BIOLOGICAL AND ENGINEERING IMPACTS OF CLIMATE CHANGE ON SLOPES: BIONICS

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BIONICS

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EPSRC
Engineering and Physical Sciences Research Council

BACKGROUND

- Earthworks slopes constitute major part of the UK infrastructure asset
  (£20B of a total £60B for highways alone)
- Failures cost significant £
  (£50m for highway maintenance in 1988/9)
- Maintenance costs a fraction of emergency repairs
  (£emergency = 10 x maintenance)

BACKGROUND 2

- Water is a key factor controlling the stability of slopes:
  - Pore water pressure
  - Shrink-swell
  - Softening
  - Cracking
  - Erosion
  - Vegetation

BACKGROUND 3

- Climate change predicts for the UK:
- Hotter, drier summers –
  - shrinkage, cracking, loss of vegetation
- Followed by:
- More intense periods of rainfall –
  - swelling, infiltration, increased water pressure, erosion, (flooding)

STAKEHOLDERS

- 11 industrial partners, including
  - Network Rail
  - Railway Safety and Standards Board
  - Metronet Rail SSL (LUL)
  - Highways Agency
  - British Waterways
- 6 Universities

STAKEHOLDER REQUIREMENTS

- Prediction, planning and preparation

  or
- What, when and how?
- Cost

AIMS OF THE PROJECT

1. Establish a facility for engineering and biological research
2. Improve basic understanding of the effects of climate on slopes
3. Improve modelling capability to examine long-term impacts

ANTICIPATED OUTCOMES

A full-scale, fully instrumented embankment representative of UK infrastructure, planted with representative vegetation with the facility to control climate over half of its length;

A validated hybrid computer model capable of predicting embankment performance under predicted future climates

A methodology for identifying parts of the UK infrastructure that require further investigation

A medium to long term research strategy, including some specific needs-based 'spin-off' projects

ENGINEERING OUTCOMES

- Construction of a fully instrumented embankment to stakeholder specifications
- Quantification of the effects of planting, rainfall, heating and compaction levels on embankment condition
- Production of a database of embankment performance data and fill characteristics for numerical modelling and future researchers

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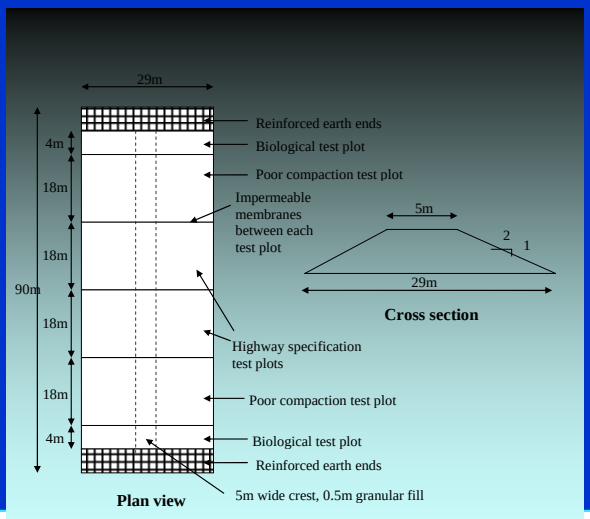
EMBANKMENT DESIGN



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CONSTRUCTION SITE

- Nafferton Farm, Northumberland
- Stiff Glacial Till proved to 15m
- Instrumentation installed in the foundation

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CONSTRUCTION

- Construction completed in November 2005
- Poor compaction difficult to achieve with modern compaction plant
- Sections separated with impermeable membranes

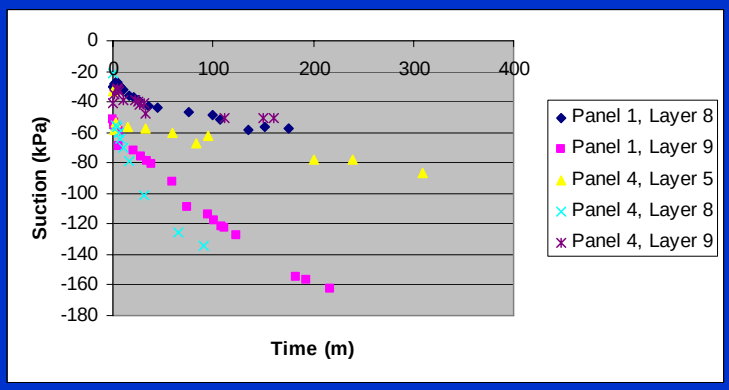
CONSTRUCTION MONITORING

Tests carried out during the construction process

- Core cutter density
- Shear vane
- Macintosh probe
- Soil suction tensiometers

ON-SITE TESTING – Soil Suction

Less-well compacted sections



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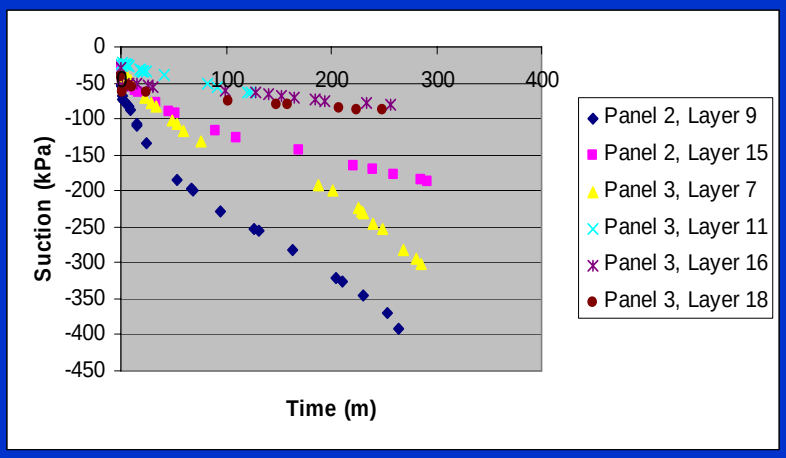
WELL-COMPACTED SECTIONS



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KEY MESSAGES

- Clear distinction between sections in terms of density and strength
- Soil suction tests indicate high (-600kPa) –ve pore water pressures in well compacted (Highway Specification) panels compared to low (less than -200kPa) in poorly compacted panels

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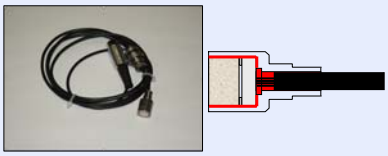
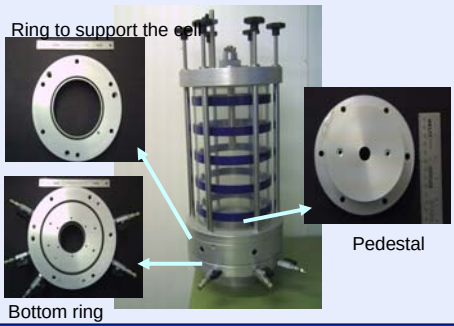
FURTHER TESTING OF FILL

1. Soil Water Retention Curves
2. Strength and Stiffness
3. Saturated Permeability
4. Field measurements of suction
5. Mineralogical analysis

Suction probe



Double-walled Triaxial Cell



MODELLING

- Numerical Modelling
  - Partial coupling of SHETRAN (hydrological model) with FLAC (mechanical model)
  - Development of fully coupled model based on T-P Flow in FLAC
  - Incorporation of a partially saturated soil model
- Centrifuge modelling

PRELIMINARY NUMERICAL MODELLING

- Basic coupling of SHETRAN and FLAC
- SHETRAN provides pore water pressures as a response to daily climatic inputs
- FLAC simulates the response of the embankment to the daily changes in pore pressures
- Examined the effect of underdrainage on long-term behaviour

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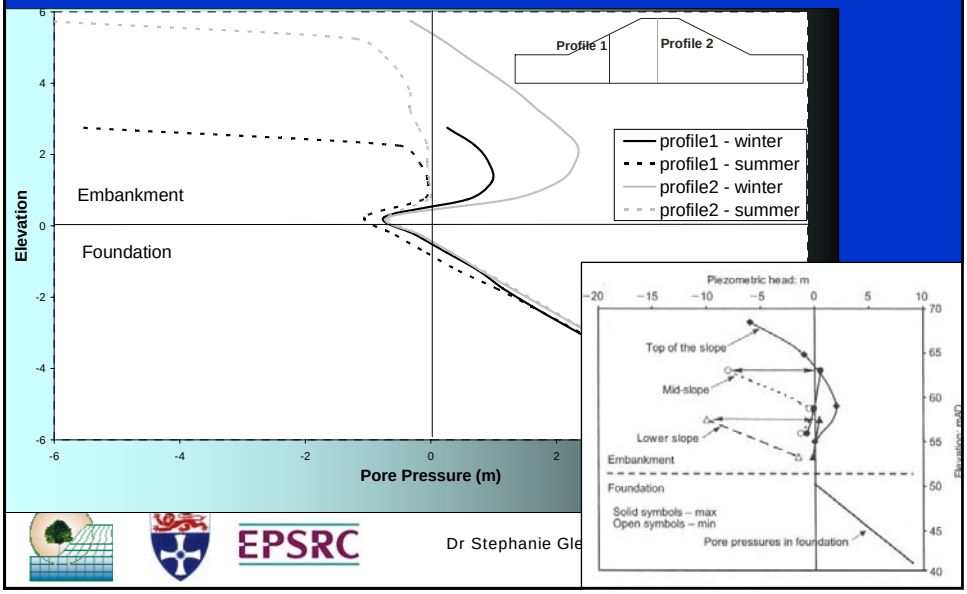
PORE PRESSURES (year 10) - Underdrained



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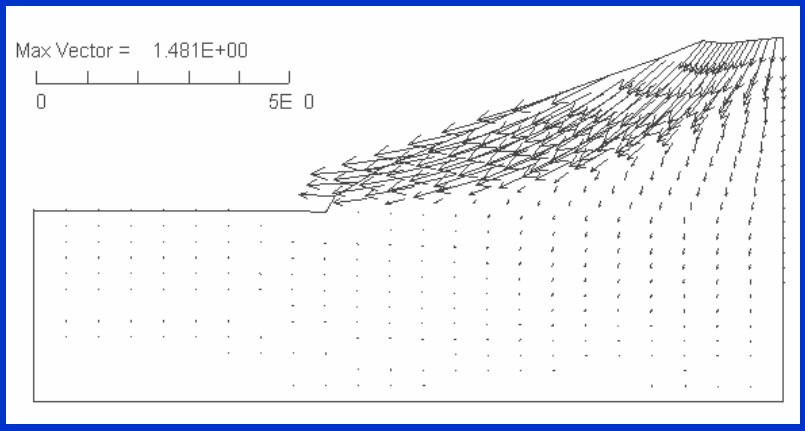
FAILURE MODE - Underdrained



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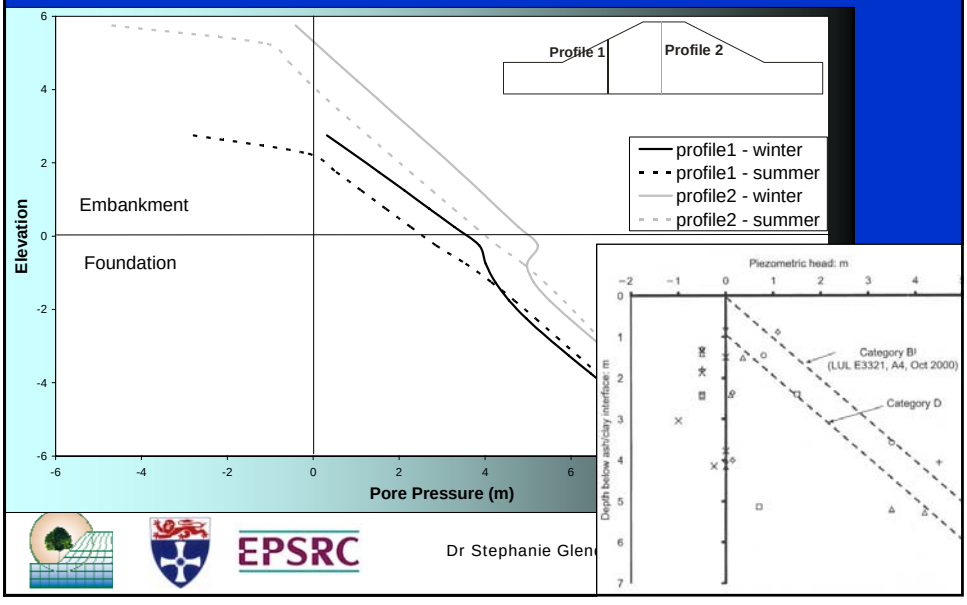
PORE PRESSURES (year 10) – No drainage



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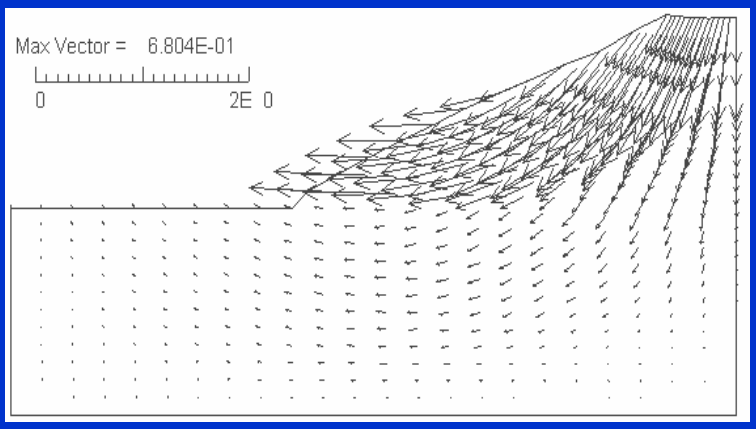
FAILURE MODE – no drainage



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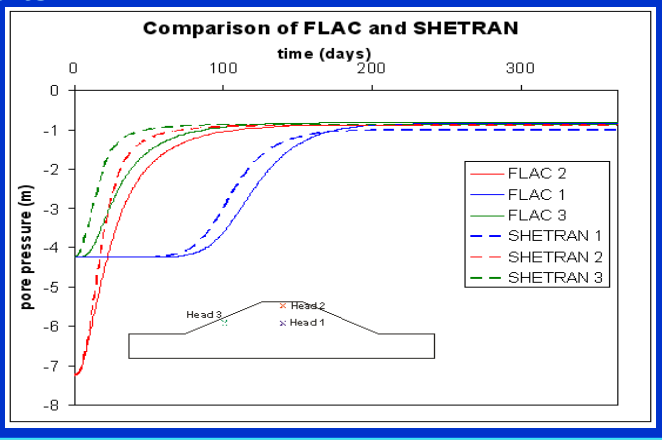
SHETRAN - FLAC tpflow comparison

- Comparison with SHETRAN has produced good results



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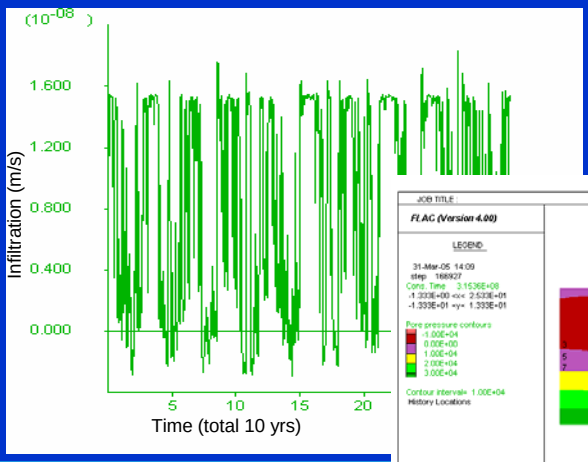
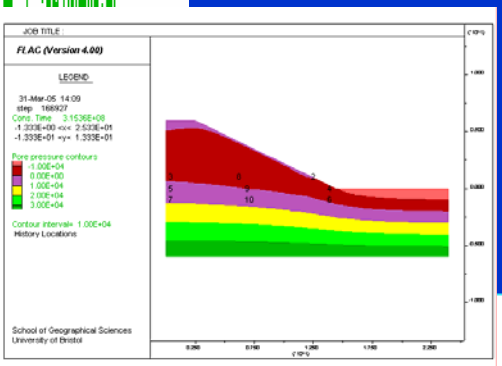
CLIMATE DATA INPUT

Infiltrations calculated by SHETRAN can be inputted into FLAC tpflow





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CENTRIFUGE MODELLING

Aims to provide data on the longer-term performance of the embankment

Will examine different slope geometries and/or boundary conditions including that of the BIONICS embankment

Will control water conditions in slope and monitor serviceability conditions

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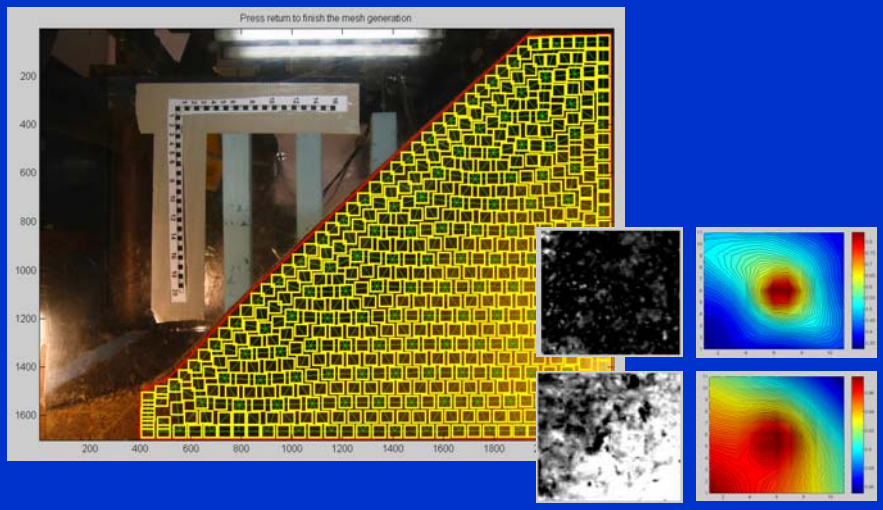
CENTRIFUGE MODEL showing image analysis



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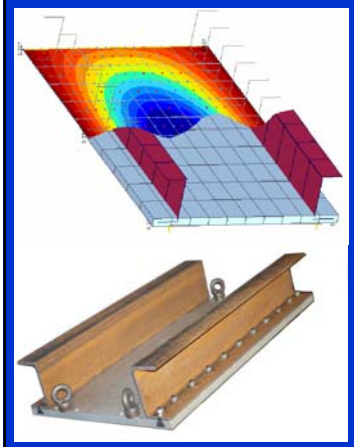
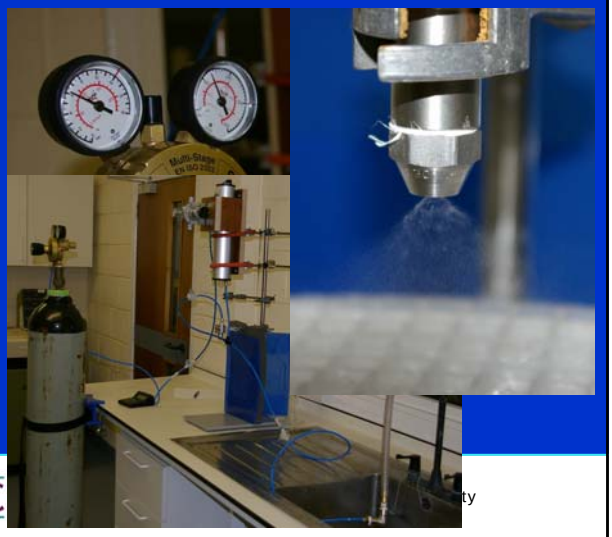
ENVIRONMENT CHAMBER

Stress calculation and the lid:



1g nozzle test setup:



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THE FUTURE OF BIONICS

- The BIONICS embankment provides a facility for collaborative research
- The numerical models provide the means of applying the research findings in other situations:
- Analysis of ‘real’ cases from UK and worldwide