Grounds for Dispute

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CIArb
Grounds for Dispute

Why the ground?

– Can’t see into it easily

– Uncertainty and risk are difficult to evaluate

– Benefit of effort/cost is difficult to visualise

– The control of risk can fall between parties

– Changing approach to the allocation of ground risk
The First Steps in Avoidance of Ground Dispute

- Front-End Engineering (FEED) and appropriate ground Investigation
- Collaboration between parties
- Simple bespoke contractual arrangements
- Careful hazard identification
- Appropriate expertise and design methods
- Ensure resources are sufficient
## Contract Form and Risk

<table>
<thead>
<tr>
<th>Traditional/ Engineer Designed</th>
<th>Design and Construct</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td><strong>Advantages</strong></td>
</tr>
<tr>
<td>• FEED</td>
<td>• Cost certainty/ Competitive</td>
</tr>
<tr>
<td>• Time to develop brief</td>
<td>• Compressed programme</td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
<td><strong>Disadvantages</strong></td>
</tr>
<tr>
<td>• Balance of risk to Owner</td>
<td>• Risk shifted to Contractor</td>
</tr>
<tr>
<td>• Best solutions may not be achieved</td>
<td>• Design resources often squeezed</td>
</tr>
<tr>
<td>• Engineer’s conflict of interest/ disputes</td>
<td></td>
</tr>
<tr>
<td>• Slow</td>
<td>• FEED difficult to achieve</td>
</tr>
<tr>
<td>• Lack of time to investigate</td>
<td>• Lack of time to investigate</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hybrid Forms</th>
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<tr>
<td><strong>Early contractor / staged involvement</strong></td>
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<tr>
<td>Has advantages but tends to be a lengthy and expensive process</td>
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Where does liability lie?

- Max Abrahamson’s Principles (abbreviated)
  - The risk is within the party’s control;
  - The economic benefit in controlling the risk lies with party in question;
  - The party in question benefits by efficiency, including planning, incentive and innovation;
  - The party can transfer the risk;
  - If the loss falls on a party in the first instance and there is no compelling benefit from transferring the risk to another party under the above principles it remains with that party.

- Risk gets passed down the food chain with recent trends in the form of contract
How is ground risk distributed today?

The Client
The Contractor
The Civil Engineer
The Structural Engineer
The Architect

GEOTECHNICAL ADVISORS?
Understanding Ground Risk: John Burland’s Geotechnical Triangle

- Geological Processes
- Ground Profile
- Ground Exploration and Description

Empiricism, case records, well-winnowed experience

- Measured Behaviour
  - Measurement, testing and Observation
- Appropriate Model
  - Idealisation, Validation, etc.
Understanding the Ground: A Designer’s Perspective?

Material variability

Ground investigation & incomplete knowledge

Temporal heterogeneity

Codes of Practice

Spatial geological hazards

The Ground

Idealisation of ground behaviour

Man-made hazards
The Geotechnical Design Report

According to BS EN 1997-2, it should contain:

- The Ground Investigation Report
  - All appropriate information
  - A geotechnical evaluation
- Known limitations of the investigation
- Detailed programme for further investigations necessary
- And be prepared by a Geotechnical Advisor

In practice, it can include geo-environmental studies, basement impact assessments...
What the UK Codes Say!

For Example, BS 5930

“In order to evaluate properly the nature of the ground and the groundwater and so to achieve the objects of the site investigation, it is essential that the work be planned, undertaken and supervised by personnel who have appropriate qualifications, skills and experience in geotechnical work....”

The Geotechnical Adviser..

Is this really the whole answer? Well, no it’s not.
Ground investigation: Who should take the lead? Geotechnical Advisors?

The Geologist/Geomorphologist

The Geotechnical Engineer

The GeoEnvironmental Engineer

The Specialist Contractor
Who actually takes the lead in practice?

The Structural Engineer

The Civil Engineer

The Contractor

The Client

The Architect
### Geotechnical Categories

(BS EN 1997-1)

1: *negligible risk* in terms of overall stability or ground movements and in ground conditions

2: conventional types of structure and foundation with *no exceptional risk* or difficult ground conditions or loading conditions

3: structures outside categories 1 & 2, for example:
   - large or unusual structures
   - difficult ground conditions
   - seismicity or ground instability
   - (specialist design methodology)

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**Knowledge, Experience & Competence**

- Structural Engineers
- Specialist Engineers & Gotechnical Advisors

**DISPUTES**
Things to Consider

- Temporal variation (time related variation)
  - Groundwater, weathering, solution, etc..
- Heterogeneity (variation within a deposit)
  - Complex, laminated materials, etc..
- Spatial variability (lateral variations)
  - Geological features, DFHs, etc..
- Ground hazards (natural and man-made)
  - Soluble rocks, landslides, etc..
- Design Issues
  - Empiricism, special design issues, etc..
What could possibly go wrong?

Groundwater – more often than not!
• Vertical flow in artesian or sub-artesian conditions
• Hydraulic instability
• Erosion and piping
An Illustration: Temporal and Heterogeneous Variation

A large basement in London

- RTD
- LAMBETH GROUP
- Upnor Formation (DRY)
- THANET SAND
- CHALK
The Lambeth Group in London

From Jackie Skipper

Laminated Beds

Lower Mottled Beds

Upnor Formation

Pebble Beds

Upnor Formation
The GDR

- The client commissioned a GI, BIA and GDR from a GI contractor to a brief from structural engineer;
  - 515 pages, mostly geo-environmental and BIA
  - Supplied to D&BC “for information only”
- The basement would lie above the “ground water level”...
- No recommendation for further work
- Structural engineer novated to D&B contractor
- Reviewed by independent D&BC’s Geotech Advisor
What happened next

• 1-2cm water accumulated on the basement floor
  – Attempts to exclude water were unsuccessful
• Contractor launched a £10M adjudication
  – Consequential losses/ delays
  – Drainage and anchor piles
• Structural engineer lost.
The groundwater model

My Interpretation

The GDR
Why was the GDR wrong?

Piezometers with long response zones!
Groundwater not hydrostatic!
Why the structural engineer lost

- No contractual link between D&BC and GI contractor
- Structural engineer controlled the risk
- Structural engineer should have questioned groundwater level in the underlying chalk
- Allowance should have been made for gwl hydrostatic from 2m below ground level
  - Duty under Standard ACE T & Cs to properly investigate ground conditions (notwithstanding the report having been prepared)
  - Should have examined possible changes in groundwater in the Chalk in the long-term – A temporal variation
Lessons

• Be wary of engineering advice when offered as an adjunct to a larger report
• Be wary of unfamiliar geology / groundwater and seek appropriate advice
• Avoid generic T &Cs/ ensure clear roles and responsibilities
• Routes of recovery should be considered on every project
• Identify and manage risk
Spatial Variation: An Illustration
Drift filled hollows in London

After Richard Ellison (BGS)
DFH Hazard Map

After Stephanie Bricker and Katherine Royce, BGS
DFHs and faults

Bond Street

Nine Elms

Walbrook

Blackfriars
Repetition of strata towards centre of site but less variation in top Chalk
Explains geology by looking at classical fault structures

Faults found to follow existing river systems
Recurring problems

Spatial Variation in Rocks—particularly volcanic
Ground Investigation: Adequacy and Interpretation

M.J. Tomlinson
Lesson: Always Question Ground Investigation

- Do the boreholes represent the worst combination/profile?
- What are the geological processes and how would these influence the spatial distribution?
- Verify and eliminate or narrow possibilities. Observe and measure.

Things I have learnt as an engineer:

- If in doubt, consult a geologist
- The seven opinions may all have a valid basis!
- Examine variability, eliminate uncertainties
Geohazards: Unstable Land

Background on Planning Policies for Unstable Land

The “Latchgate” Condition

Requires that a report be prepared by a specialist soils consultant in which the stability of the land is assessed and which identifies any measures needed to ensure the stability of the land. The report should be prepared and submitted to the local planning authority for consideration before the development commences.

Planning Policy Guideline 14: Development on Unstable Land

Appropriate strategies should be adopted at planning for dealing with the problems arising thus preventing the unnecessary sterilisation of land;

*Due account is to be taken of the constraints imposed by slope instability at all stages of the planning process;*
An Illustration:
Landslides in London!

Direction of ground water flow, from Wimbledon Common
Landslides in London
Unstable Land: An Example

Historical Landslides and Latchgate
The D&C Chain of Deferred Responsibility

2007: Developer purchases site
      £250k allowed for stabilisation: Latchgate applied but not discharged

2008: Developer appoints Structural Engineer
      Investigation by another company reports no landslide risk, but SE badges report—report does not meet Latchgate requirements.

2011: Developer appoints himself as principal contractor and employs the structural engineer to develop design
      Ignores warnings given by two sub-contractors
      November: PC appoints piling sub-contractor
      December: sub-contractor appoints retaining wall designer with 1 month to go to construction

2012: February: Client ignores Latchgate excavates site & triggers landslide
      March: principal contractor wound up
      December: remedial works undertaken

2013: Mediation: Wall designer has to pay the Developer.
What Can Be Learnt?

- Relevant competence is essential
- Advice to clients needs to direct and honest, and recorded
- Do not adopt GI reports without question
- Be wary of Developers and be aware of who controls risk
- Be wary of how the design responsibility slides down the contract chain
- Ensure time resources are adequate
- Always do the right thing – Stop when necessary
Recurring problems

Risk Taking:
For example, building on coastal cliffs, quarries, etc.
Very Rapid Landslides in Superficial Deposits

Simple Model of Flow down a Slope

Infiltration of Rainfall
precipitation = $2 \times 10^{-8}$ m/s
length of slope = 22 m
The Consequences of Periodic / Episodic very rapid and dangerous landslides responding to:

- High intensity rainfall
- Changes in land drainage
- Changes in slope geometry


Peat slope failure in Ireland, QJEG, v41, 93-108
Recurring geohazard problems

failure to identify and respond to in a timely fashion, for example:

• Unstable land
• **Mining**
• Soluble rocks
• Expansive soils
• Mineralogy
• Peat and filled ground
• Building over burnt/ unburnt waste
Coal Mining Subsidence
Chalk Mining

Walters Ash
2014

Fontmell Close 2015
Salt dissolution in Stafford

Active Subsidence

Diagrammatic section showing relationship of sandstone reservoir to the salt-beds of the Stafford area. (not to scale)

Information from Poole (1968)
Ripon Gypsum Solution 2016

After Tony Cooper (BGS)
November 2016
A SCHEMATIC REPRESENTATION
SINK HOLE FORMATION—MAGDALEN’S ROAD
Sequence of Events

- Fresh water leaks from waste water drains and seeps downward to soluble gypsum.
- Fresh water accelerates gypsum solution locally forming a void.
- Void becomes sufficiently large to become unstable and migrate upwards by progressive collapse.
- Crown hole breaks trough the surface and soft peat/ drift slumps into crown hole.
- Tension cracks form in soft alluvium which widen as ground drains and relaxes.
Chalk Solution

Kingsfield Road  1927

Kingsfield Road 2015
Peat and Soft Clays

From Allan Tew
Recurring Problems: Mineralogy

- Pyrite/ Sulphide/ Sulphate and reactive materials: Limestone, crushed concrete, carbonates, etc
- Salt and gypsum
- Steel furnace slag (heave)
- **Incinerator Ash**
  - Unburnt waste (decomposition →settlement)
  - Furnace bottom ash (aluminium →heave)
- Allophanes, Zeolites and Laumontite
- Smectites
- ASR in aggregates, etc..
What Lessons Are There: John Burland’s Geotechnical Triangle

Geological Processes → Ground Profile → Ground Exploration and Description

Ground Profile

Geological Processes

Empiricism, case records, well-winnowed experience

Ground Profile

Measured Behaviour → Empiricism, case records, well-winnowed experience → Appropriate Model

Measured Behaviour

Measurement, testing and Observation

Appropriate Model

Idealisation, Validation, etc
Tunnel Design methods and Mineralogy
An Illustration from Chile

Hydro electric tunnel

Headrace has 1000m rock cover

Design using Barton Q!

Payment according to ground class
Dispute over Adopted Design

Andesitic rocks:

Problems experienced with shotcrete sticking & delamination
Mineral Analysis: Laumontite is tricky and dangerous
Adopted Empirical Design Method

Client refused to accept problems with design method and blamed contractor for poor workmanship

Constant dispute over ground class (contractor consistently half a class lower)

Client refused to pay for heavier support suggested by Contractor

Headrace tunnel collapses after two years of peak demand operation

Client blamed contractor for collapse rather than mineralogy
Dispute over Adopted Design

Review showed

- Lamontite responsible for delamination and gas bubbles

<table>
<thead>
<tr>
<th>Laumontite (LAU)</th>
<th>Ca₄(Al₈Si₃₆O₄₈)·16H₂O</th>
<th>0.40 x 0.53</th>
<th>-</th>
<th>K, Na, Ca</th>
</tr>
</thead>
</table>

- Major design issues with Barton Q
  - Makes no allowance for rock deterioration
  - Makes no allowance for end use/operation and fatigue
Tunnel Design - Glendoe
Idealisation, Soil-Structure Interaction and the “Well-Winnowed” Model?
Displacement Prediction of Basement Walls in Stiff Fissured Clay

Are conditions drained or undrained?
What are the risks?
Numerical Analysis –
• Do we know what the programme is doing?
• Is tension permitted in the soil?
Driven Pile Design: Buckling
The Design of Stone Columns

![Graph showing settlement reduction versus stone replacement percentage for various authors. The graph includes data from Baumann & Bauer, Watt, Vautrain, Greenwood, Kirsch, Castelli, Munfakh, Engelhardt, McKenna, Charles and Watts, and 40kPa dry.*]
Design of Transfer Mattresses

From George Milligan
The Design of Anchored Slopes

From Jerry Love
Recurring problems

“well-winnowed experience” needs validation of conditions and relevance checked were necessary:

• Over-simplification of models and analysis (groundwater, interaction)
• Drained v undrained behaviour of retaining walls
• Empirical/semi-empirical design methods
• Assumed material characteristics of some formations, e.g.:
  • London Basin
  • Sherwood Sandstone
  • Mercia Mudstone
  • Chalk
  • Bracklesham Group
  • Lias Mudstones
What is really needed?

• Publication/discussion of failures and design issues
• Make sure that methods are “well-winnowed”
• Look for possible temporal changes
  – Weathering and scour
  – Decomposition/chemical
  – Groundwater changes
• Awareness of geohazards
• Awareness of geotechnical design category
• Check limitations of design methods
And..

- Try not to mix geotechnical and geo-environmental investigations— one is not a substitute for the other

- Ensure that the GDR covers all risks identified, especially groundwater

- Be aware of who controls risks

- Be clear about roles and responsibilities

- Ensure experience and resources are adequate
Thank you all