UNIVERSITY OF LEEDS

The Geological Society
Engineering Group Forum

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Geotechnics of Glaciogenic Deposits

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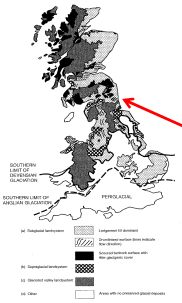
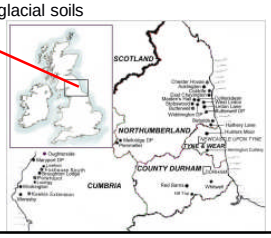
- Introduction
  - Variability, hazards and design parameters
- Geological Model
  - Formation, content
- Geotechnical Model
  - Characteristic strength, stiffness and permeability
- Parameter selection

Introduction

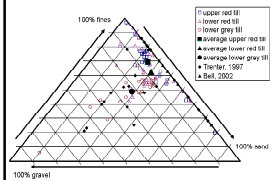
The extent of glacial deposits



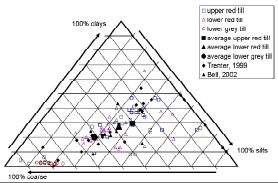
- Glacial soils amount to 60% of the soils in the UK
- Globally 10%
- Most major cities and national infrastructure in the UK are founded on glacial soils



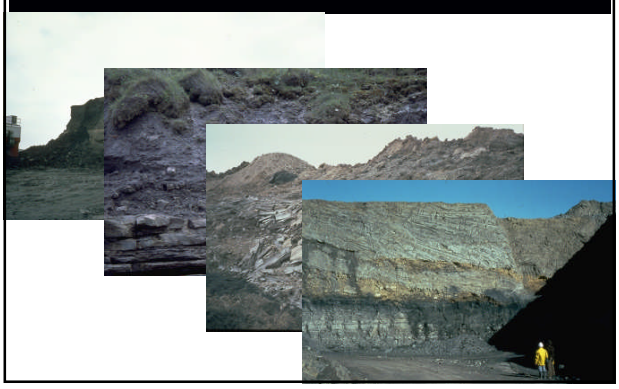
Particle size distribution



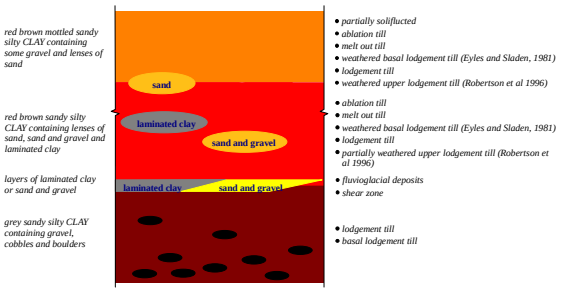
Till can contain a range of particle sizes from clays to boulders and can vary from clay matrix dominant till that contains discrete granular particles to clast dominated tills, which contain some fines; they can be fissured and laminated.



Spatial variation

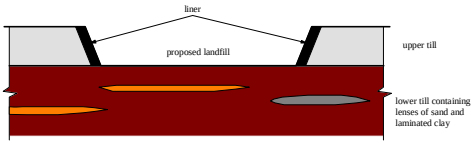


Clarity of description



‘Till is more variable than any other sediment known by a single name’ (Hambrey, 1994)

Groundwater flow

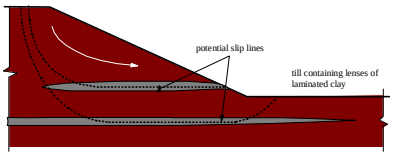


Proposal
- *in situ and laboratory tests gave acceptable values of hydraulic conductivity within lower till*
  - *use lower till as natural liner*
- *hydraulic conductivity of upper till unacceptable*
  - *construct liner*

Results of Public Inquiry
- *lenses of more permeable material within lower till raise mass conductivity*
- *leachate likely to contaminate surrounding area*
  - *need to construct liner*

Result
- *abandon project*

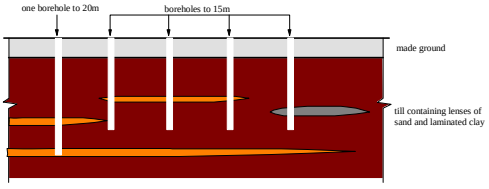
Instability



Standard Slope
- *recommend 1:2.5 slopes in 'boulder clay'*

Issues
- *laminated clay layers are zones of weakness causing instability*
- *extensive water bearing sands and gravels cause instability and surface erosion*

Groundwater



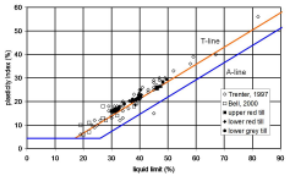
Consultants Proposal
- *construct 15m long 500mm diameter bored piles within till*

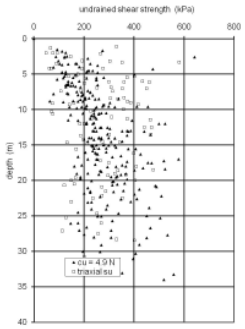
Contractors Proposal
- *construct 20m long 400 mm diameter bored piles using open hole techniques*

Actual Construction
- *encountered water bearing layer of sand and gravel at 19m*
- *fully cased 20m long piles*

Glacial soils are a hazard

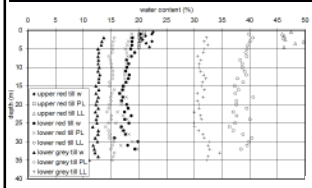
Classification

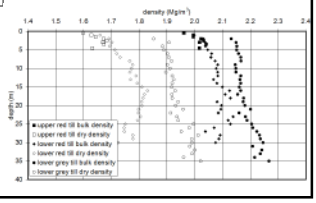




- Clay matrix tills fall on T-line
- Scatter in undrained strength due to sampling and natural variability
- Empirical classification correlations do not apply

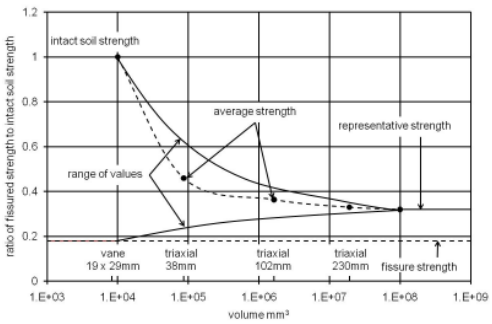
Density and water content





- Density and water content more consistent
- Density indicative of heavily overconsolidated clay

Impact of sampling on strength



Mobilised strength

- Pore pressure development is a function of soil stiffness
- Pore pressure dissipation is a function of hydraulic conductivity
- Clay matrix tills are relatively impermeable but their stiffness means that
  - Some of the load is taken by the soil skeleton
  - And the rate of pore pressure dissipation is relatively rapid

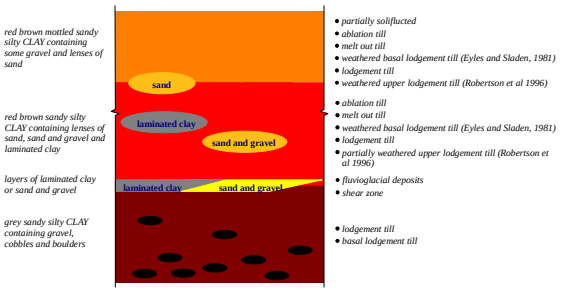
$$c_v = \frac{k}{m_v \gamma_w}$$

- Hence tills behave as partially drained soils
- Undrained shear strength is a underestimation of mobilised strength

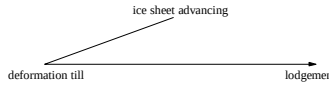
Selection of design parameters is challenging

Geological model

Clarity of description



First advance

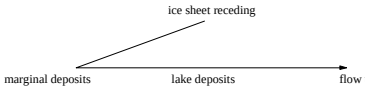


- *rock base*
- *abrasive and plucked products*
- *source material clearly identified*
- *original fabric and structure present in places*

- *abrasive and plucked products*
- *source material identified by elements*
- *original fabric and structure lost*
- *increased homogeneity*

- Basal deposits
  - compacted into place through shearing and compression
  - degree of compression varies with drainage conditions

First recession



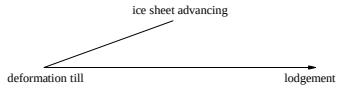
- *fluvio glacial features*
- *spatially variable*

- *extensive layers of laminated clay*
- *sand and gravel layers at lake margins*

- *extensive layer of englacial till*
- *containing fluvioglacial features*
- *homogenised occurring within ice*

- Ablation deposits
  - compressed into place by self weight

Subsequent advance

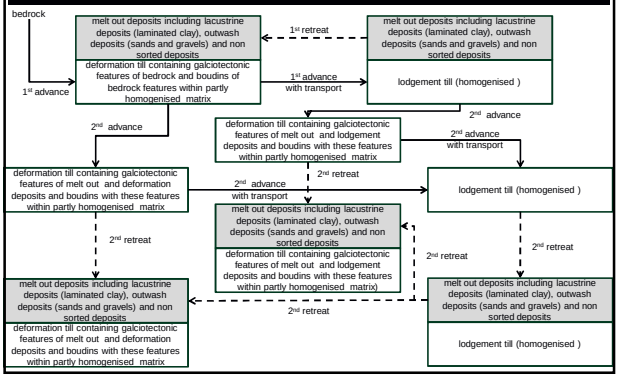


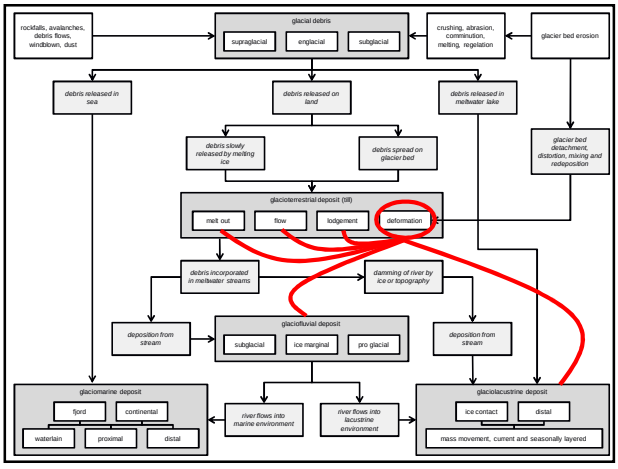
- *basal deposits*
- *sheared products*
- *source material clearly identified*
- *original fabric and structure present in places*
  - *deformation till*
  - *lodgement till*
  - *melt out till*
  - *flow till*
  - *lake deposits*

- *sheared products*
- *original source material identified by elements*
- *original fabric and structure lost*
- *increased homogeneity*
- *most recent fabric structure and fabric lost*

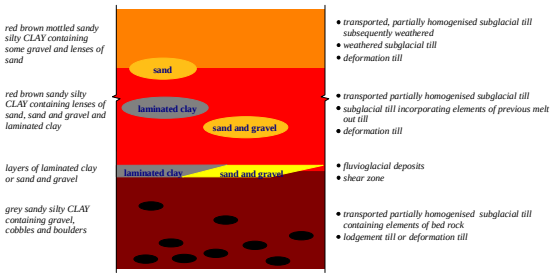
- Basal deposits
  - compacted into place through shearing and compression
  - degree of compression varies with drainage conditions
  - can include 'compacted' ablation deposits

Impact of numerous glacial periods



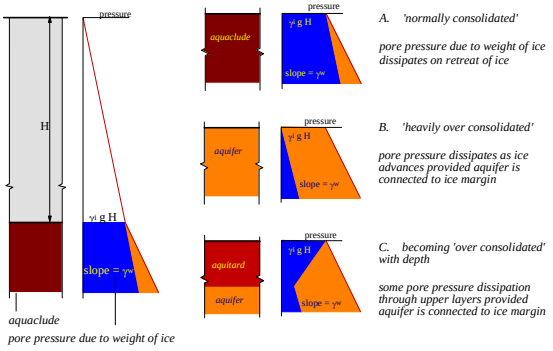


Proposed tripartite sequence



Geotechnical model

Concept of consolidation

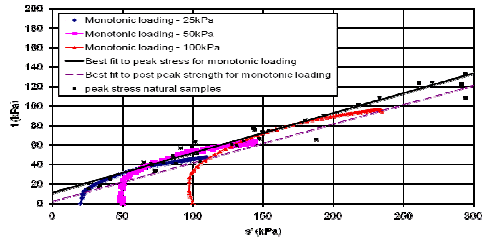


Glacial tills may not be overconsolidated despite their strength

Compression AND shearing produce dense glacial tills

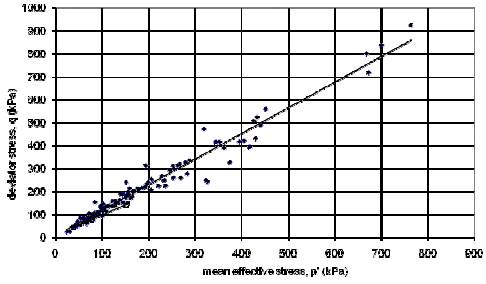
Assessing strength

- Number of quality samples is limited
- Tests on dense matrix dominated clay give similar results to tests on quality undisturbed samples



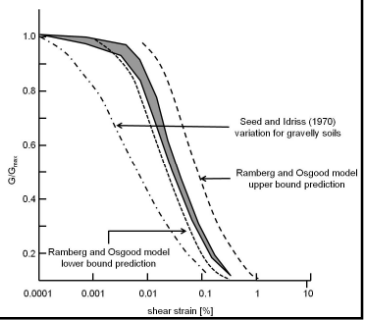
Characteristic strength

- Use classification data to determined soil horizons
- Use of remoulded, scarified matrix to measure characteristic strength



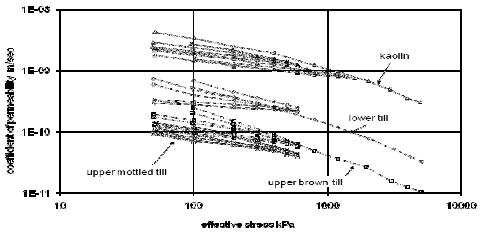
Stiffness

- Stiffness degradation is typical; of fine grained soils



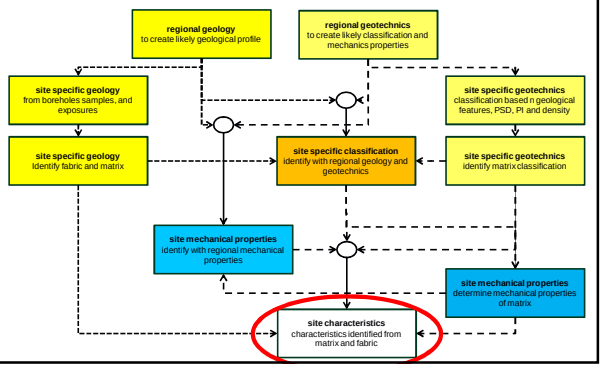
Hydraulic conductivity

- Hydraulic conductivity is function of fine particle content and stress level
- But fabric will dominate permeability



Parameter selection process

Parameter selection process



Effect of regional database

e.g. active pressures
e.g. bearing capacity

Parameter	Regional				Site Specific					
	Mean	Characteristic Values			Mean	Characteristic Values				
		Schneider (low)	Cautious mean (low)	Cautious mean (high)		Schneider (low)	Cautious mean (low)	Cautious mean (high)	Bayes mean (low)	Bayes mean (high)
Till A										
γ_b (Mg/m³)	2.00	1.960	1.993	2.003	2.11	2.07	2.09	2.13	2.10	2.11
w (%)	21.5	19.74	21.28	21.72	20.8	18.2	19.7	21.9	20.8	20.8
PL (%)	20.3	18.98	20.17	20.53	20.1	18.3	19.2	21.0	20.1	20.1
LL (%)	46.5	43.18	46.06	46.93	42.4	38.8	40.6	44.3	42.5	42.6
s_u (kPa)	99	76	96	102	89	71	77	100	89	89
Till B										
γ_b (Mg/m³)	2.06	2.023	2.059	2.065	2.16	2.12	2.13	2.19	2.16	2.16
w (%)	18.1	16.56	18.02	18.25	16.4	13.6	15.5	17.4	16.48	16.48
PL (%)	17.6	16.39	17.51	17.69	15.6	14.3	15.0	16.3	15.7	15.7
LL (%)	38.7	36.02	38.49	38.89	34.6	31.6	33.2	36.0	34.7	34.7
s_u (kPa)	100	78	98	101	89	60	65	104	86	86

Based on standard deviation

Based on coefficient of variation

Taking into account regional database

Conclusions

Glacial till composition

Many glacial clay tills

- Are sub glacial tills
- Are a combination of deformation and lodgment tills
- Contain remnants of previous glaciations including ablation deposits and local derived lodgment till
- Contain new lodgment material from a remote source
- Are very dense because of the action of compression and shearing during deposition

Glacial till properties

- Are dense and stiff
  - Density and stiffness is a function of the mode of deposition and not necessarily due to consolidation
- Contain softer and less dense material
  - Ablation deposits within lodgment/deformation till
- Are normally consolidated or over consolidated
  - Degree of consolidation depends on drainage profile and stiffness of underlying soils
- Behave as a ‘drained’ material because of the stiffness even though they are of low permeability