Quality Control of Ground Improvement by in-situ and laboratory testing

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CONTENTS

- Specific properties of some testing methods
  - CPT
  - Ménard pressuremeter
  - Drilling and sampling, lab testing
  - Destructive rotary drilling with measurement of drilling machine parameters
- Examples of test results
- Evaluation of testing methods for different types of ground improvement

Specific properties of some testing methods

CPT

- continuous profiling
- measurement of cone inclination versus depth, so position known over the entire depth
- risk of premature refusal, so not applicable in hard ground
- small horizontal impact area
- cone will deviate from vertical
  The cone “seeks” the easiest route to penetrate, and therefore measurent takes place in the softest spots.
  This can be often avoided more or less by making an inclined CPT.
- very rapid, therefore cost effective
- other soil parameters may be derived from CPT results

Specific properties of some testing methods

Inclined CPT

Specific properties of some testing methods

Inclined CPT

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Inclined CPT

Specific properties of some testing methods

Ménard pressuremeter

- discontinuous profiling (depth interval standard 1.5 m)
- no measurement of probe inclination versus depth, so position over the whole depth not known
- drill bit will not much deviate from vertical, even when inclusion of soft spots
- no risk of premature refusal, so applicable in every ground.
- large horizontal impact area
- inclined pressuremeter holes may be used in case of heterogeneous ground
- in heterogeneous soil it is less difficult to bore a suitable test hole than taking undisturbed samples
- not very rapid, so cost not always
- other soil parameters may be derived from pressuremeter results

Specific properties of some testing methods

Drilling, sampling and lab testing

- discontinuous profiling (depth interval 1 m or more)
- no measurement of borehole inclination versus depth, so position over the whole depth not known
- drill bit will not much deviate from vertical, even when inclusion of soft spots
- no risk of premature refusal, so applicable in every ground
- in heterogeneous ground difficult to get good and representative samples
- small size of test specimen, so possibly not representative
- inclined boreholes may be used in case of heterogeneous ground
- rather slow, so not much cost effective
- other soil parameters may be derived from pressuremeter results

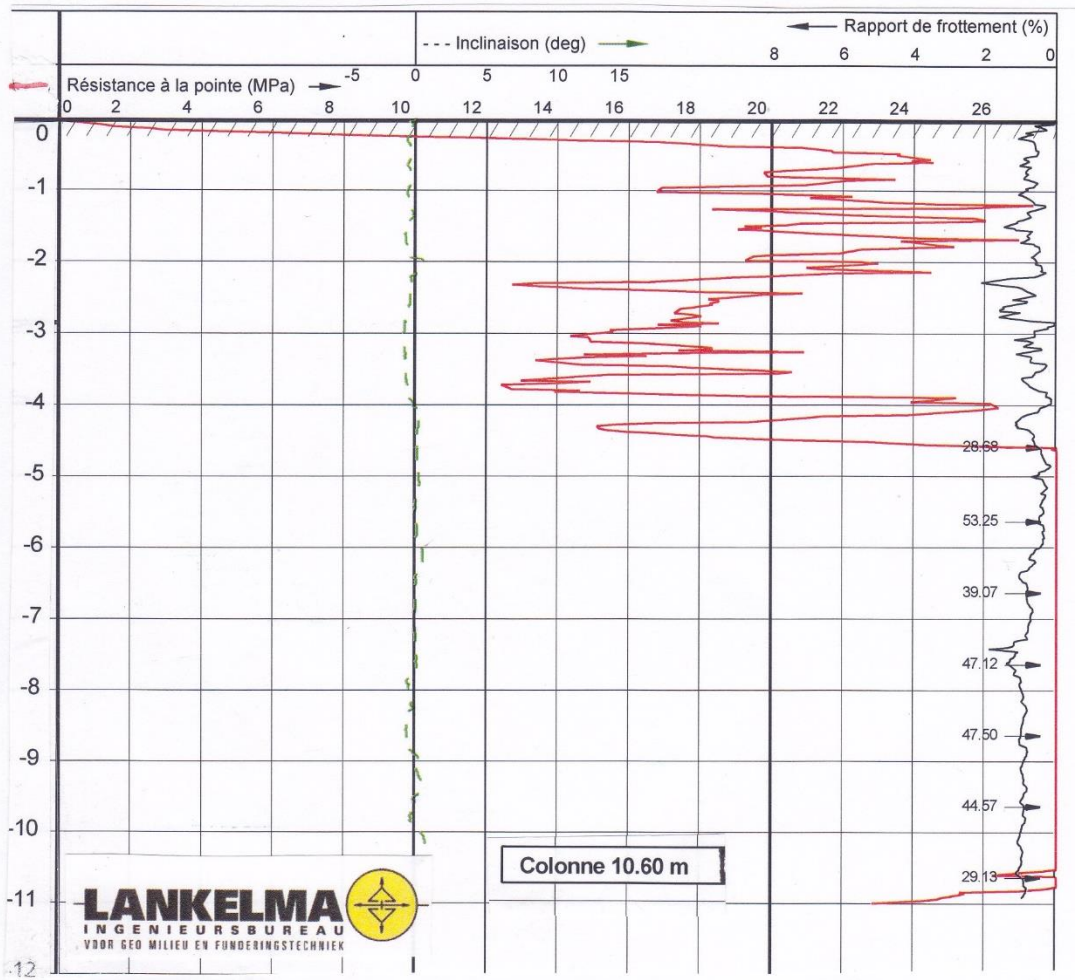
Specific properties of some testing methods

Destructive rotary drilling with measurement of drilling machine parameters

- continuous profiling
- no measurement of borehole inclination versus depth, so position over the whole depth not known
- drill bit will not much deviate from vertical, even when inclusion of soft spots
- no risk of premature refusal
- inclined boreholes may be used in case of heterogeneous ground
- very rapid, so much cost effective
- soil parameters hard to derive and only in cemented ground

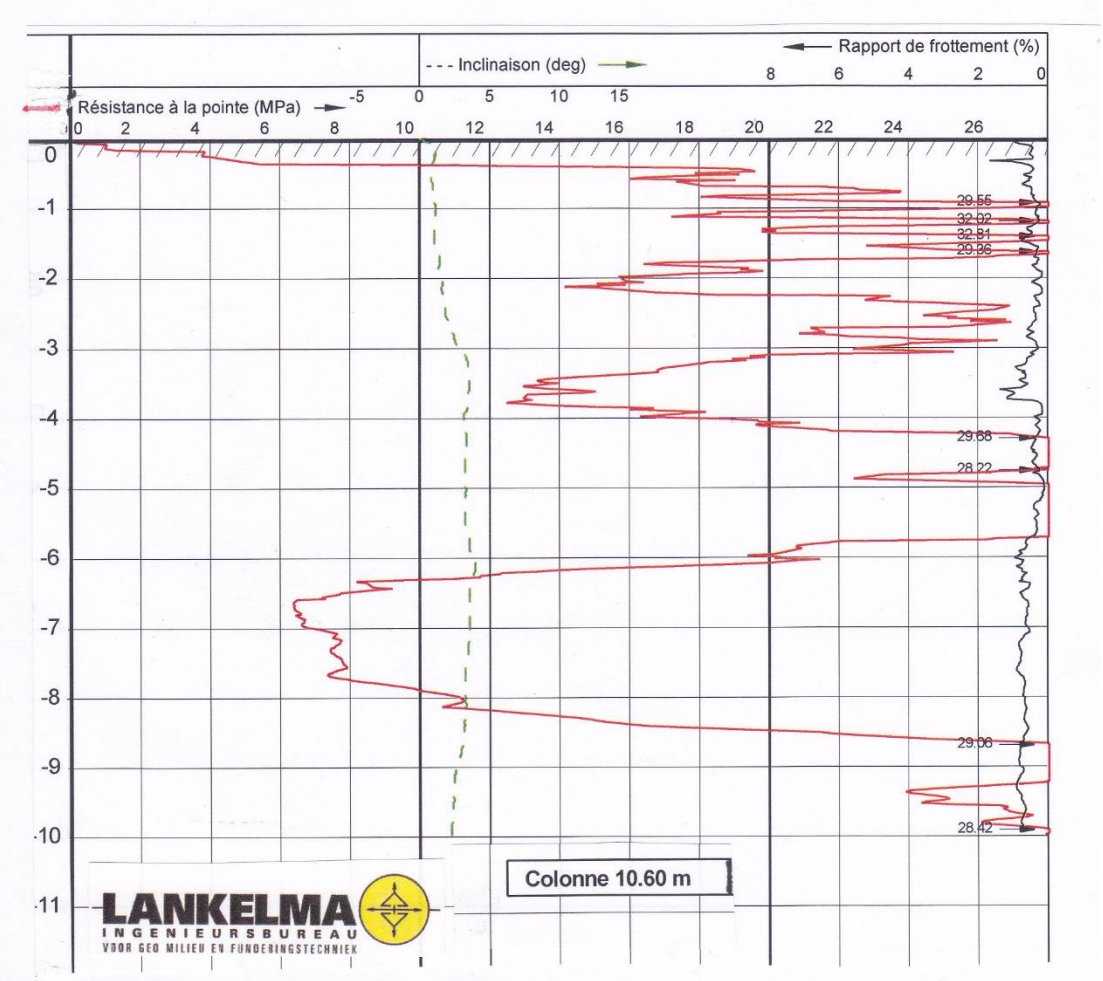
Examples of test results

CPT in stone column



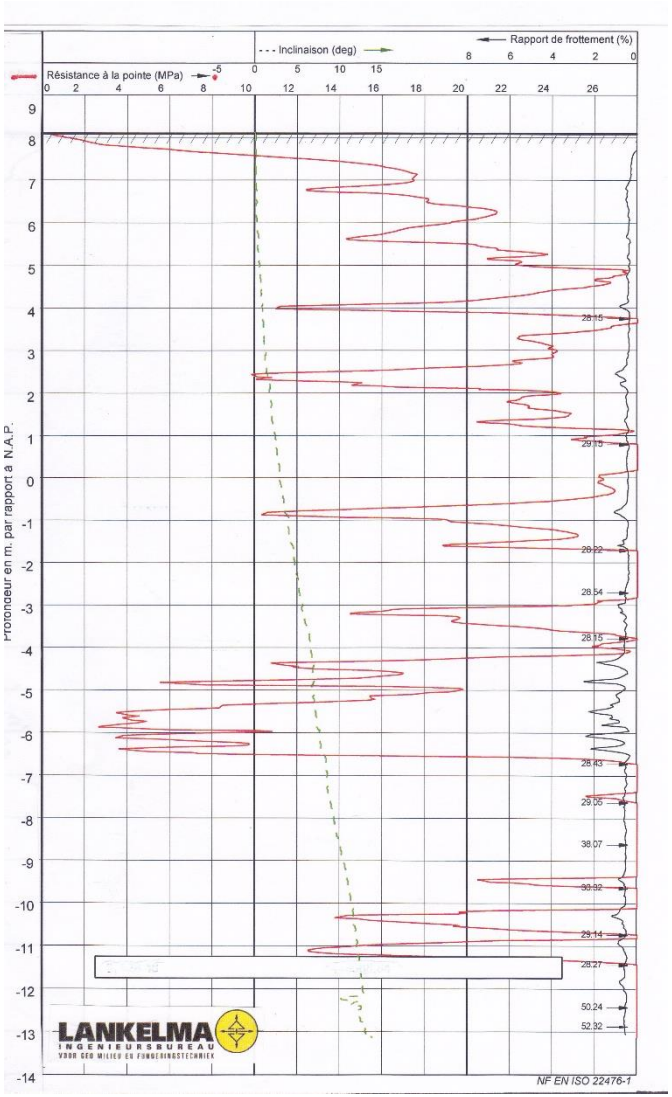
Examples of test results

CPT in stone column



Examples of test results

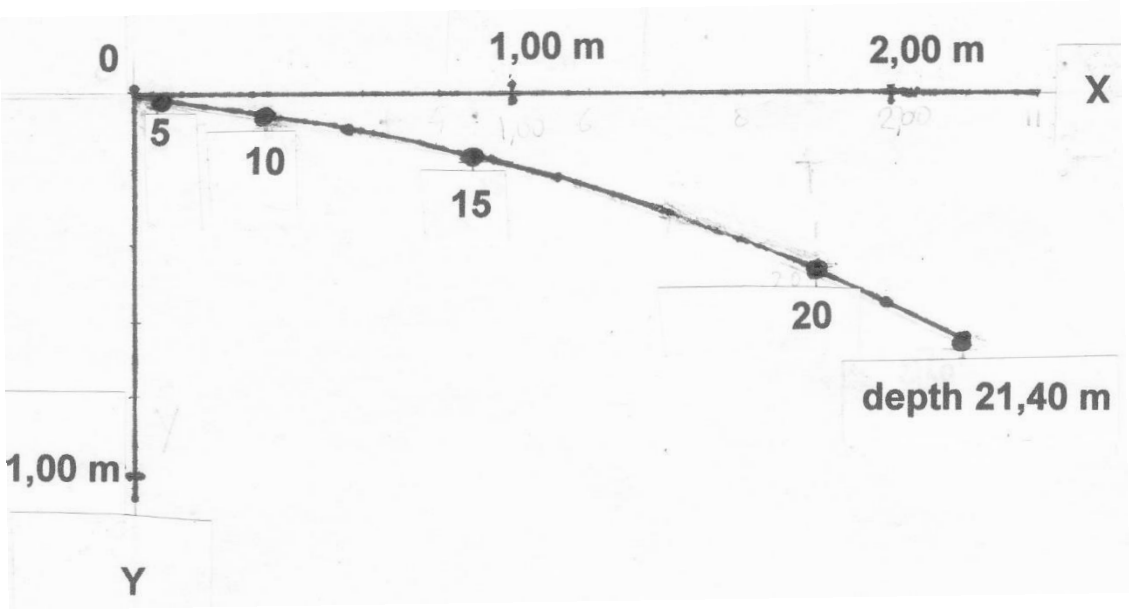
CPT after compaction by vibrofloatation



Examples of test results

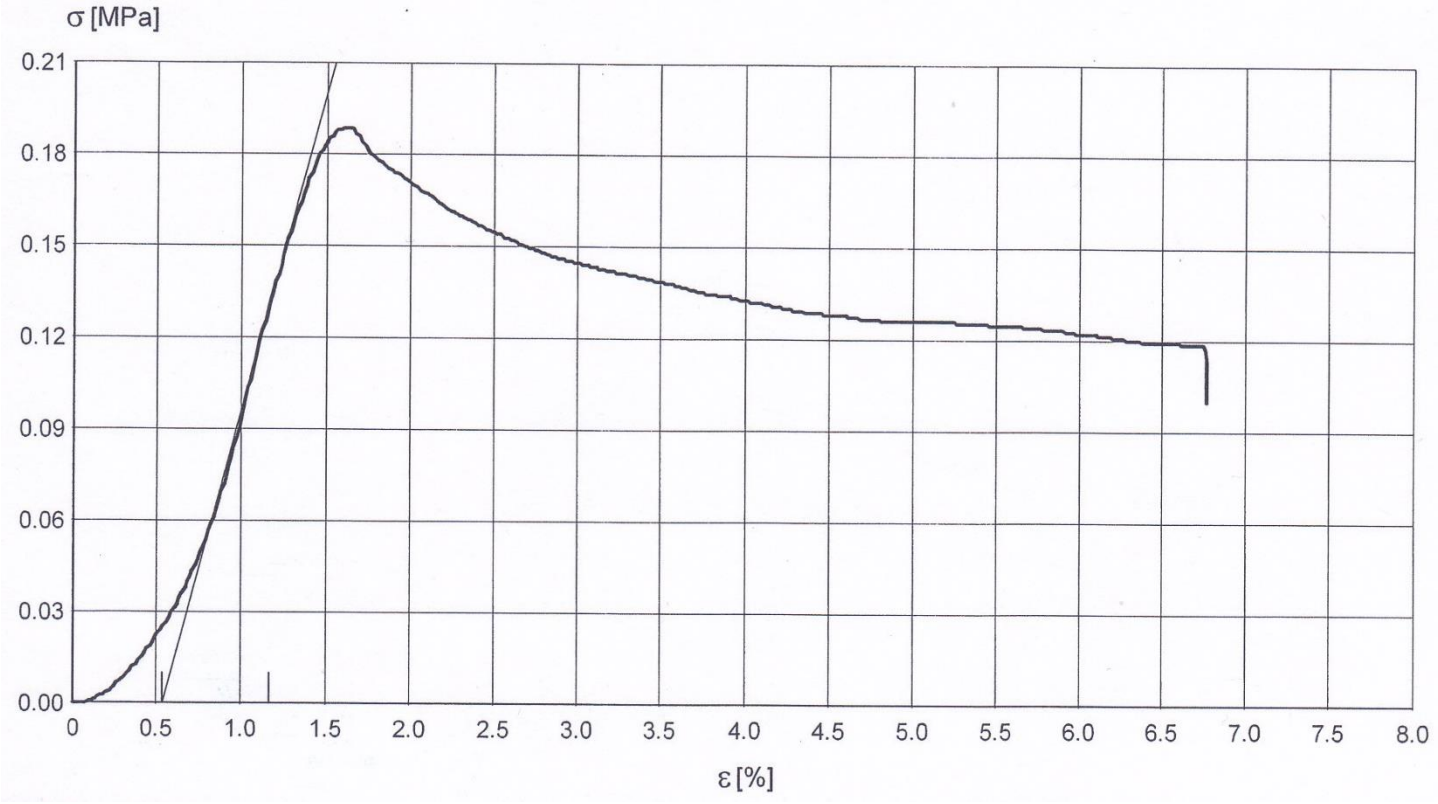
CPT after compaction by vibrofloatation

Horizontal deviation of the cone



Examples of test results

Compression test on peat sample mixed with cement



Evaluation of testing methods for different types of ground improvement

EVALUATION OF QUALITY TESTING METHODS (1)

Type of ground improve-ment	Soil type	Testing method	Soil parameter		Technical suitability	Cost effectivity	Remark
			measu-red	derived			
compaction	sand	CPT	q_c	D_r, E	+++	+++	
		Ménard pressure-meter	P_l, E	phi	+++	+	
		Sampling and triaxial testing	phi, E, D_r	none	0		required sampling class 1 not feasible in cohesionless sand
compaction	clay, loam	CPT	q_c	E, s_u	+	+++	
		Ménard pressure-meter	P_l, E	s_u	++	++	
		Sampling and triaxial testing	phi, E	none	+++	+	

EVALUATION OF QUALITY TESTING METHODS (2)

Type of ground improve-ment	Soil type	Testing method	Soil parameter		Technical suitability	Cost effectivity	Remark
			measu-red	derived			
stone columns (testing **IN** stone columns)	clay, loam	CPT	q_c	phi, E	++	+++	
		Ménard pressure-meter	P_l, E	phi	+++	+	
		Sampling and triaxial testing	0	0	0	0	material too coarse for class 1 sampling

EVALUATION OF QUALITY TESTING METHODS (3)

Type of ground improve-ment	Soil type	Testing method	Soil parameter		Technical suitability	Cost effectivity	Remark
			measu-red	derived			
mixing with binder, injection, grouting, freezing (when expected to be more or less homo-geneous)	all	CPT	qc	0	+	+++	only to be used for checking perifery when ground too hard
		Ménard pressure-meter	P_l, E	phi	+++	+++	
		Sampling and compres-sion testing	compression strength, E	0	+++	++	
		Sampling and permeability testing in lab	k_h, k_v	0	+	++	
		Borehole permeability test	k_h	k_v	++	++	advantage of large impact zone
		3-D Pumping test	k_h	k_v	+++	+	

EVALUATION OF QUALITY TESTING METHODS (4)

Type of ground improve-ment	Soil type	Testing method	Soil parameter		Technical suitability	Cost effectivity	Remark
			measu-red	derived			
mixing with binder, injection, grouting, freezing (when expected to be heterogeneous)	all	Inclined CPT,	qc	0	+	++	to be used for detecting soft spots
		Inclined Ménard pressure-meter,	Pl, E	phi	+++	+++	advantage of large impact zone
		Inclined sampling and compres-sion testing	compression strength, E	0	++	+	small size samples, so not entirely representative
		Inclined sampling and permeability testing in lab	k_h, k_v	0	+	++	
		Inclined borehole in-situ permeability test	k_h	k_v	++	++	advantage of large impact zone
		3-D Pumping test	k_h, k_v	0	+++	+	

General recommendation

- Simple cases: chose the best test method
- More complicated cases: define a mix of different test methods

THANK YOU FOR YOUR ATTENTION