GEOTECHNICAL LABORATORY TESTING
VS
IN SITU TESTING

Dr John J M Powell

Technical Director

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GEOTECHNICAL LABORATORY TESTING
VS
IN SITU TESTING
REALLY??

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THE GROUND INVESTIGATION

A ground investigation should proceed in phases as follows:

Phase 1: Desk study and field reconnaissance

Phase 2: Preliminary investigation;

Phase 3: Detailed (design) investigation;

Phase 4: Control investigation; construction review, including any follow-up investigations during construction, and the appraisal of performances

THE GROUND INVESTIGATION

NOTE 1: Phases 2 and 3 can be conducted together and can comprise one or more phases of **investigation *including sampling and testing***, topographic and hydrographic surveying and any special studies (see Section 3 to Section 9).

WHY

THE GROUND INVESTIGATION

Because we need information and parameters for

Design – BSEN 1997

•Ultimate Limit State

•Serviceability Limit State

•Safe, Reliable, Economic and environmentally friendly

THE GROUND INVESTIGATION

Because we need information and parameters for

Design – BSEN 1997

Ultimate Limit State

Serviceability Limit State

- Safe, Reliable, over design??? Rough conservative parameters maybe.
- Economic and environmentally friendly, Quality information to maximise efficient and safe design.

- How to obtain

IN SITU TESTS

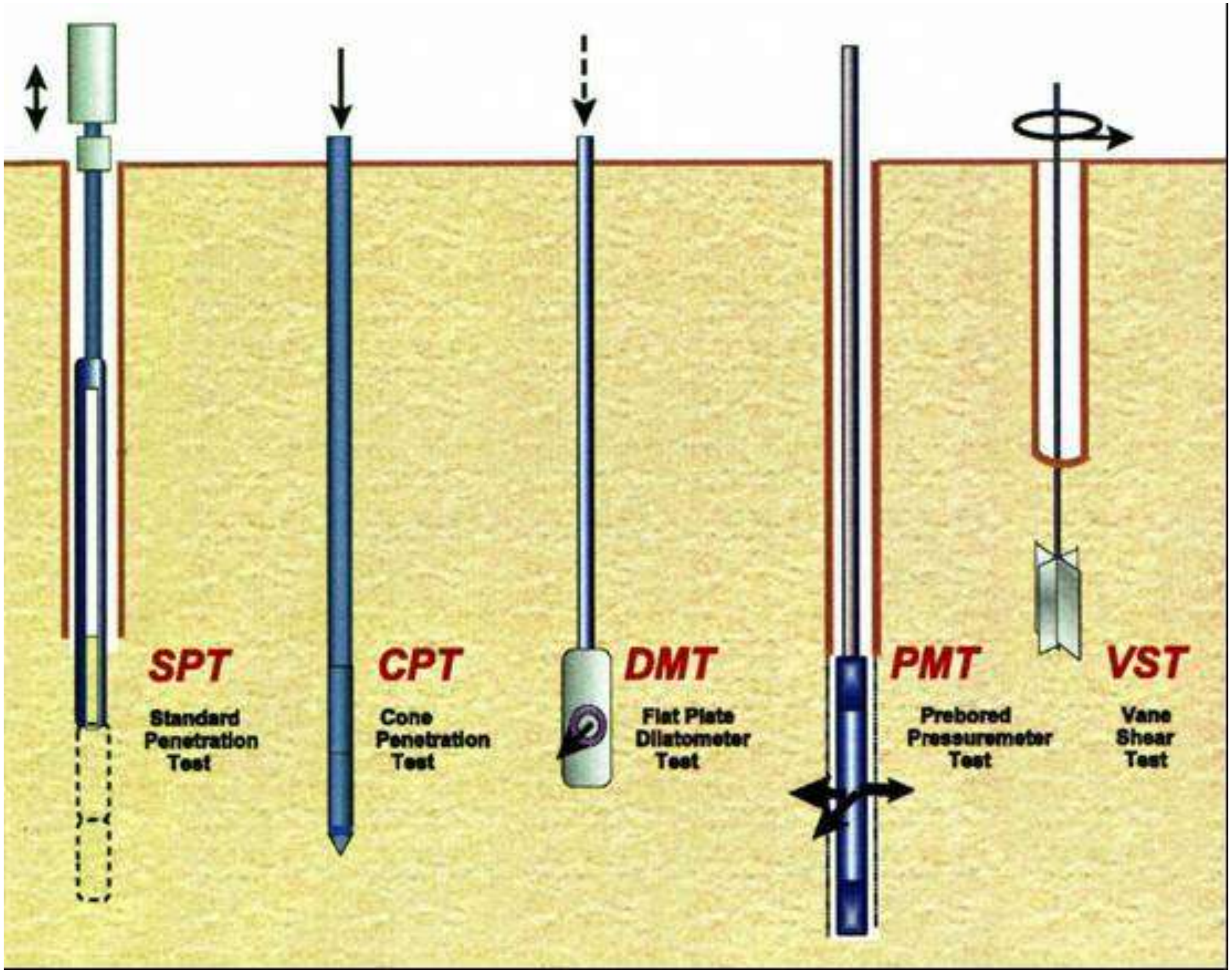
they can be quicker, easier and cheaper than sampling and laboratory testing,

the soil can be assessed in its natural environment without the potential problems of sample disturbance,

and the spatial variability of the deposit can be more fully investigated

SOME IN SITU DEVICES – ALL IS WONDERFUL

GEOLABS



WHAT WE CAN GET (MAY BE EVEN BETTER)

		Soil Parameters													Ground type						
Group	Device	Soil Type	Profile	u	*φ'	Su	I_D	m_v	c_v	k	G_0	σ_h	OCR	σ–ε	Hard rock	Soft rock	Gravel	Sand	Silt	Clay	Peat
Penetrometers	Dynamic	C	B	-	C	C	C	-	-	-	C	-	C	-	-	C	B	A	B	B	B
	Mechanical	A	A/B	-	C	C	B	C-	-	-	C	C	C	-	-	C	C	A	A	A	A
	Electric (CPT)	B	A	-	C	B	A/B	C	-	-	B	B/C	B	-	-	C	C	A	A	A	A
	Piezocone (CPTU)	A	A	A	B	B	A/B	B	AB	B	B	B/C	B	C	-	C	-	A	A	A	A
	Seismic (SCPT/SCPTU)	A	A	A	B	A/B	A/B	B	AB	B	A	B	B	B	-	C	-	A	A	A	A
	Flat Dilatometer (DMT)	B	A	C	B	B	C	B	-	-	B	B	B	C	C	C	-	A	A	A	A
	Standard (SPT)	A	B	-	C	C	B	-	-	-	C	-	C	-	-	C	B	A	A	A	A
	Resistivity probe	B	B	-	B	C	A	C	-	-	-	-	-	-	-	C	-	A	A	A	A
Pressuremeters	Pre-Bored (PBP)	B	B	-	C	B	C	B	C	-	B	C	C	C	A	A	B	B	B	A	B
	Self boring (SBP)	B	B	A[1]	B	B	B	B	A[1]	B	A[2]	A/B	B	AB[2]	-	B	-	B	B	A	B
	Full displacement (FDP)	B	B	-	C	B	C	C	C	-	A2	C	C	C	-	C	-	B	B	A	A
Others	Vane (FVT)	B	C	-	-	A	-	-	-	-	-	-	B/C	B	-	-	-	-	-	A	B
	Plate load	C	-	-	C	B	B	B	C	C	A	C	B	B	B	A	B	B	A	A	A
	Screw plate	C	C	-	C	B	B	B	C	C	A	C	B	-	-	-	-	A	A	A	A
	Borehole permeability	C	-	A	-	-	-	-	B	A	-	-	-	-	A	A	A	A	A	A	B
	Hydraulic fracture	-	-	B	-	-	-	-	C	C	-	B	-	-	B	B	-	-	C	A	C
	Crosshole /Downhole / Surface seismic	C	C	-	-	-	-	-	-	-	A	-	B	-	A	A	A	A	A	A	A

WHAT WE CAN GET - CPT

Group	Device	Soil Parameters													Ground type						
		Soil Type	Profile	u	*φ'	Su	I_D	m_v	c_v	k	G_0	σ_h	OCR	σ-ε	Hard rock	Soft rock	Gravel	Sand	Silt	Clay	Peat
Penetrometers	Dynamic	C	B	-	C	C	C	-	-	-	C	-	C	-	-	C	B	A	B	B	B
	Mechanical	A	A/B	-	C	C	B	C-	-	-	C	C	C	-	-	C	C	A	A	A	A
	Electric (CPT)	B	A	-	C	B	A/B	C	-	-	B	B/C	B	-	-	C	C	A	A	A	A
	Piezocone (CPTU)	A	A	A	B	B	A/B	B	AB	B	B	B/C	B	C	-	C	-	A	A	A	A
	Seismic (SCPT/SCPTU)	A	A	A	B	A/B	A/B	B	AB	B	A	B	B	B	-	C	-	A	A	A	A
	Flat Dilatometer (DMT)	B	A	C	B	B	C	B	-	-	B	B	B	C	C	C	-	A	A	A	A
	Standard (SPT)	A	B	-	C	C	B	-	-	-	C	-	C	-	-	C	B	A	A	A	A
	Resistivity probe	B	B	-	B	C	A	C	-	-	-	-	-	-	-	C	-	A	A	A	A
Pressuremeters	Pre-Bored (PBP)	B	B	-	C	B	C	B	C	-	B	C	C	C	A	A	B	B	B	A	B
	Self boring (SBP)	B	B	A[1]	B	B	B	B	A[1]	B	A[2]	A/B	B	AB[2]	-	B	-	B	B	A	B
	Full displacement (FDP)	B	B	-	C	B	C	C	C	-	A2	C	C	C	-	C	-	B	B	A	A
Others	Vane (FVT)	B	C	-	-	A	-	-	-	-	-	-	B/C	B	-	-	-	-	-	A	B
	Plate load	C	-	-	C	B	B	B	C	C	A	C	B	B	B	A	B	B	A	A	A
	Screw plate	C	C	-	C	B	B	B	C	C	A	C	B	-	-	-	-	A	A	A	A
	Borehole permeability	C	-	A	-	-	-	-	B	A	-	-	-	-	A	A	A	A	A	A	B
	Hydraulic fracture	-	-	B	-	-	-	-	C	C	-	B	-	-	B	B	-	-	C	A	C
	Crosshole /Downhole / Surface seismic	C	C	-	-	-	-	-	-	-	A	-	B	-	A	A	A	A	A	A	A

WHAT WE CAN GET - CPTU

Group	Device	Soil Parameters													Ground type						
		Soil Type	Profile	u	*φ'	Su	I_D	m_v	c_v	k	G_0	σ_h	OCR	σ–ε	Hard rock	Soft rock	Gravel	Sand	Silt	Clay	Peat
Penetrometers	Dynamic	C	B	-	C	C	C	-	-	-	C	-	C	-	-	C	B	A	B	B	B
	Mechanical	A	A/B	-	C	C	B	C-	-	-	C	C	C	-	-	C	C	A	A	A	A
	Electric (CPT)	B	A	-	C	B	A/B	C	-	-	B	B/C	B	-	-	C	C	A	A	A	A
	Piezocone (CPTU)	**A**	**A**	**A**	**B**	**B**	**A/B**	**B**	**AB**	**B**	**B**	**B/C**	**B**	**C**	**-**	**C**	**-**	**A**	**A**	**A**	**A**
	Seismic (SCPT/SCPTU)	A	A	A	B	A/B	A/B	B	AB	B	A	B	B	B	-	C	-	A	A	A	A
	Flat Dilatometer (DMT)	B	A	C	B	B	C	B	-	-	B	B	B	C	C	C	-	A	A	A	A
	Standard (SPT)	A	B	-	C	C	B	-	-	-	C	-	C	-	-	C	B	A	A	A	A
	Resistivity probe	B	B	-	B	C	A	C	-	-	-	-	-	-	-	C	-	A	A	A	A
Pressuremeters	Pre-Bored (PBP)	B	B	-	C	B	C	B	C	-	B	C	C	C	A	A	B	B	B	A	B
	Self boring (SBP)	B	B	A[1]	B	B	B	B	A[1]	B	A[2]	A/B	B	AB[2]	-	B	-	B	B	A	B
	Full displacement (FDP)	B	B	-	C	B	C	C	C	-	A2	C	C	C	-	C	-	B	B	A	A
Others	Vane (FVT)	B	C	-	-	A	-	-	-	-	-	-	B/C	B	-	-	-	-	-	A	B
	Plate load	C	-	-	C	B	B	B	C	C	A	C	B	B	B	A	B	B	A	A	A
	Screw plate	C	C	-	C	B	B	B	C	C	A	C	B	-	-	-	-	A	A	A	A
	Borehole permeability	C	-	A	-	-	-	-	B	A	-	-	-	-	A	A	A	A	A	A	B
	Hydraulic fracture	-	-	B	-	-	-	-	C	C	-	B	-	-	B	B	-	-	C	A	C
	Crosshole /Downhole / Surface seismic	C	C	-	-	-	-	-	-	-	A	-	B	-	A	A	A	A	A	A	A

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WHAT WE CAN GET - SCPTU

Group	Device	Soil Parameters													Ground type						
		Soil Type	Profile	u	*φ'	Su	I_D	m_v	c_v	k	G_0	σ_h	OCR	σ–ε	Hard rock	Soft rock	Gravel	Sand	Silt	Clay	Peat
Penetrometers	Dynamic	C	B	-	C	C	C	-	-	-	C	-	C	-	-	C	B	A	B	B	B
	Mechanical	A	A/B	-	C	C	B	C-	-	-	C	C	C	-	-	C	C	A	A	A	A
	Electric (CPT)	B	A	-	C	B	A/B	C	-	-	B	B/C	B	-	-	C	C	A	A	A	A
	Piezocone (CPTU)	A	A	A	B	B	A/B	B	AB	B	B	B/C	B	C	-	C	-	A	A	A	A
	Seismic (SCPT/SCPTU)	A	A	A	B	A/B	A/B	B	AB	B	A	B	B	B	-	C	-	A	A	A	A
	Flat Dilatometer (DMT)	B	A	C	B	B	C	B	-	-	B	B	B	C	C	C	-	A	A	A	A
	Standard (SPT)	A	B	-	C	C	B	-	-	-	C	-	C	-	-	C	B	A	A	A	A
	Resistivity probe	B	B	-	B	C	A	C	-	-	-	-	-	-	-	C	-	A	A	A	A
Pressuremeters	Pre-Bored (PBP)	B	B	-	C	B	C	B	C	-	B	C	C	C	A	A	B	B	B	A	B
	Self boring (SBP)	B	B	A[1]	B	B	B	B	A[1]	B	A[2]	A/B	B	AB[2]	-	B	-	B	B	A	B
	Full displacement (FDP)	B	B	-	C	B	C	C	C	-	A2	C	C	C	-	C	-	B	B	A	A
Others	Vane (FVT)	B	C	-	-	A	-	-	-	-	-	-	B/C	B	-	-	-	-	-	A	B
	Plate load	C	-	-	C	B	B	B	C	C	A	C	B	B	B	A	B	B	A	A	A
	Screw plate	C	C	-	C	B	B	B	C	C	A	C	B	-	-	-	-	A	A	A	A
	Borehole permeability	C	-	A	-	-	-	-	B	A	-	-	-	-	A	A	A	A	A	A	B
	Hydraulic fracture	-	-	B	-	-	-	-	C	C	-	B	-	-	B	B	-	-	C	A	C
	Crosshole /Downhole / Surface seismic	C	C	-	-	-	-	-	-	-	A	-	B	-	A	A	A	A	A	A	A

WHAT WE CAN GET - SCPTU

Group	Device	Soil Type	Profile	u	$*\phi'$	Su	I_D	m_v	c_v	k	G_0	σ_h	OCR	$\sigma-\varepsilon$
		Soil Parameters												
Penetrometers	Dynamic	C	B	-	C	C	C	-	-	-	C	-	C	-
	Mechanical	A	A/B	-	C	C	B	C-	-	-	C	C	C	-
	Electric (CPT)	B	A	-	C	B	A/B	C	-	-	B	B/C	B	-
	Piezocone (CPTU)	A	A	A	B	B	A/B	B	AB	B	B	B/C	B	C
	Seismic (SCPT/SCPTU)	A	A	A	B	A/B	A/B	B	AB	B	A	B	B	B
	Flat Dilatometer (DMT)	B	A	C	B	B	C	B	-	-	B	B	B	C
	Standard (SPT)	A	B	-	C	C	B	-	-	-	C	-	C	-

Applicability A – high B – moderate C – low

WHAT WE CAN GET - SCPTU

Ground type						
Hard rock	Soft rock	Gravel	Sand	Silt	Clay	Peat
-	C	B	A	B	B	B
-	C	C	A	A	A	A
-	C	C	A	A	A	A
-	C	C	A	A	A	A
-	C	C	A	A	A	A
C	C	-	A	A	A	A
-	C	B	A	A	A	A

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WHAT WE CAN GET (MAY BE EVEN BETTER)

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Group	Device	Soil Parameters													Ground type						
		Soil Type	Profile	u	*φ'	Su	I_D	m_v	c_v	k	G_0	σ_h	OCR	σ–ε	Hard rock	Soft rock	Gravel	Sand	Silt	Clay	Peat
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	Mechanical	A	A/B	-	C	C	B	C-	-	-	C	C	C	-	-	C	C	A	A	A	A
	Electric (CPT)	B	A	-	C	B	A/B	C	-	-	B	B/C	B	-	-	C	C	A	A	A	A
	Piezocone (CPTU)	A	A	A	B	B	A/B	B	AB	B	B	B/C	B	C	-	C	-	A	A	A	A
	Seismic (SCPT/SCPTU)	A	A	A	B	A/B	A/B	B	AB	B	A	B	B	B	-	C	-	A	A	A	A
	Flat Dilatometer (DMT)	B	A	C	B	B	C	B	-	-	B	B	B	C	C	C	-	A	A	A	A
	Standard (SPT)	A	B	-	C	C	B	-	-	-	C	-	C	-	-	C	B	A	A	A	A
	Resistivity probe	B	B	-	B	C	A	C	-	-	-	-	-	-	-	C	-	A	A	A	A
Pressuremeters	Pre-Bored (PBP)	B	B	-	C	B	C	B	C	-	B	C	C	C	A	A	B	B	B	A	B
	Self boring (SBP)	B	B	A[1]	B	B	B	B	A[1]	B	A[2]	A/B	B	AB[2]	-	B	-	B	B	A	B
	Full displacement (FDP)	B	B	-	C	B	C	C	C	-	A2	C	C	C	-	C	-	B	B	A	A
Others	Vane (FVT)	B	C	-	-	A	-	-	-	-	-	-	B/C	B	-	-	-	-	-	A	B
	Plate load	C	-	-	C	B	B	B	C	C	A	C	B	B	B	A	B	B	A	A	A
	Screw plate	C	C	-	C	B	B	B	C	C	A	C	B	-	-	-	-	A	A	A	A
	Borehole permeability	C	-	A	-	-	-	-	B	A	-	-	-	-	A	A	A	A	A	A	B
	Hydraulic fracture	-	-	B	-	-	-	-	C	C	-	B	-	-	B	B	-	-	C	A	C
	Crosshole /Downhole / Surface seismic	C	C	-	-	-	-	-	-	-	A	-	B	-	A	A	A	A	A	A	A

IN SITU TESTING CPT/CPTU

Use of CPT/CPTU and other sensors

Stratigraphy

Soil Type

Soil properties

Direct Design

LIFE IS WONDERFUL

ALL YOU WOULD EVER NEED

BUT!!!!!

IN SITU TESTING CPT/CPTU

Use of CPT/CPTU and other sensors

Stratigraphy

Soil Type

Soil properties

Direct Design

The tests themselves can have quality issues and
the geotechnical information they give is only as good as the data they are correlated with!!!

IN SITU TESTING – THE TRUTH

Most insitu testing techniques rely on EMPIRICAL CORRELATIONS of some form!

They are as good as the database that they are correlated with!

Where does that database come from?

<u>LABORATORY TESTING!</u>

DESIGN – BSEN 1997

Ultimate Limit State

Serviceability Limit State

Can we get the parameters from insitu tests alone?

Can we get the parameters from past experience alone?

and

With confidence?

NO

THE PAST?

Not always reliable?

Today?

"PUT ANOTHER SHOVEL IN, FRED— REMEMBER THEY WANT FULL CORES."

ESSENTIAL LABORATORY TESTING

Our Practice has been questionable at times but now at the top end we are second to none in delivering high quality samples that can be tested with precision.

LABORATORY TESTING

A research toy?

No Routine
Advanced
Laboratory Testing

PROS AND CONS

Pros

Visual inspection

Controlled boundaries

Accuracy of measurements
small strain

Orientations

Simulate loadings/stress paths

Rate effects/drainage etc

Cons

??????

PROS AND CONS

Pros

Visual inspection

Controlled boundaries

Accuracy of measurements
small strain

Orientations

Simulate loadings/stress paths

Rate effects/drainage etc

Cons

Sample quality and disturbance.

Sorted! we can - but do we?

Laboratories can destroy even the best samples

Training and QA!

ESSENTIAL LABORATORY TESTING

THE LONDON CLAY

How would we have ever understood its complexity without

LABORATORY TESTING!

ESSENTIAL LABORATORY TESTING

This Year's and many past Rankine lectures

Built around our understanding from

<u>LABORATORY TESTING!</u>

ESSENTIAL LABORATORY TESTING

UNDERSTANDING Behaviour of many soils would be impossible without

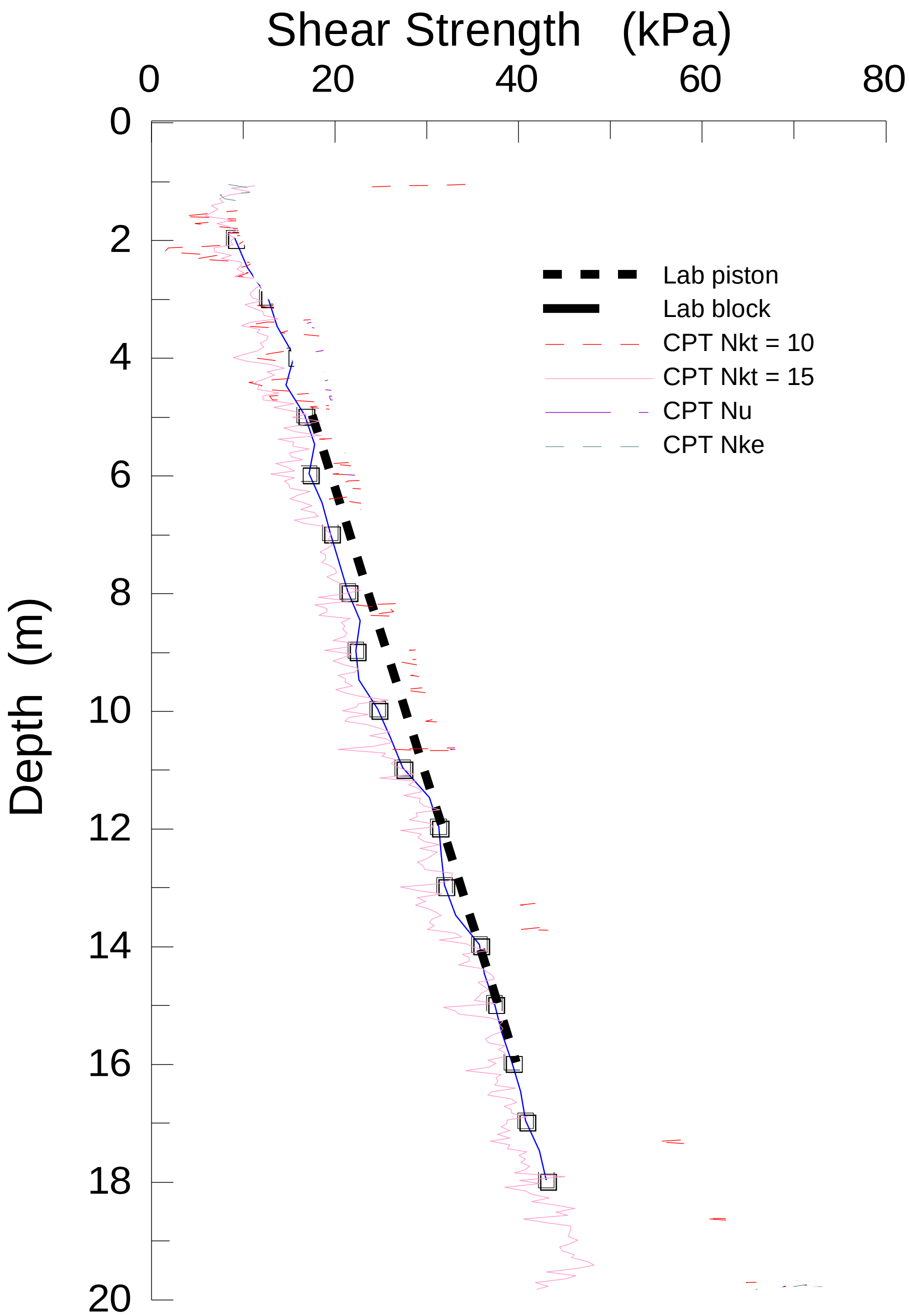
LABORATORY TESTING!

OLD AND NEW!

SHEAR STRENGTH - BOTHKENNAR

CORRELATION TO MATCH SOURCE

SAMPLE DISTURBANCE ASSESSMENT?



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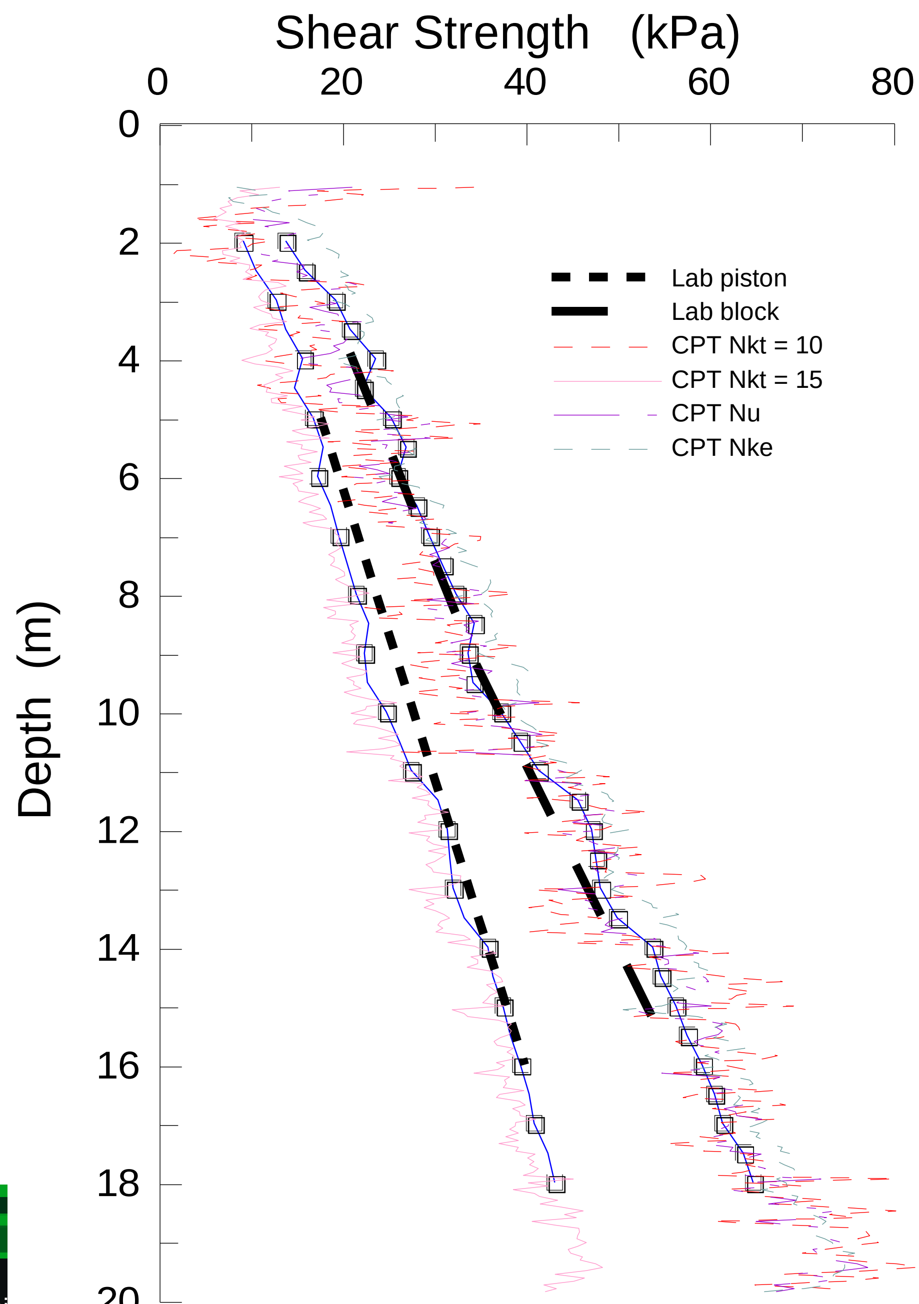
OLD AND NEW!

SHEAR STRENGTH - BOTHKENNAR

CORRELATION TO MATCH SOURCE

SAMPLE DISTURBANCE ASSESSMENT?



QUALITY LABORATORY TESTING

How would we have known?

What would this mean

- For design
- For costs
- For safety

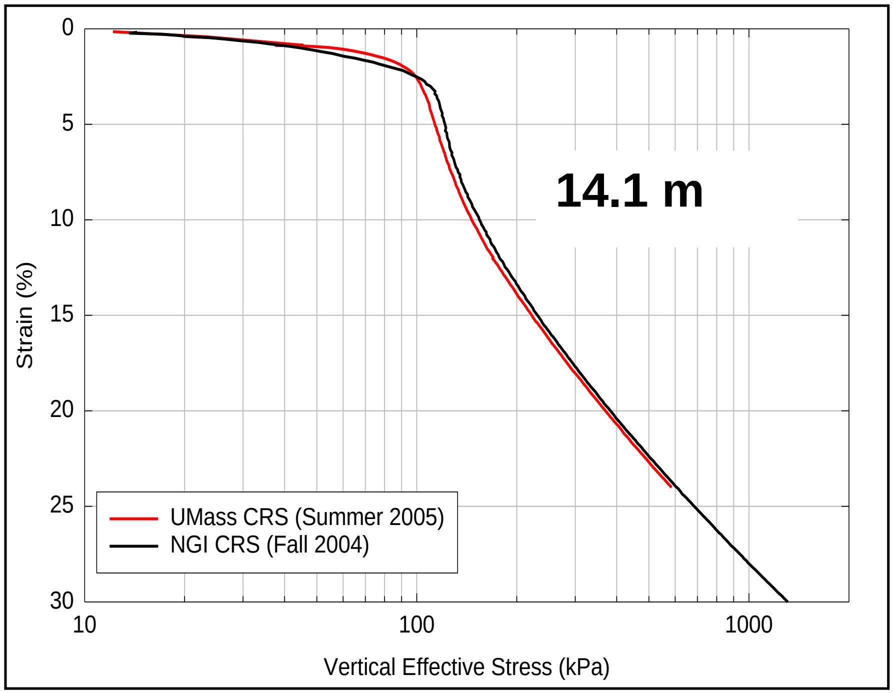
QUALITY LABORATORY TESTING

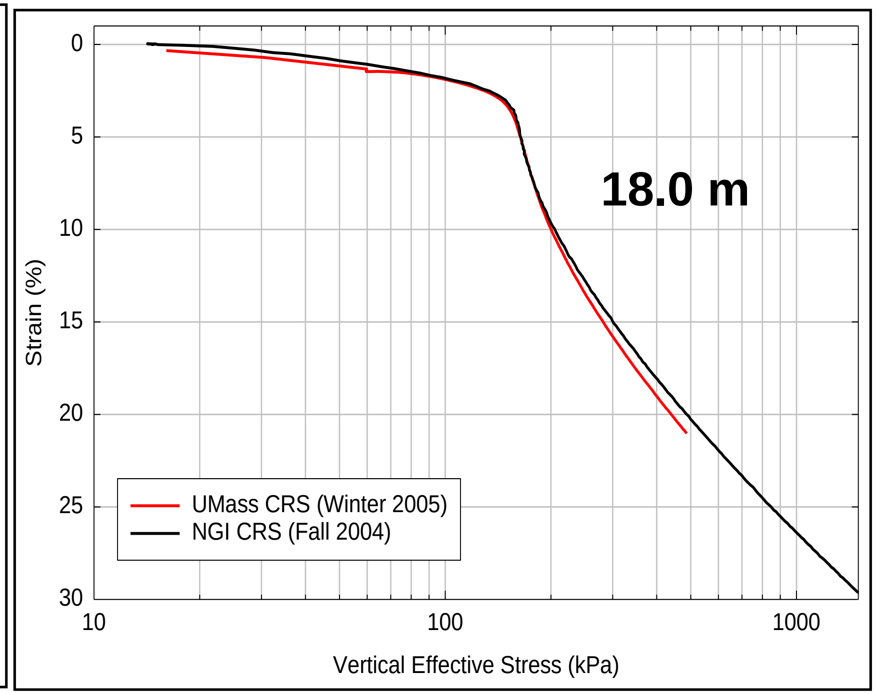
Do we suffer from:

Over design because of lack of confidence in parameters????

Poor UK routine Practice in GI?

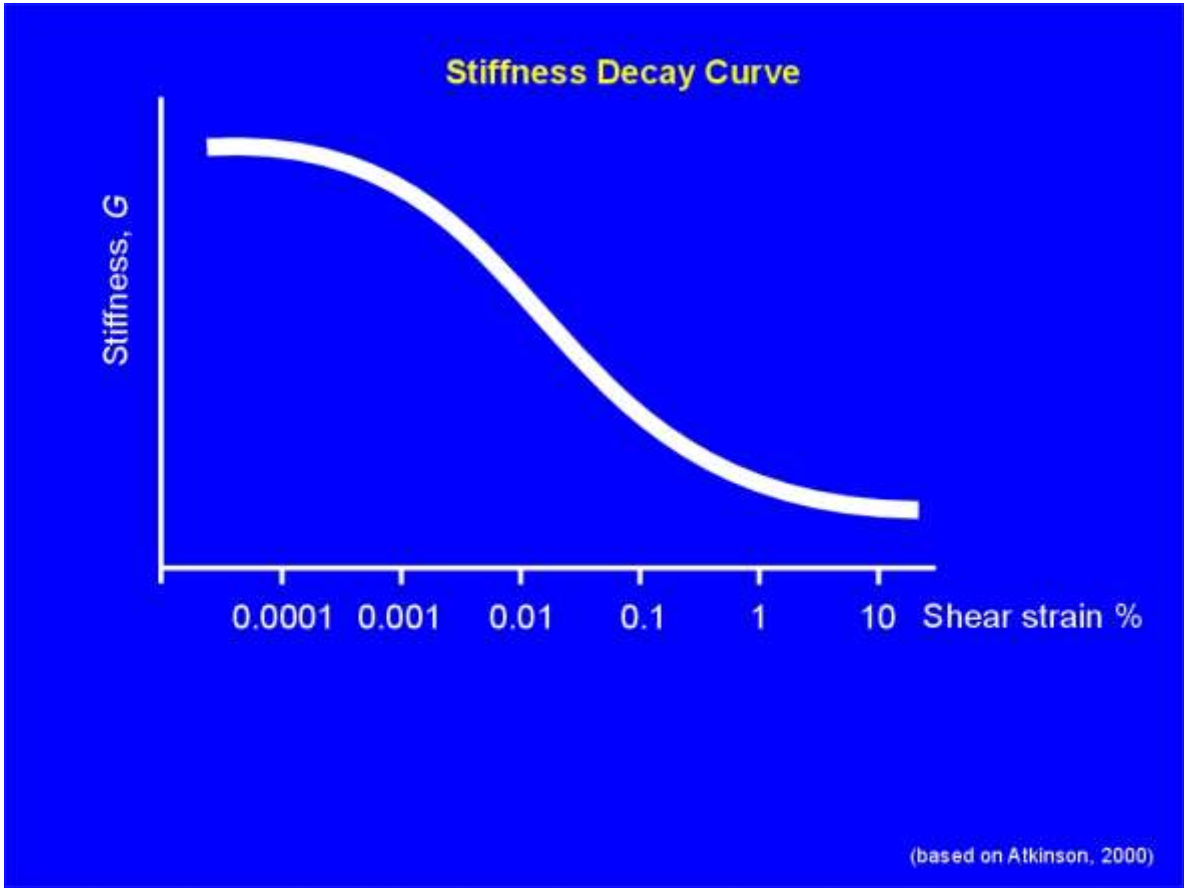
QUALITY OF GI –
SAMPLE DISTURBANCE – WHICH FACTORS ARE MOST IMPORTANT ?



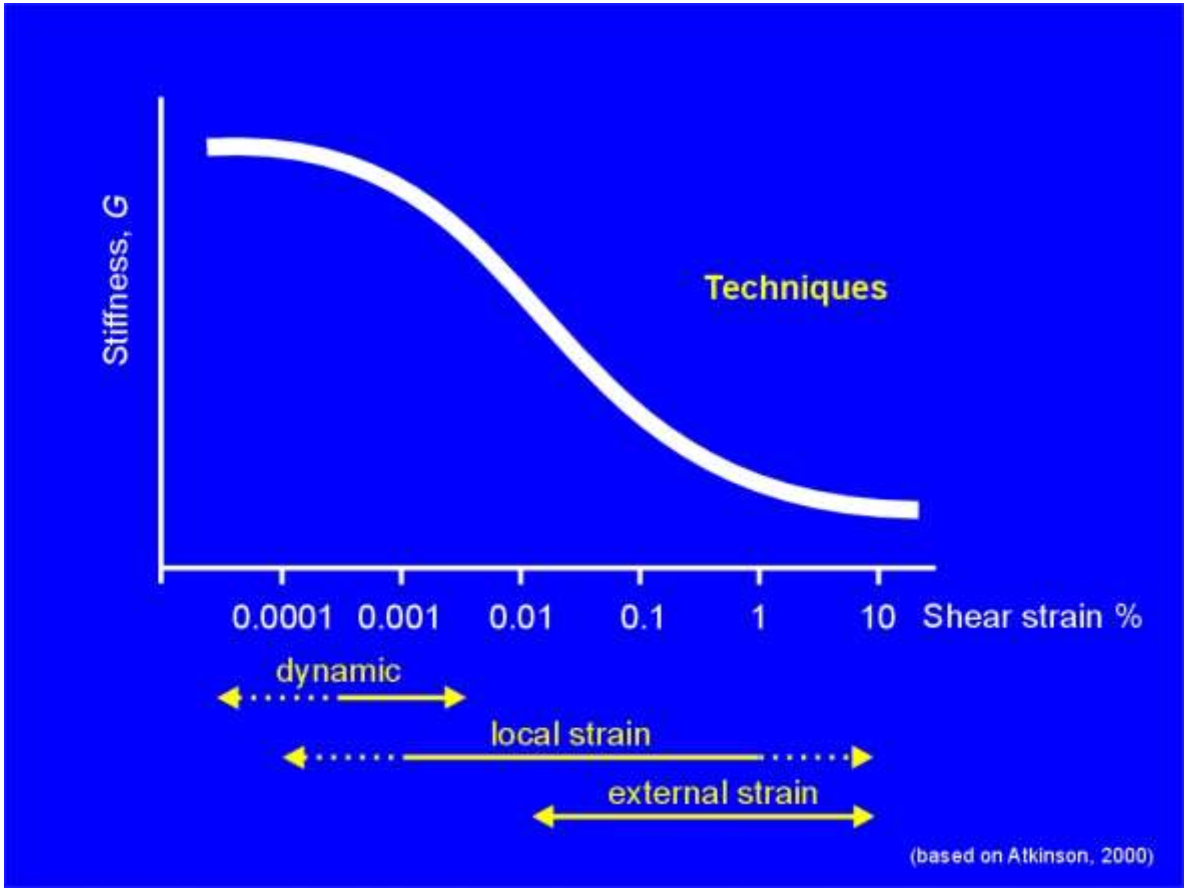


Onsøy block samples
Tested at NGI and at UMass

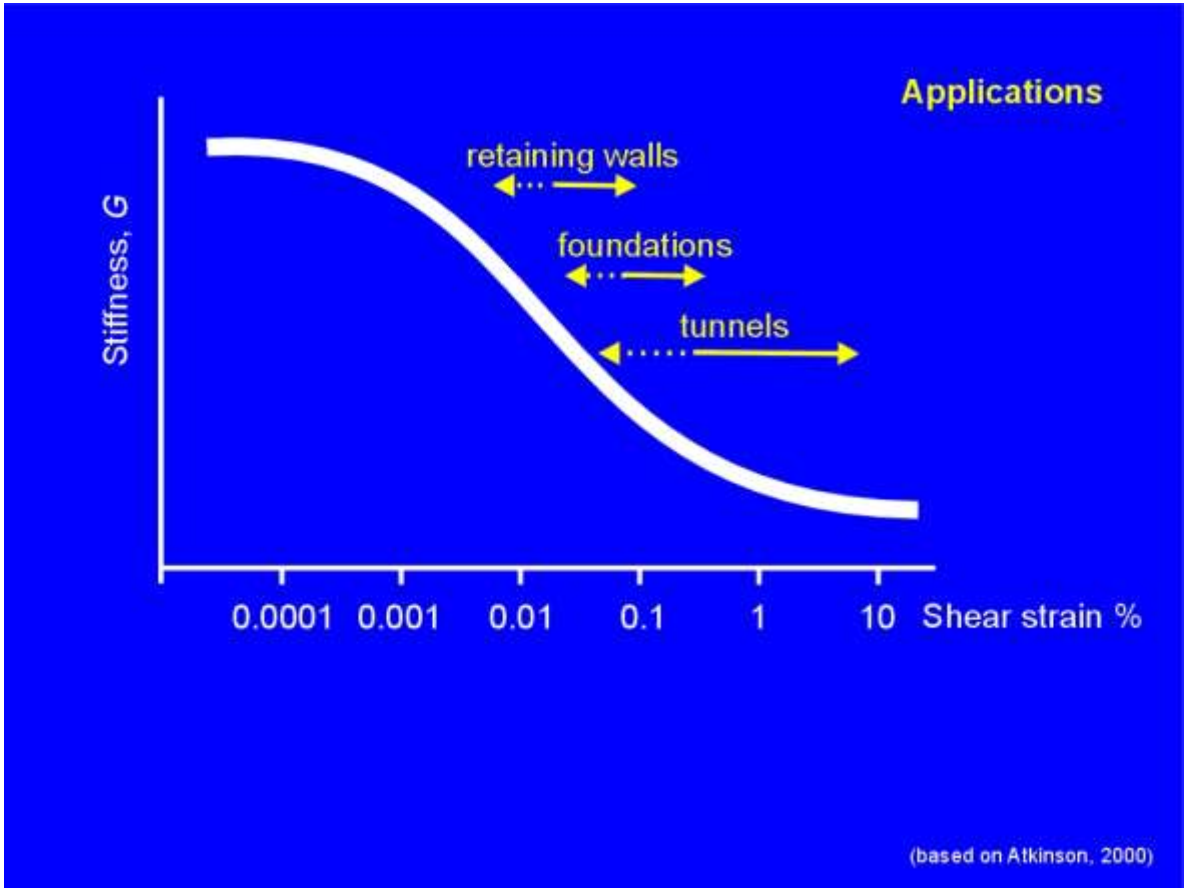
STIFFNESS


Stiffness Decay Curve
Stiffness, G
0.0001 0.001 0.01 0.1 1 10 Shear strain %
(based on Atkinson, 2000)

STIFFNESS


Stiffness, G
Techniques
0.0001 0.001 0.01 0.1 1 10 Shear strain %
dynamic
local strain
external strain
(based on Atkinson, 2000)

STIFFNESS



How without LABORATORY testing

Pressuremeter??

SCHEDULING LABORATORY TESTING

Not a prescriptive process 6 x A, 4 x B etc; same as last time!

It needs to be thought out and planned. Tests need to be targeted and quality ensured.

A few well selected tests are of far more value than hundreds of random tests.

You need people who understand the tests to specify them

You need confidence in the results

We need efficiency in design!

SCHEDULING IN SITU TESTS

Not a prescriptive process 6 x A, 4 x B etc; same as last time!

It needs to be thought out and planned. Tests need to be targeted and quality ensured.

You need people who understand the tests to specify them

You need confidence in the results

We need efficiency in design!

We have powerful IN SITU tests

We have highly sophisticated LABORATORY tests

BUT

ALL need GOOD specification

AND

GOOD execution

CONCLUSIONS

Laboratory Testing is ESSENTIAL in all projects

In situ tests should be ESSENTIAL in all projects

But

It ALL needs to be properly planned, on samples of the right quality, the right types of insitu tests and ALL undertaken with care and the correct QA.

WE CAN DO IT if we all TRY

CONCLUSIONS

Love and marriage

Horse and carriage

May not rhyme

BUT Insitu testing is lost/useless without

LABORATORY   testing

GEOTECHNICAL LABORATORY TESTING
AND
IN SITU TESTING

They Go Together!!!

For a better Ground Investigation

THANK YOU

POWELLJ@GEOLABS.CO.UK