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OSAMAT

SIMUNA-VAIATU QUALITY CONTROL

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APPENDICES

1. QUALITY CONTROL

Simuna-Vaiatu mass stabilisation quality controlling consists of X-ray fluorescence (XRF) analysis and column penetrometer soundings.

During the stabilisation process the binder contents of the stabilised soil were measured by using XRF analysis. The tests were carried out with Niton XL3 XRF device which measures the calcium content of the soil. The content of calcium in the samples of mass stabilised soil corresponds to the success of the mass stabilisation work.

After the stabilisation process the actual strength level on the field was determined in late November 2013 (28th Nov – 29th Nov 2013) and again in the summer 2014 (30th June – 1st July 2014). The quality control soundings were determined ca. 3 months and 10 months after the stabilisation.

The quality tests are listed in Table 1 and locations are presented in Figure 1.

Table 1. The quality controlling tests and the target of the tests.

Test Method	**Target of the test**
XRF analysis	To measure the amount of binder in the stabilised soil.
Column penetrometer sounding	Compression and shear strength of the mass stabilised peat. Uniformity and homogeneity of the mass stabilised peat.
Vane test	Defining the N_c-factor. (The measured penetration resistance is converted into shear strength by dividing it by the N_c-factor)

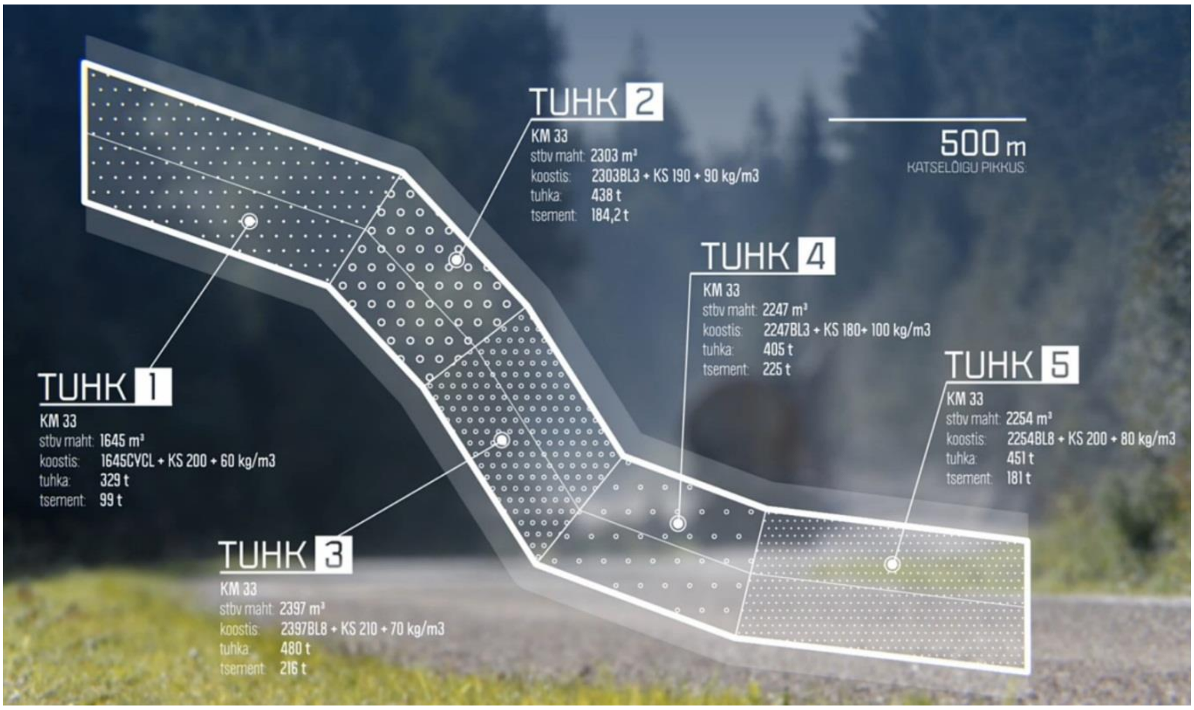

Figure 1. The locations of the quality soundings X-Ray fluorescence (XRF) analysis.

1.1 X-Ray fluorescence (XRF) analysis

Calcium content of the stabilised soil was determined with Niton XL3t X-ray fluorescence device. XRF is a type of spectroscopy and based on the release and identification of element-specific wavelengths. An XRF device irradiates the sample, causing a discharge of surplus energy. The device measures the wavelength and intensity of the emitted energy for element and amount recognition, respectively.

The Niton XL3t is a handheld device (see Figure 1.1), suitable for both on-site and laboratory measurements. The accuracy of the Niton XL3t is suitable for on-site quality control and in Simuna-Vaiatu case the calcium content was measured. Calcium content indicates the amount of binder used in the mass stabilisation.

Figure 1.1. On site measurements with the Niton XL3t device.

Measuring time of 20 seconds on the low range setting was determined for calcium quantity readings. The samples were taken on-site every half a meter with a light auger sampler and stored in resealable plastic bags. The measurements were carried out around 1-1,5 week after the sampling. Some consolidation will take place in that time, but the reaction should not effect on the accuracy of the XRF analysis. Five readings per sample were recorded and the results is an average of the five readings.

In tables 1.1-1.5 the measured calcium contents from the site are compared to the theoretically correct amounts (so called calibration mixture). The theoretical amounts are based on the laboratory mixtures with the same binders and their XRF measurements. Comparison shows that the stabilisation work has succeeded well. Most of the measured calcium contents are nearly the same or over the theoretical amounts. In other words the amount of the binder in the stabilised peat is as planned. In Block 10 in the section 1, the stabilisation may have been failed according to the measurement.

In the tables the result of XRF analysis is left without bolding if the value is more than 10 % less than the result of the calibration mixture. The lower values can indicate that the binder amount is smaller than it should be or that the binder is spread unevenly.

Table 1.1. Section 1 XRF-analysis.

	XRF-analysis Concentration of Ca (10^3 ppm)		Calibration mixture Concentration of Ca (10^3 ppm)	
	Depth (m)	Result	Binder recipe	Result
Section 1 Block 6 (VP-L1) (25.07.2013)	0,5	**132**	CYCL + KS 200 + 60 kg/m^3	**119**
	1	**123**		
Section 1 Block 10 (PP-L1) (22.07.2013)	0,5	67		**123**
	1	31		
	1,5	17		
Section 1 Block 13 (PP-L1) (24.07.2013)	0,5	113		**131**
	1	**163**		
	1,5	**151**		
	2	**178**		
Section 1 Block 15 (PP-L1) (PP-L1) (23.07.2013)	0,5	101		**131**
	1	103		
	1,5	98		
	2	118		

Table 1.2. Section 2 XRF-analysis.

	XRF-analysis Concentration of Ca (10^3 ppm)		Calibration mixture concentration of Ca (10^3 ppm)	
	depth (m)	Result	Binder recipe	Result
Section 2 Block 5 (VP-L2) (16.08.2013)	0,5	**120**	EF PF + KS 190 + 90 kg/m^3	**113**
	1,0	**130**		
	1,5	**137**		
	2,0	**135**		
	2,5	**133**		
Section 2 Block 6 (PP-L2) (14.08.2013)	0,5	**127**		**113**
	1,0	101		
	1,5	**103**		
	2,0	**139**		
	2,5	**138**		
Section 2 Block 12 (VP-L2) (22.08.2013)	0,5	**131**		**113**
	1,0	**127**		
	1,5	**126**		
	2,0	**111**		
	2,5	82		
Section 2 Block 15 (PP-L2) (16.08.2013)	0,5	**119**		**113**
	1,0	**132**		
	1,5	**137**		
	2,0	**130**		
	2,5	**105**		
Section 2 Block 19 (VP-L2) (22.08.2013)	0,5	**148**		**113**
	1,0	**131**		
	1,5	**134**		
	2,0	**138**		
	2,5	71		

Table 1.3. Section 3 XRF-analysis.

	XRF-analysis Concentration of Ca (10^3 ppm)		Calibration mixture Concentration of Ca (10^3 ppm)	
	depth (m)	Result	Binder recipe	Result
Section 3 Block 1 (VP-L3) (12.09.2013)	0,5	91	EF CFB + KS 210 + 70 kg/m^3	**110**
	1,0	**100**		
	1,5	89		
	2,0	97		
	2,5	90		
Section 3 Block 13 (VP-L3) (18.09.2013)	0,5	93		**110**
	1,0	**104**		
	1,5	**117**		
	2,0	**113**		
	2,5	**113**		
Section 3 Block 17 (PP-L3) (20.09.2013)	0,5	**112**		**110**
	1,0	**127**		
	1,5	**114**		
	2,0	**101**		
	2,5	92		
Section 3 Block 18 (PP-L3) (24.09.2013)	0,5	97		**110**
	1,0	**118**		
	1,5	**110**		
	2,0	**109**		
	2,5	**103**		
Section 3 Block 20 (VP-L3) (24.09.2013)	0,5	**108**		**110**
	1,0	**100**		
	1,5	**111**		
	2,0	**115**		
	2,5	**118**		

Table 1.4. Section 4 XRF-analysis.

	XRF-analysis Concentration of Ca (10^3 ppm)		Calibration mixture Concentration of Ca (10^3 ppm)	
	depth (m)	Result	Binder recipe	Result
Section 4 Block 3 (VP-L4) (04.09.2013)	0,5	**130**	EF PF + KS 180 + 100 kg/m^3	**102**
	1,0	**127**		
	1,5	**129**		
	2,0	**121**		
	2,5	**120**		
Section 4 Block 8 (VP-L4) (30.08.2013)	0,5	**114**		**102**
	1,0	**133**		
	1,5	**127**		
	2,0	77		
	2,5	**109**		
Section 4 Block 9 (PP-L4) (28.08.2013)	0,5	**133**		**102**
	1,0	**110**		
	1,5	**129**		
	2,0	**109**		
	2,5	**97**		
Section 4 Block 16 (VP-L4) (28.08.2013)	0,5	**120**		**102**
	1,0	**120**		
	1,5	**136**		
	2,0	**127**		
	2,5	63		
Section 4 Block 19 (PP-L4) (02.08.2013)	0,5	**139**		**105**
	1,0	**135**		
	1,5	**121**		
	2,0	**121**		
	2,5	**112**		
	3,0	86		

Table 1.5. Section 5 XRF-analysis.

	XRF-analysis Concentration of Ca (10^3 ppm)		Calibration mixture Concentration of Ca (10^3 ppm)	
	depth (m)	avg	Binder recipe	avg
Section 5 Block 1 (VP-L5) (24.09.2013)	0,5	**123**	EF CFB + KS 200 + 80 kg/m^3	**101**
	1,0	**94**		
	1,5	**96**		
	2,0	83		
Section 5 Block 6 (PP-L5) (28.08.2013)	0,5	**122**		**103**
	1,0	**123**		
	1,5	**117**		
	2,0	**139**		
	2,5	**110**		
	3,0	71		
Section 5 Block 14 (VP-L5) (12.09.2013)	0,5	**82**	EF CFB + KS X+X kg/m3*	-
	1,0	**82**		
	1,5	**89**		
	2,0	**77**		
	2,5	**77**		
Section 5 Block 16 (PP-L5) (08.08.2013)	0,5	**108**	EF CFB + KS 200 + 80 kg/m^3	**103**
	1,0	**93**		
	1,5	**101**		
	2,0	**96**		
	2,5	**95**		
	3,0	56		
Section 5 Block 19 (PP-L5) (04.09.2013)	0,5	**96**		**103**
	1,0	**103**		
	1,5	86		
	2,0	**101**		
	2,5	**106**		
	3,0	49		

*The used oil shale ash quality was called "BL11" which was said to be pretty much exactly like "BL8" (both under the code EF CFB), but the readings here are very low. Either the stabilisation failed, or the used "BL11" is not like "BL8".

As it is noted with mark '*' the used oil shale ash quality might have differed from the quality used othwerwise, as the XRF analysis show the calcium contents are low in block 14 VP-L5. There are also no comparison values from the calibration mixture. This indicates that the used quality "BL11" is different from "BL8" or the stabilisation is not succeeded as it should have been. *Note: the codes of oil shale ash quality has been altered in January 2015, previously used codes BL8 and BL11 are now under the same code of EF CFB.*

1.2 Quality control soundings

Figures 1.2 - 1.8 illustrate the results of the quality control soundings which were conducted as column penetrometer soundings. The results show the average shear strengths detected in five different stabilisation sections in relation to depth. Each section has a different mixture of binder used in the stabilisation of the peat. The first quality control soundings were conducted when the age of mass stabilisation was 76 - 133 days. The second quality control soundings were conducted when the age of the mass stabilisation was 10 months. The diagrams show that the shear strength is over the target strength of 50 kPa in every tested block. Only in block 11 VPL-2 the average shear strength is just above the target strength. However, the strength of the stabilised peat increased between the first and the second quality control soundings.

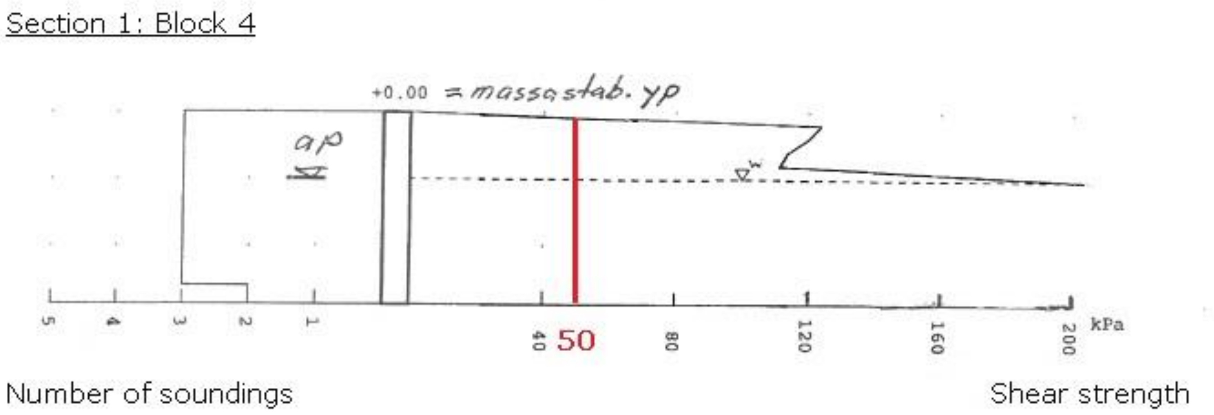

Figure 1.2a. The average shear strength of stabilised peat in block 4 PPL-1. The age of the mass stabilisation is 133 days. The used binder material mixture is CYCL + KS 200 + 60 kg/m^3.

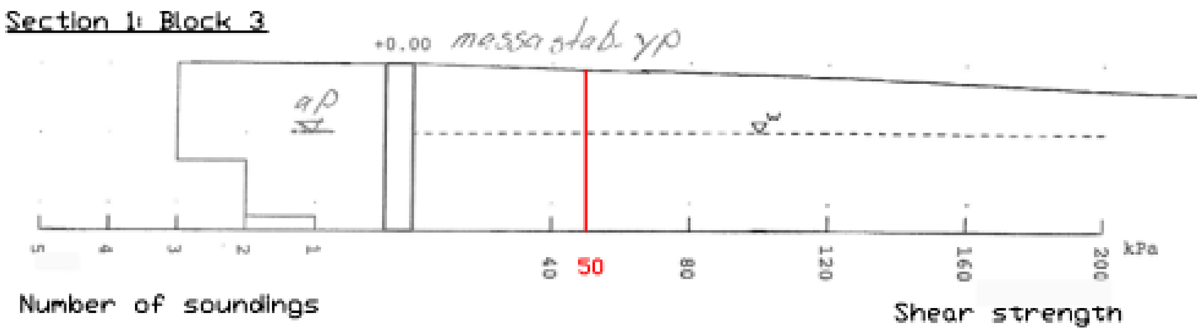

Figure 1.2b. The average shear strength in block 3 PPL-1 at the age of ten months.

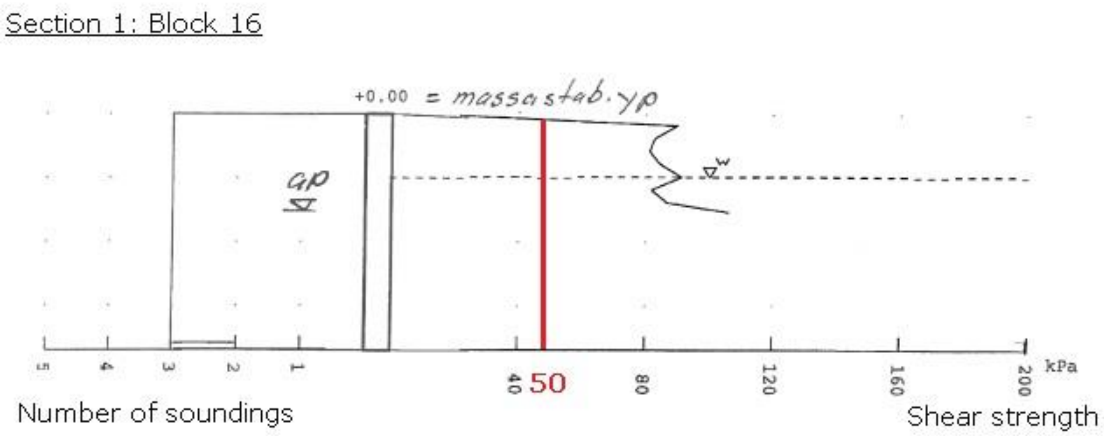

Figure 1.3a. The average shear strength of the stabilised peat in block 16 PPL-1. The age of the mass stabilisation is 122 days. Used binder material mixture is CYCL + KS 200 + 60 kg/m^3.

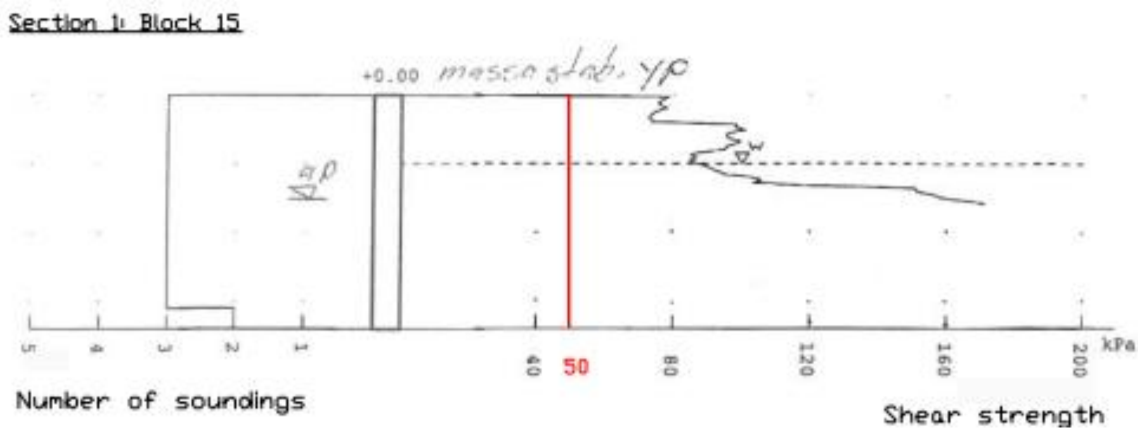

Figure 1.3b. The average shear strength in block 15 PPL-1 at the age of ten months.

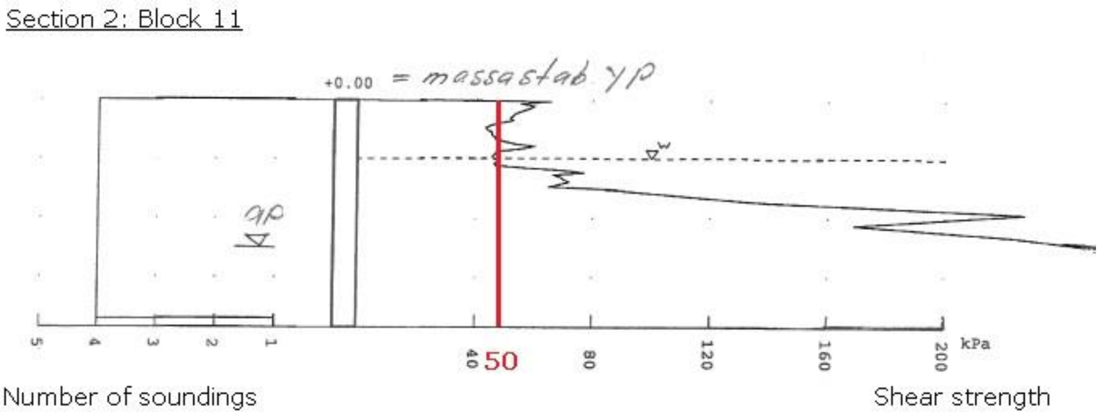

Figure 1.4a. The average shear strength of stabilised peat in block 11 VPL-2. The age of mass stabilisation is 104 days. The used binder material mixture is EF PF + KS 190 + 90 kg/m³.

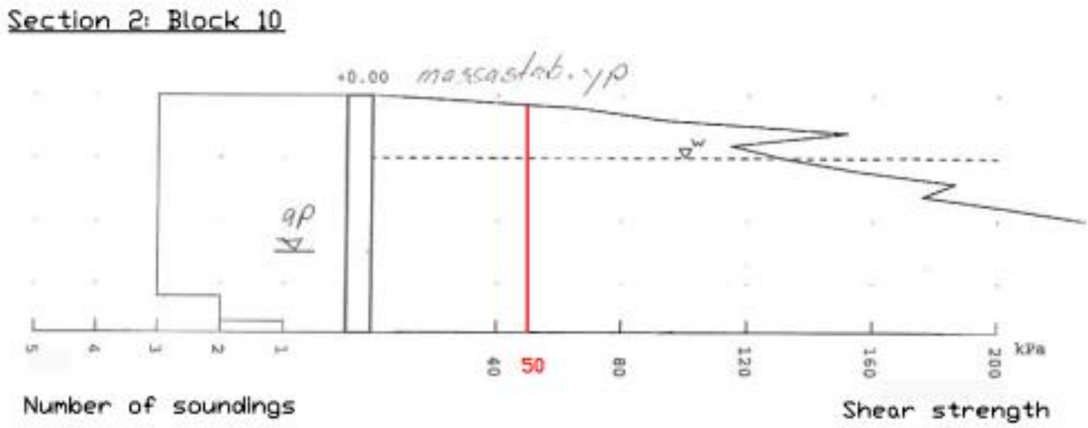

Figure 1.4b. The average shear strength in block 10 VPL-2 at the age of ten months.

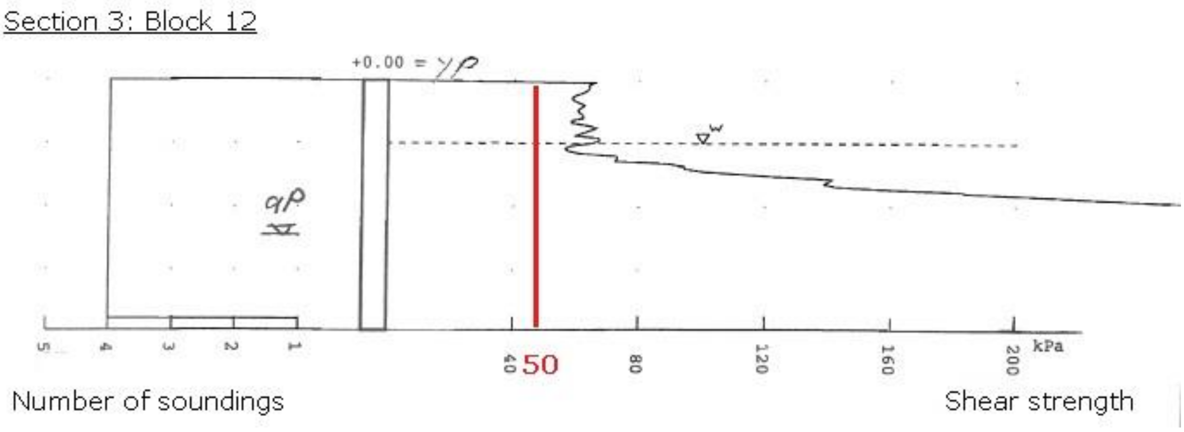

Figure 1.5a. The average shear strength of stabilised peat in block 12 VPL-3. The age of the mass stabilisation is 76 days. The used binder material mixture is EF PF + KS 170 + 110 kg/m³.

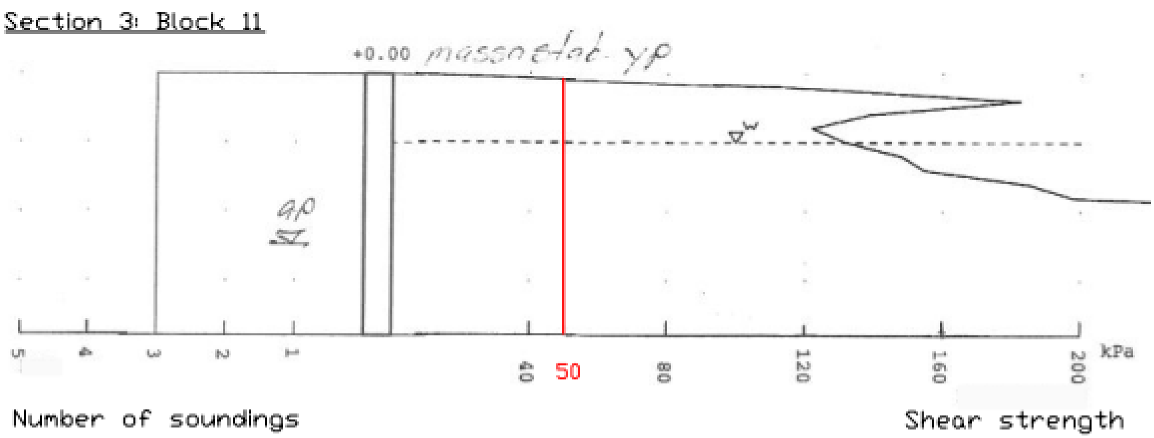

Figure 1.5b. The average shear strength in block 11 VPL-3 at the age of ten months.

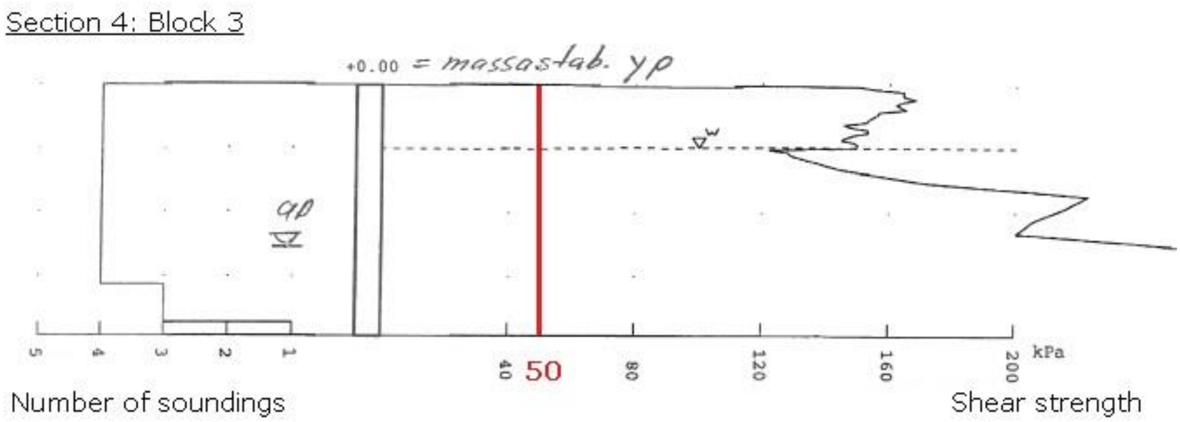

Figure 1.6a. The average shear strength of stabilised peat in block 3 VPL-4. The age of the mass stabilisation is 87 days. The used binder material mixture is EF PF + KS 180 + 100 kg/m³.

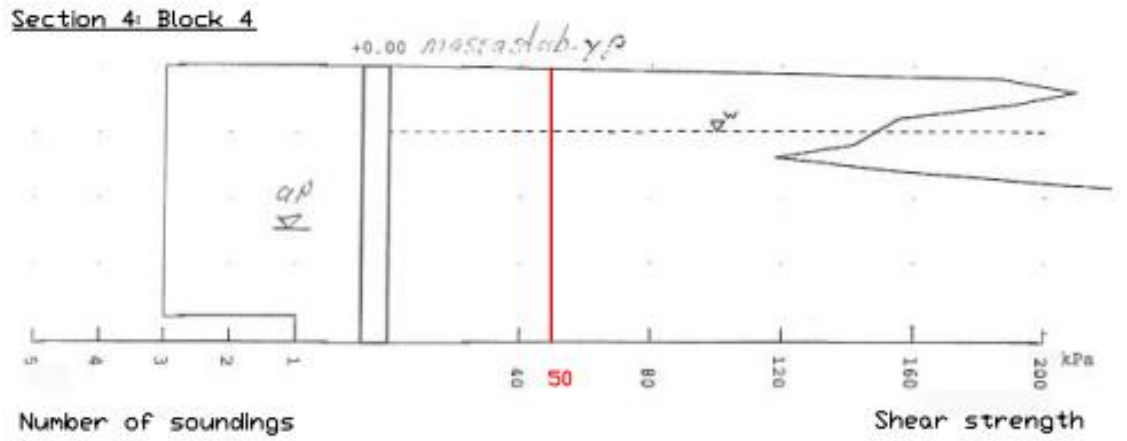

Figure 1.6b. The average shear strength in block 4 VPL-4 at the age of ten months.

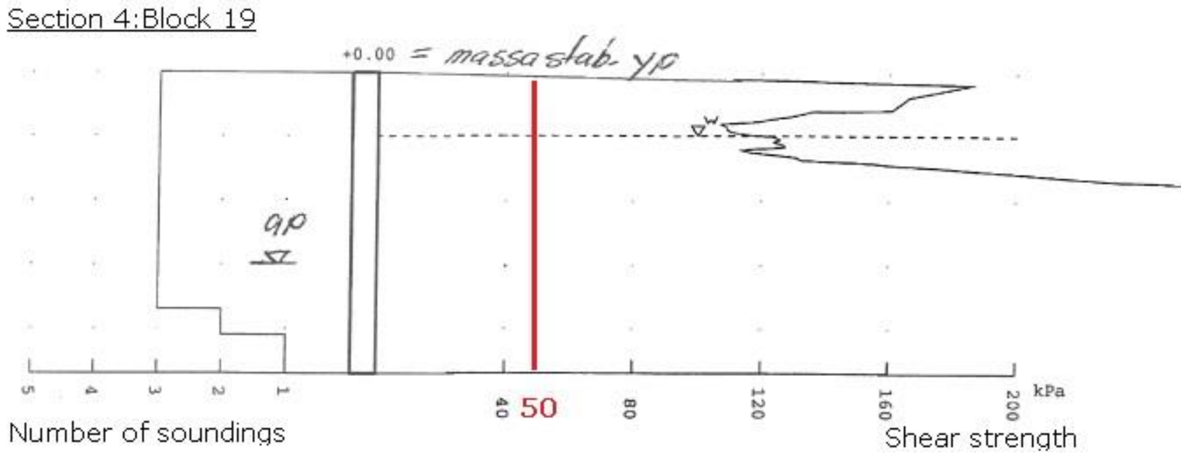

Figure 1.7a. The average shear strength of the stabilised peat in block 19 PPL-4. The age of the mass stabilisation is 120 days. Used binder material mixture is EF PF + KS 180 + 100 kg/m^3.

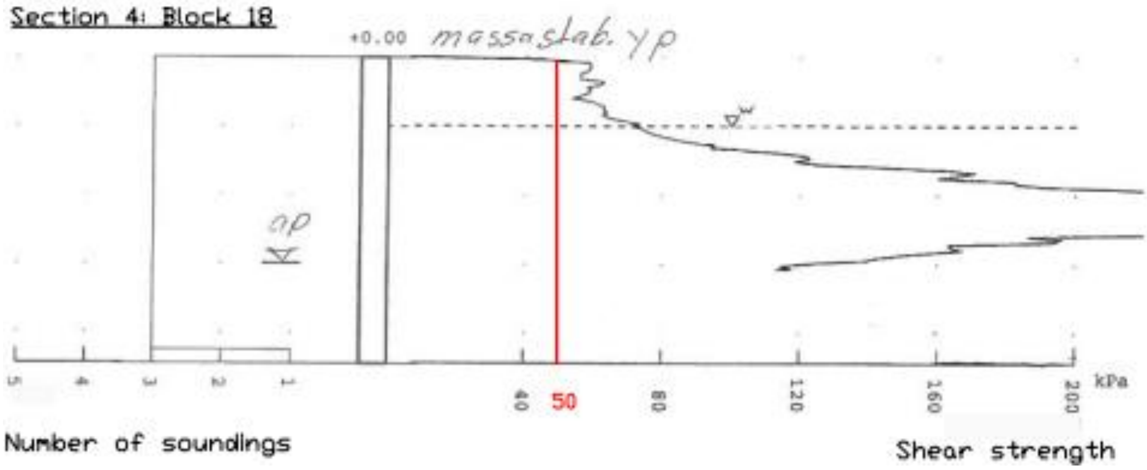

Figure 1.7b. The average shear strength in block 18 PPL-4 at the age of ten months.

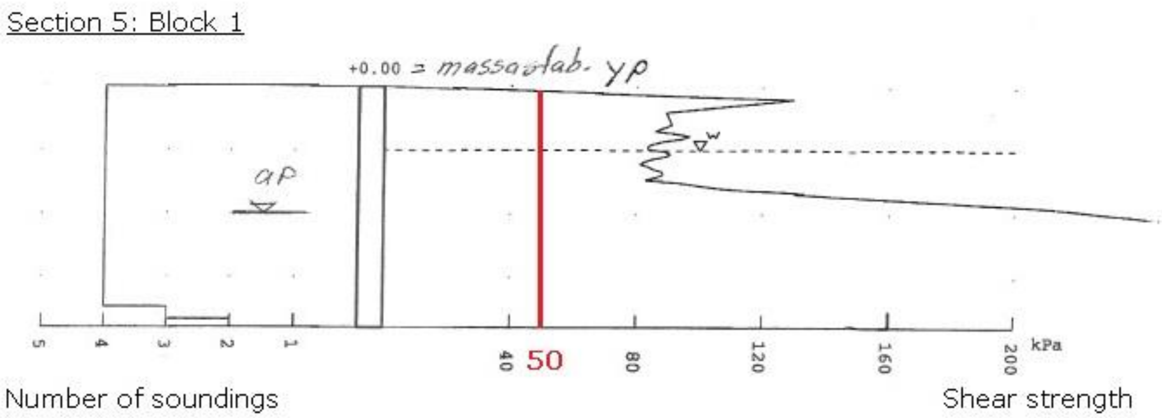

Figure 1.8a. The average shear strength of the stabilised peat in block 1 VPL-5. The age of the mass stabilisation is 67 days. The used binder material mixture is EF CFB + KS 200 + 80 kg/m^3.

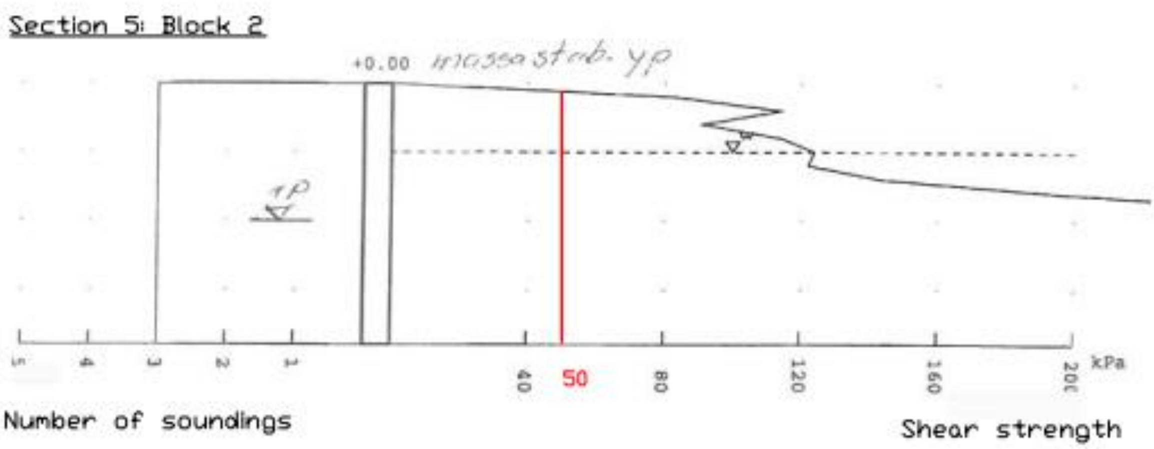

Figure 1.8b. The average shear strength in block 2 VPL-5 at the age of ten months.

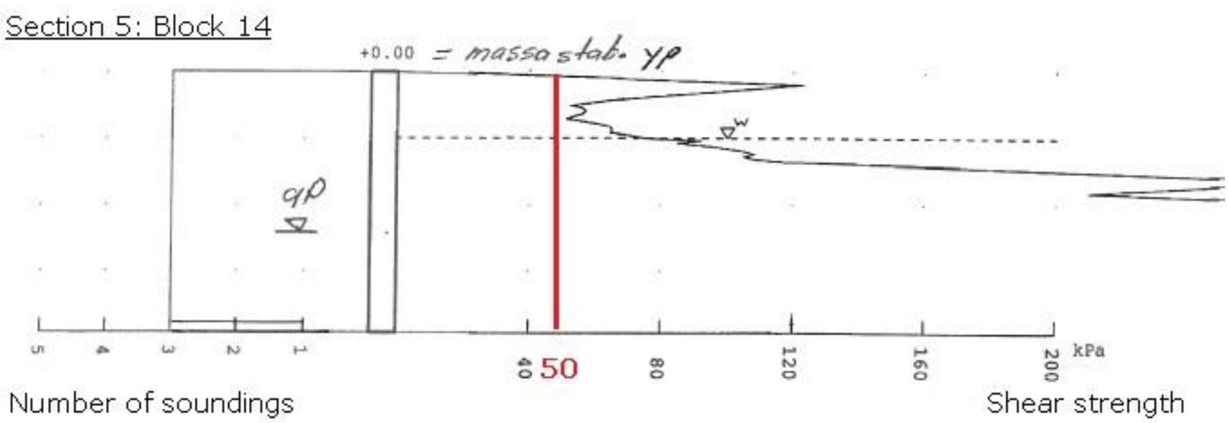

Figure 1.9. The average shear strength of the stabilised peat in block 14 VPL-5. The age of the mass stabilisation is 85 days. The used binder material mixture is EF CFB + KS 200 + 80 kg/m^3.

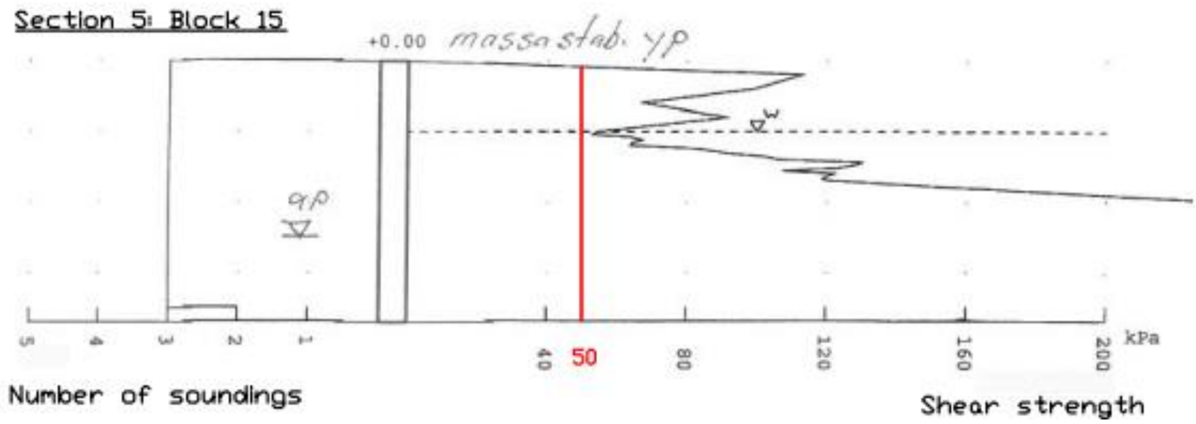

Figure 1.9b. The average shear strength in block 15 VPL-5 at the age of ten months.

The column penetration sounding is by far the most used method of the quality control for the column and mass stabilisation in Finland and Sweden. The column penetration sounding equipment and method is presented in the Figure 1.10. The width of the column sounding tip is 375 mm so the research area under the tip is about 400 mm x 20 mm. The method, however, is not flawless. In some cases on the basis of the column soundings, it is virtually impossible to tell if the material examined is a homogenous, continuous structure ("a monolith") or if there is strength variations within the material, e.g. the material is a non-uniformly strengthened mixture of strengthened granules/lumps and un-strengthened soil.

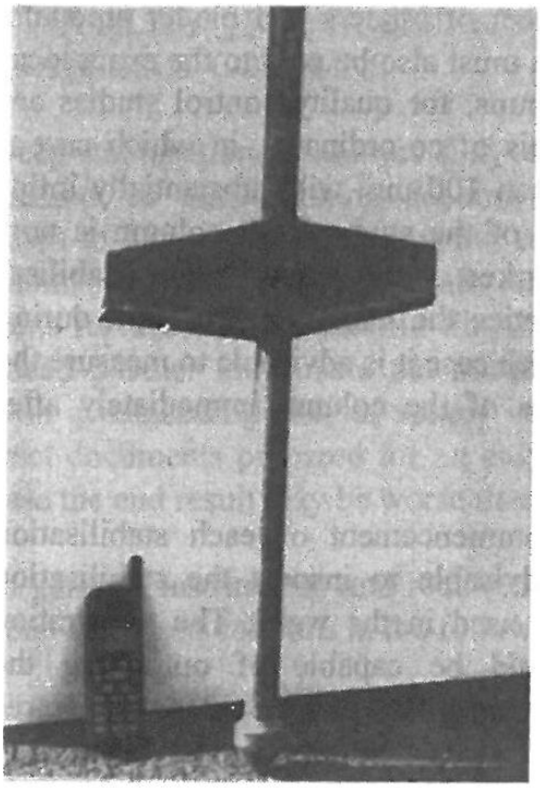

Figure 1. Column penetrometer

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Dry Mix Methods for Deep Soil Stabilization

4.2 Column penetrometer

In this method a mechanical penetrometer equipped with two vanes (see Figure 1) is pressed down (without rotation), and the compressive strength employed is measured at the upper end of the penetrometer rod. The cross-sectional area of the penetrometer is A = 100cm2 and the diameter D = 375mm. The device was originally developed in Sweden at the start of the 1980's (Torstensson 1980) and a slightly adapted version was used in Finland from 1981 (Halkola 1983). The aim was to shape the penetrometer head so that the sleeve friction would be as little as possible and that the penetrating resistance would be mainly formed outside the centre part of the column.

Because the cross-sectional area of the column penetrometer is ten times as large as that of a normal CPT cone, its application area (due to its capacity) is in relatively soft columns in which the shear strength S_u < 200 kPa. Because the penetrometer is durable, the dynamic penetration method has been experimented with in the harder columns, although the interpretation of results has then proved more difficult. As the dimensioning value used in engineering is either uni-axial compressive strength or shear strength, the measured penetration resistance is converted into shear strength by dividing it by the factor N_c = 10 (in Sweden) or N_c = 10-15 (in Finland). In Finland the shear strength values measured by the vane penetrometer are used in defining the N_c-factor.

Figure 1.10. Column penetrometer method (Halkola 1999).

1.3 Conclusion

The purpose of the XRF-analysis was to ensure the success of the stabilisation by measuring the amount of calcium in the samples taken on-site. The calcium contents measured in the laboratory and with the Niton analyser in the field were very much alike. There were some minor variation but the mixing level in the field was fulfilled and the stabilisation work has succeeded well.

According to the penetrometer soundings the stabilised sections have achieved shear strength of 50 - 160 kPa in two to three months. The target shear strength was 50 kPa. The highest strength level was achieved in section 4 with EF PF + KS 180 + 100 kg/m^3 binder mixture.

In the second quality control soundings the stabilised sections have achieved shear strength of 60…> 200 kPa at the age of ten months. In all stabilised blocks the shear strength has increased or remained constant between the first and the second quality control soundings. In the second soundings the highest strength level of over 200 kPa was achieved in section 1 with CYCL + KS 200 + 60 kg/m^3 binding mixture. However, decreasing the amount of binder is not necessary or reasonable since some of the shear strength levels were quite close to the target strength of 50 kPa.

Overall the stabilisation has been successful as the technical and environmental targets and requirements have been fulfilled.

APPENDIX 1
QUALITY CONTROL SOUNDINGS IN NOVEMBER 2013

APPENDIX 2
QUALITY CONTROL SOUNDINGS IN JUNE AND JULY 2014