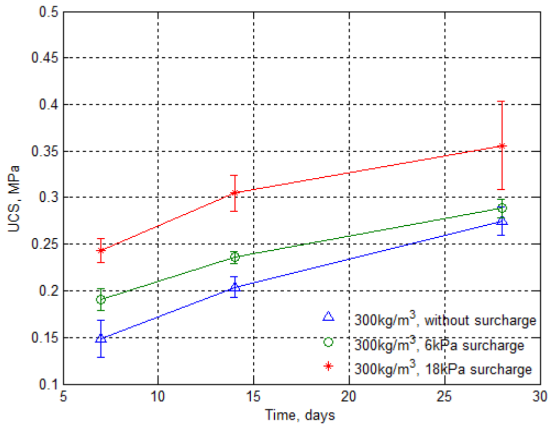

Figure 8. UCS values as a function of time for different surcharge rates and with 300kg/m^3 binder dosage

CONCLUSION

Peat in its natural state consists of water and decomposing plant fragments with practically no measurable bearing strength and high compressibility. Therefore, it is of critical importance to improve its engineering properties, considering shear failure, settlements and critical plains of failure, in order to use these extents of the prospective construction area in Riga Region, Garkalne municipality, near the Riga-Pskov road by the edge of the WESS Motors Auto Bergi, in the place where a fen is formed by peat of up to 5 meter in thickness (see Figure 1). Cement stabilization is introduced.

In this study, the stabilization of peat with ordinary Portland cement showed a considerable strength increase to more than 20 times the strength of the natural peat and stabilized peat with 300kg/m^3 Portland cement dosage and 18kPa surcharge. The unconfined compressive strength of stabilized peat varied from 108.0kPa to 403.3kPa after 28 days curing depending on the binder dosage amount and the surcharge rate. Both the effect of the binder dosage and preloading on the strength of stabilized peat was evaluated.

It was found that there is a remarkable effect of surcharge in the early stage of stabilization, while stabilization effectiveness in the later stage is determined generally by the binder dosage rate. Nevertheless, this surcharge rate of 18kPa corresponds to a normal preload from approximately 1m of sand fill and it ensures the required base for construction machinery to move and continue the stabilization process. It is clearly noticed that a more homogeneous stabilized peat mixture is constructed when preload is applied.

The greatest effect on the strength of the stabilized peat was demonstrated by the Portland cement dosage. It was discovered that the larger binder dosage, the greater the predictable stabilized mass strength. But the binder amount in the mixture should be determined so to ensure that the stabilization processes continues in time. Although the optimal Portland cement dosage for the best stabilization effect has not been determined in this study, the indication of it was found by trial and error. Comparing the effect of three different binder dosages on the strength of stabilized peat with a constant surcharge rate, it was found that the mixture with 300kg/m^3 binder dosage shows a considerably larger strength increase in the later stage, i.e., after 14 days and 28 days curing, comparing with mixtures of lower binder dosages. Stabilized peat samples with 300kg/m^3 binder dosage show a continuity of the stabilization processes, and therefore can be assumed to be the optimal Portland cement dose for this particular peat stabilization. However, there are more precise and advanced techniques of how to determine the optimal binder amount in hydraulically bound mixtures, e.g., pH test, Atterberg (consistency) limits analysis, used in the previous study (Skels, 2011). These tests were not in the scope of this study.

There is still plenty of room for development in the stabilization of soils with poor bearing capacity. For future work, it would be essential to evaluate the peat stabilization effectiveness in the field. This would provide results to compare with the laboratory study.

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