Rock Mechanics Research at Nottingham

Rod Stace, Associate Professor,
Nottingham Centre for Geomechanics

University of Nottingham

- UK campuses – University Park, Jubilee, King's Meadow and Sutton Bonnington, in the vicinity of Nottingham City
- UNIM (KL,Malaysia) and Ningbo (China)

University of Nottingham

- Student and Staff numbers
  - 2007/08
    - 30,444 full and part time, u/g and p/g in Nottingham
    - 2,637 in UNIM and
    - 2,765 in Ningbo.
  - 5786 employees, incl. 2770 teaching and research staff
  - overseas percentage in Nottingham
    - u/g 18%, pgt 53%, pgr 51%
- Income for research and teaching
  - Total income was £382m in 2006/07
  - Research income totalled £78m

The University of Nottingham

University Campus

The University of Nottingham

Mining Related Teaching

- Mining Degree courses for undergraduates were offered at Nottingham between 1912 and 2002.

Staff and Students of The Mining Engineering Department - 1922

Mining Related Research

- Minerals related research continues and focuses on mineral processing, carbon capture and storage, environmental issues associated with mining and rock mechanics.
- Nottingham Centre for Geomechanics (NCG) was formed in 2003 bringing together:-
  - civil and mining engineering,
  - soil and rock,
  - underground and surface,
  - theory and practice,
  - research and commercial activity,
  - geotechnics teaching.

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Staff and postgraduates

- 6 staff, incl. Professor Hai Sui Yu, who is also Dean of Engineering
- 1 Experimental Officer
- 4 Post-Doc. Research Fellows
- 4 Lab. Technicians
- 2 Admin.
- 13 postgraduate students

The Outputs

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- Satisfy the requirements of our sponsoring organisations – provision of reports and data
- train our postgraduates as researchers (possibly for an academic career and possibly overseas) and supervise their progression to PhD
- publish our work in both conferences but also refereed journals
- satisfy university requirements with respect to RAE which measures level of activity and includes establishing and maintaining an international profile
- feed research into teaching material

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- Research approaches available
  - Analytical approaches, commonly using numerical modelling to develop an understanding of fundamental geomaterial behaviour.
  - Experimental approaches based on laboratory work to validate theoretical approaches and modelling results, also to obtain parameters to feed into numerical models
  - Field observations to validate model data

NCG Facilities

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- Soils laboratory element testing equipment and CPT truck (£500K).
- Railway ballast testing equipment.
- Geotechnical centrifuge (£500K)
- Rock Mechanics laboratory testing equipment.

- Extensive numerical modelling capability.

Element testing (soil mechanics)

Understanding the fundamental behaviour of small samples of soil

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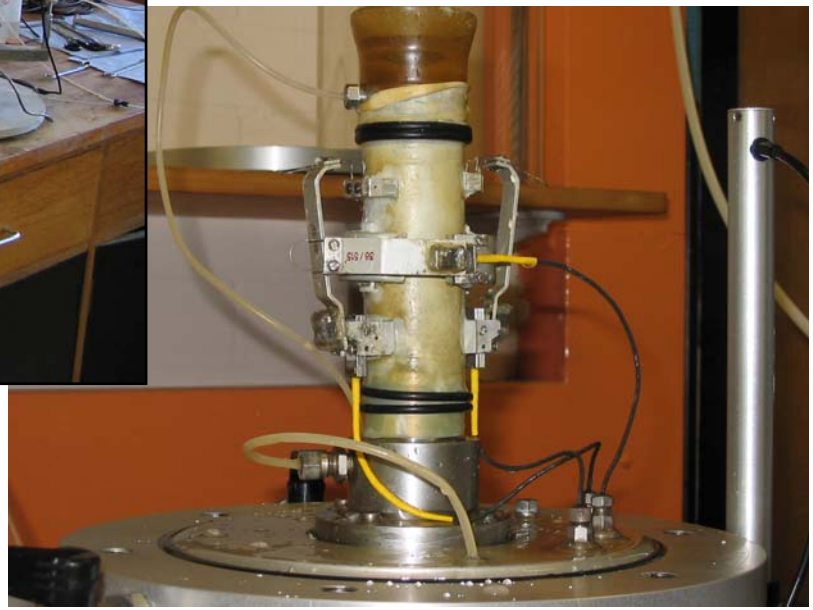

Granular Material Behaviour

Element and full-scale testing of Railway Ballast

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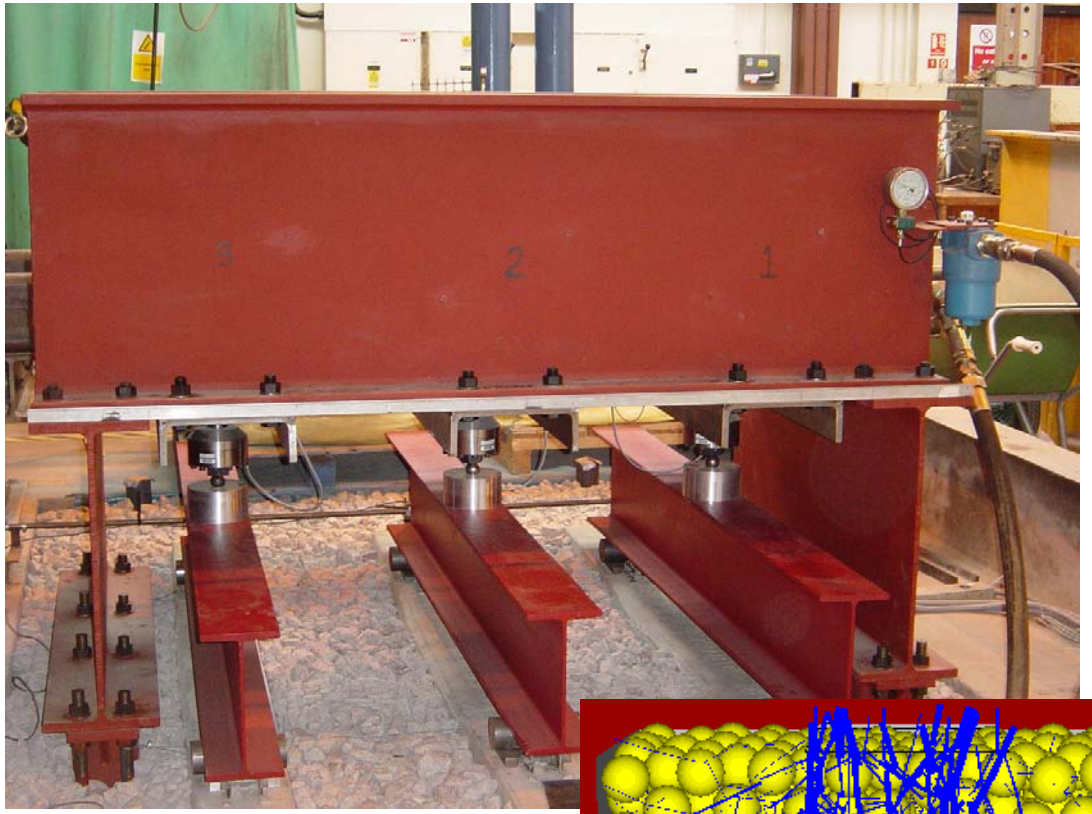

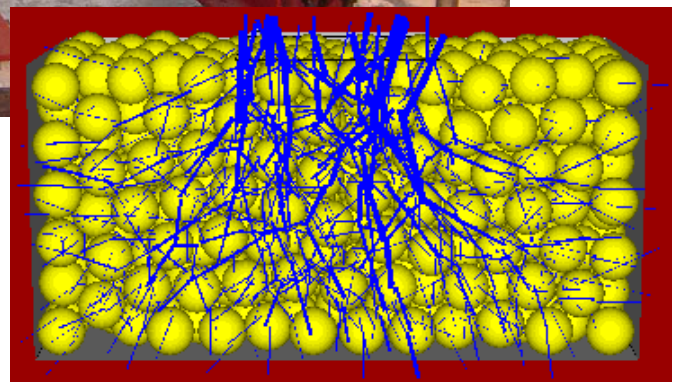

Cone Penetrometer Test Truck

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Geotechnical Centrifuge

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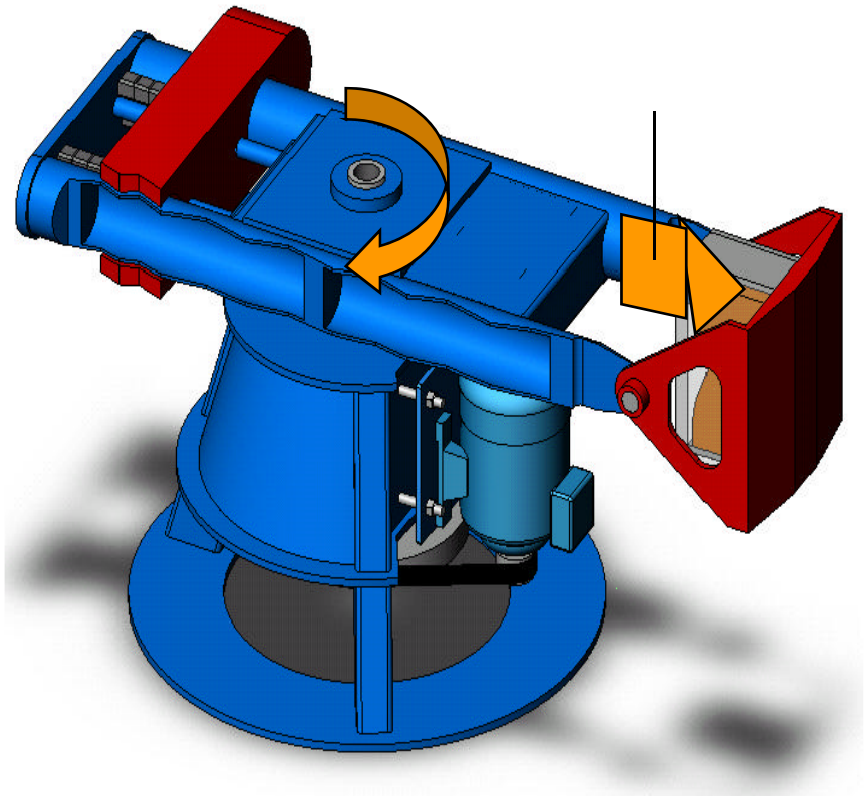
•Geotechnical engineers are interested in the behaviour of ‘soil’ at say 10 m for deep piled foundations.

•Testing a scale model using actual soil would be attractive. However, the behaviour of soil at depth is influenced by the ‘confining stress’ resulting from the weight of material above it.

•In a geotechnical centrifuge full scale confining stresses are generated in a reduced scale model by applying a centrifugal acceleration many times greater than normal gravitational acceleration to effectively increases the ‘self-weight’ of the soil.

•Testing at (say) 100*g* makes the soil behave as if the model was 100 times larger!

Centrifugal acceleration many times larger than normal gravity



Centrifuge specification

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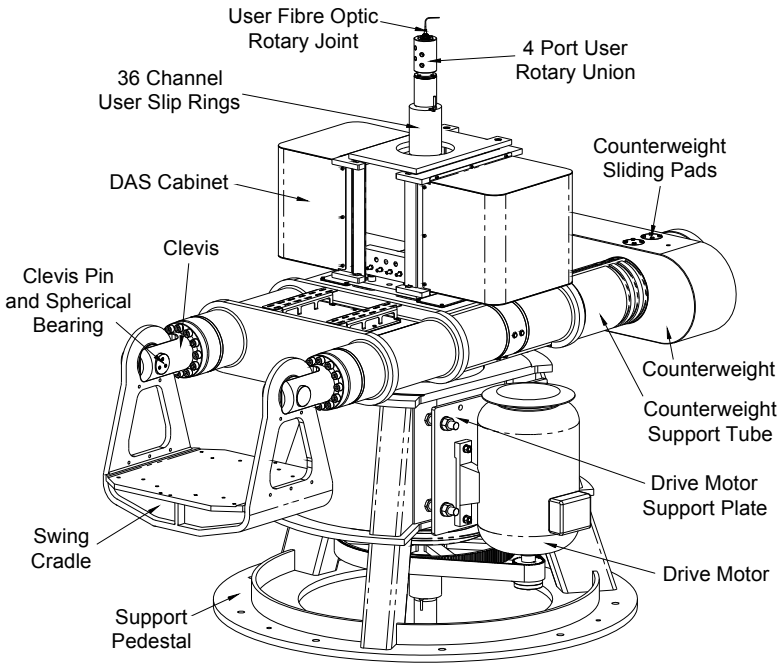
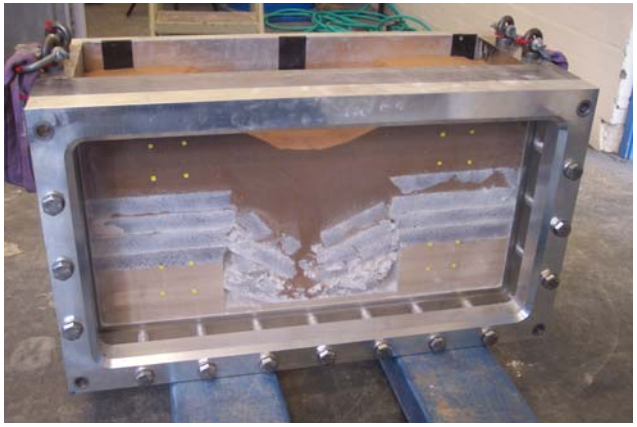
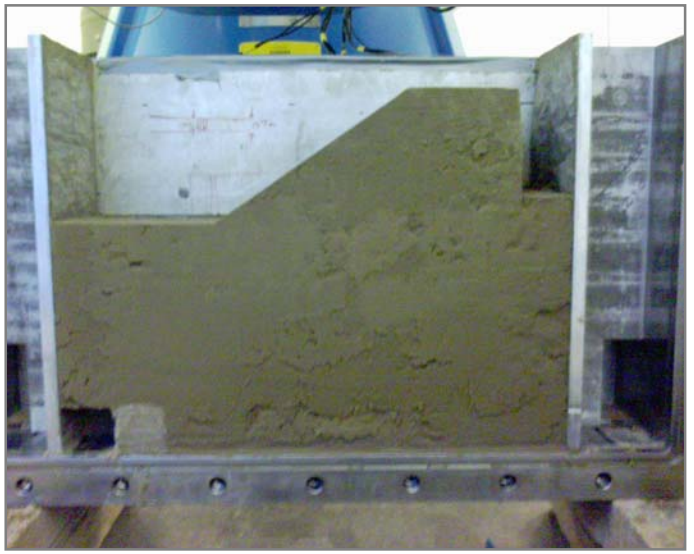
- Beam with counterweight & one swinging platform
- Platform radius - 2.0 m
- Max. size of payload
  - 0.6-0.9 m
- Max. payload - 500 kg
  up to 100*g*
- Max. acceleration - 150*g*
- Speed - 280 rpm (200 km/hr!)
- The machine is one of 5 of it's type in the UK



Geotechnical centrifuge - Ongoing work

- Sinkhole migration
- Piled embankments
- Slope stabilisation





Miniature devices measure loads and water pressures
Digital cameras are used to 'track' movement of the soil at the ground surface, or through a window

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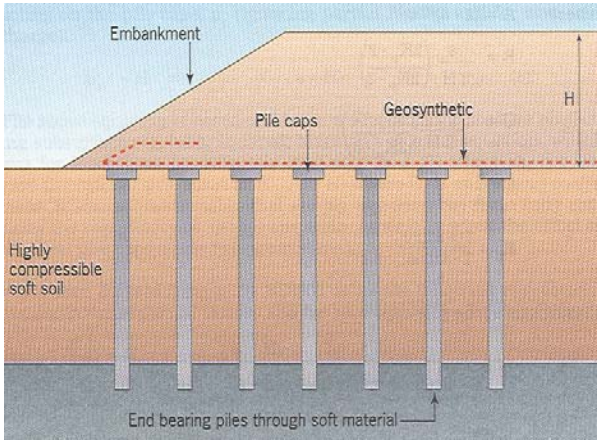
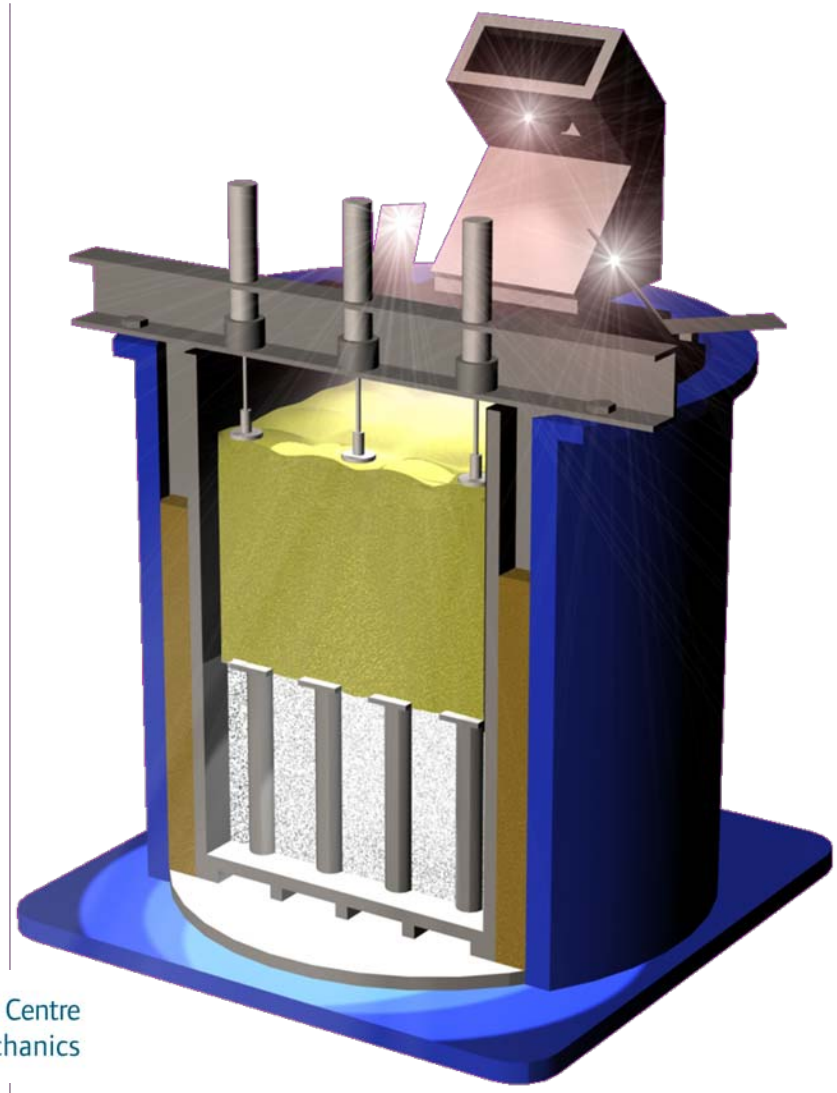
Centrifuge Modelling of Reinforced Piled Embankments





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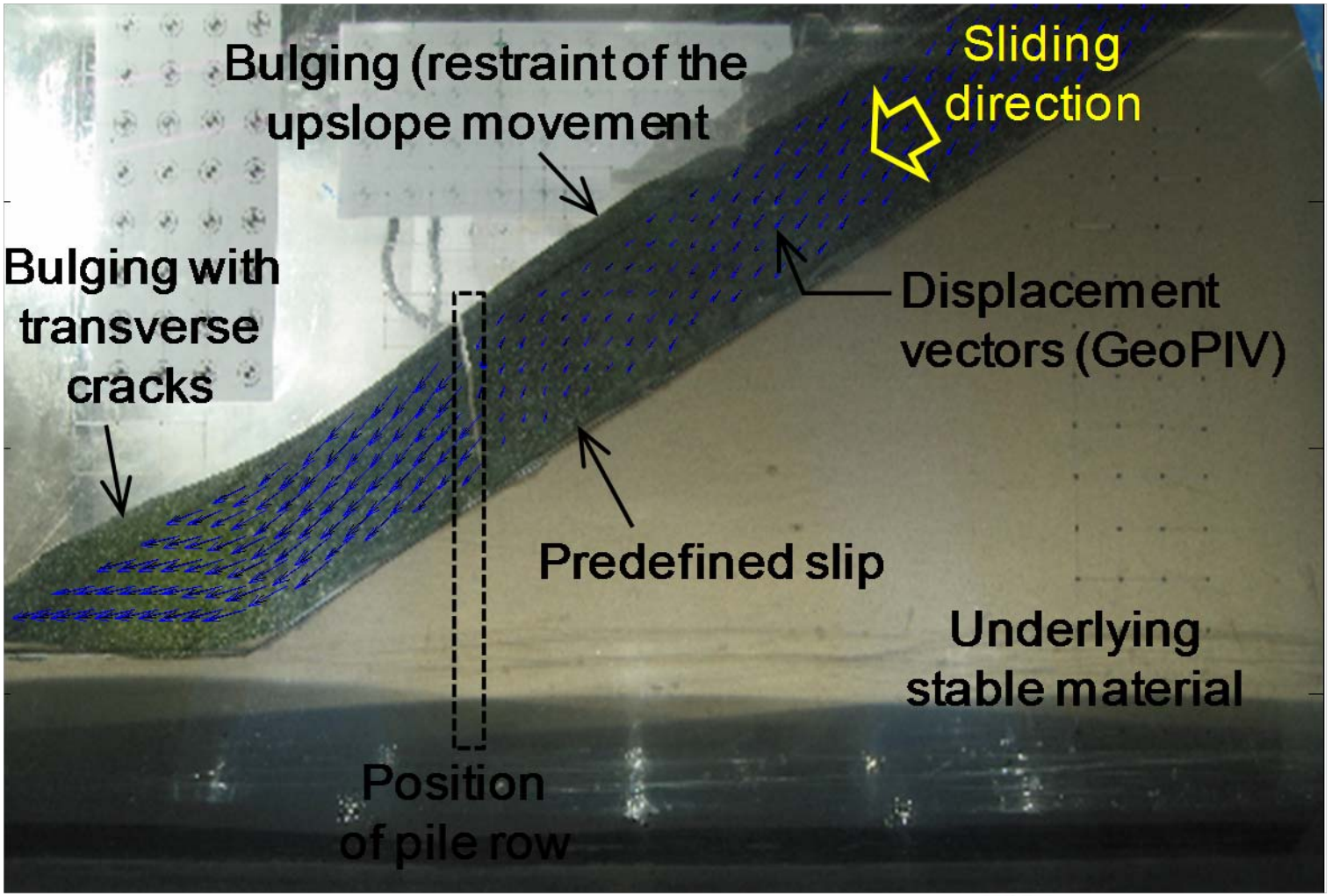
Slope stabilisation with discrete pile row



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Rock Mechanics

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- Laboratory Facilities
  - Rock test sample preparation
  - RDP Howden 1000kN stiff press
  - Shear rig
  - Tensile test machine/ 500 t press
  - Creep rig

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In-house, monitored, rock test sample preparation facility

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Used for research and commercial testing

RDP 1000 kN Stiff Rock Testing Press

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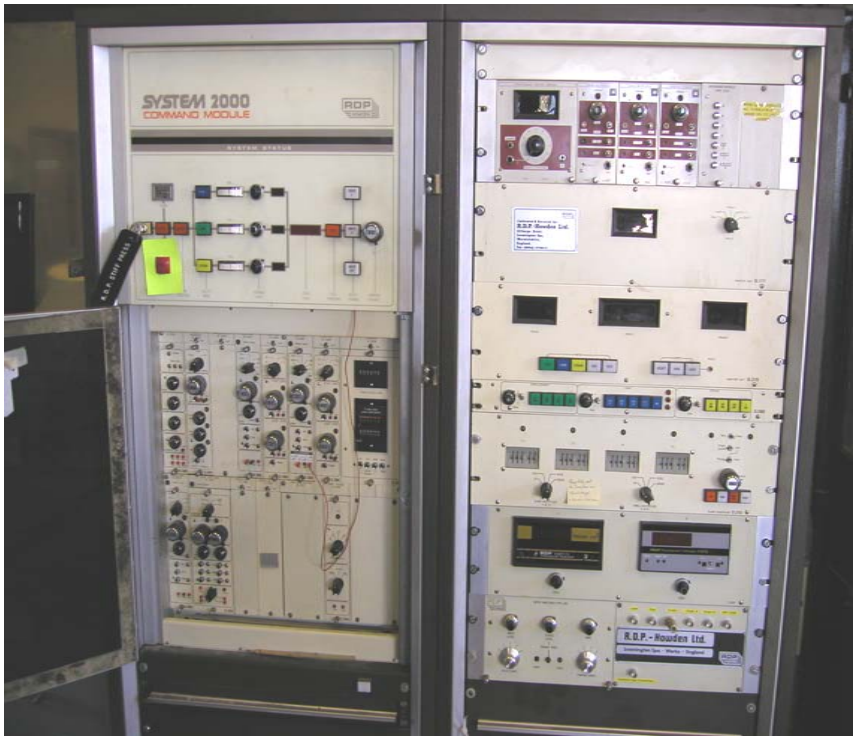
- Stiff press is main facility for rock testing at Nottingham
- Used to determine properties of rocks, grouts and resins, and support elements
- Testing results feed into most of our research work

RDP 1000 kN Stiff Rock Testing Press

- New System Concept -

A Software Driven Machine

- Hydraulics/Frame in good condition
- Old system essentially analogue
- Control and monitoring hardware 20 years old
- Reliability issues - component life
- Safety issues – component failure
- Operating limitations



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New Hardware

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- Logging card and PC conditioning cards
- Rack to hold above -
- All are off the shelf - standard components
- Sensors – pressure/displacement
- Moog valve controllers

Software Driven Control

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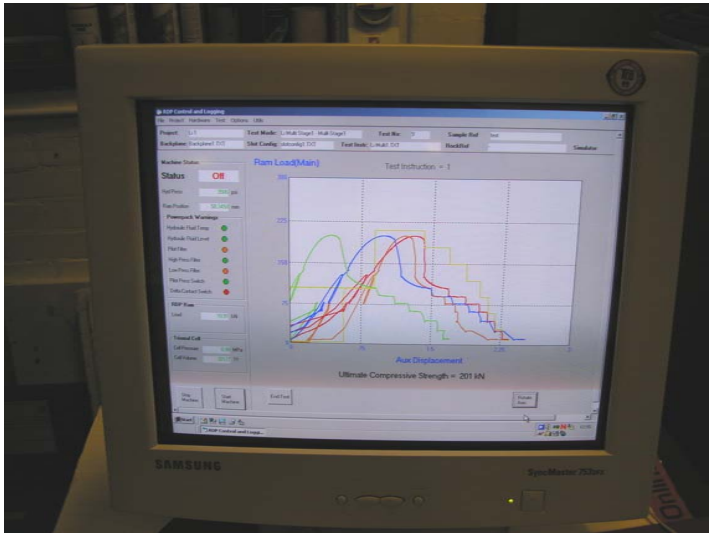
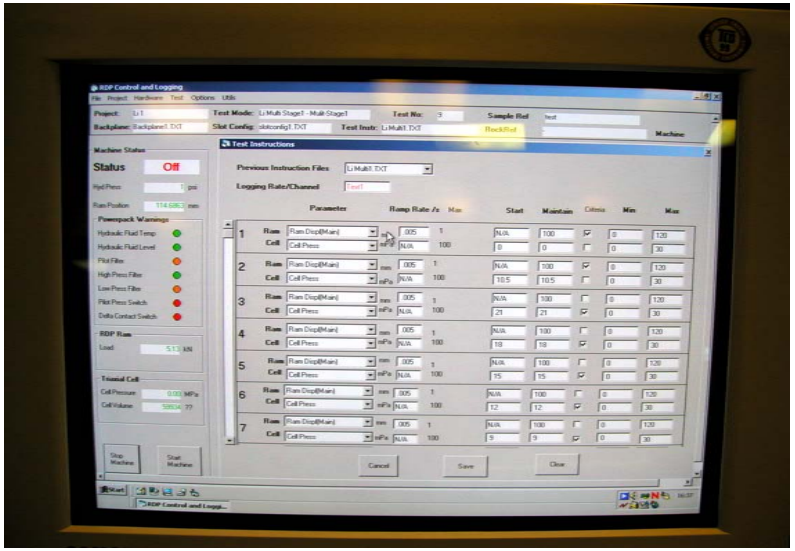
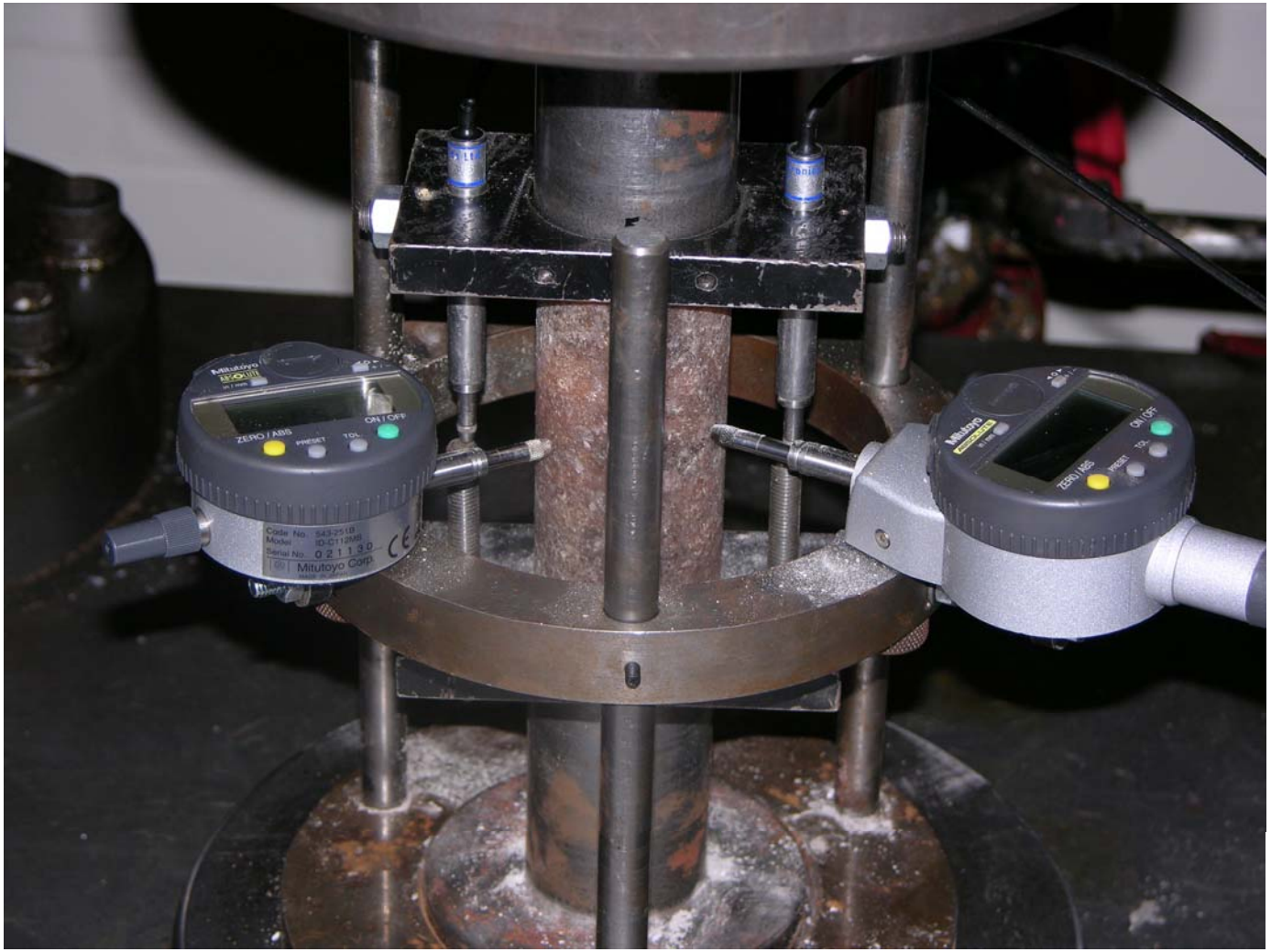
- All control functions moved from hardware systems to software allowing much greater flexibility





- Windows based system all coded in MS Visual Basic
  - Customised directly to our requirements
  - Can be modified and adapted as required
  - No shells – No licenses

Young's Modulus / Poisson's Ratio



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Multi stage triaxial testing

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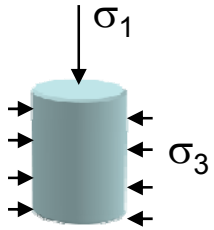
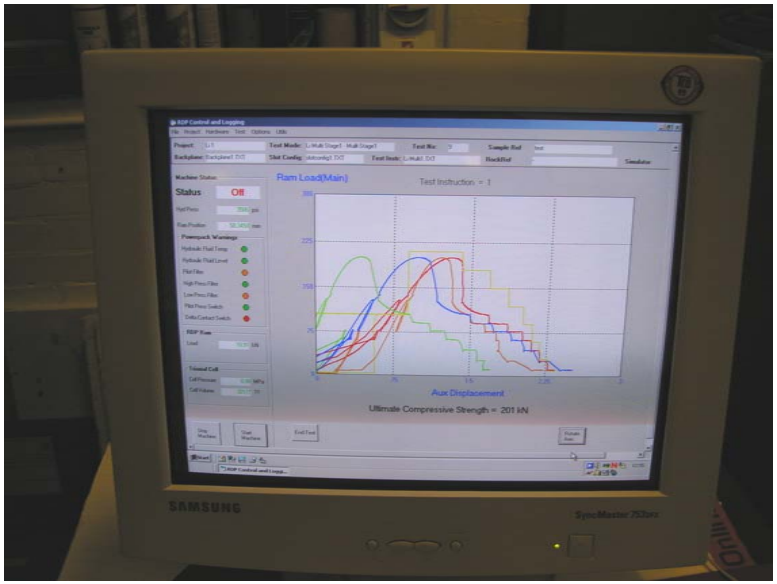


Multi Stage Triaxial Test



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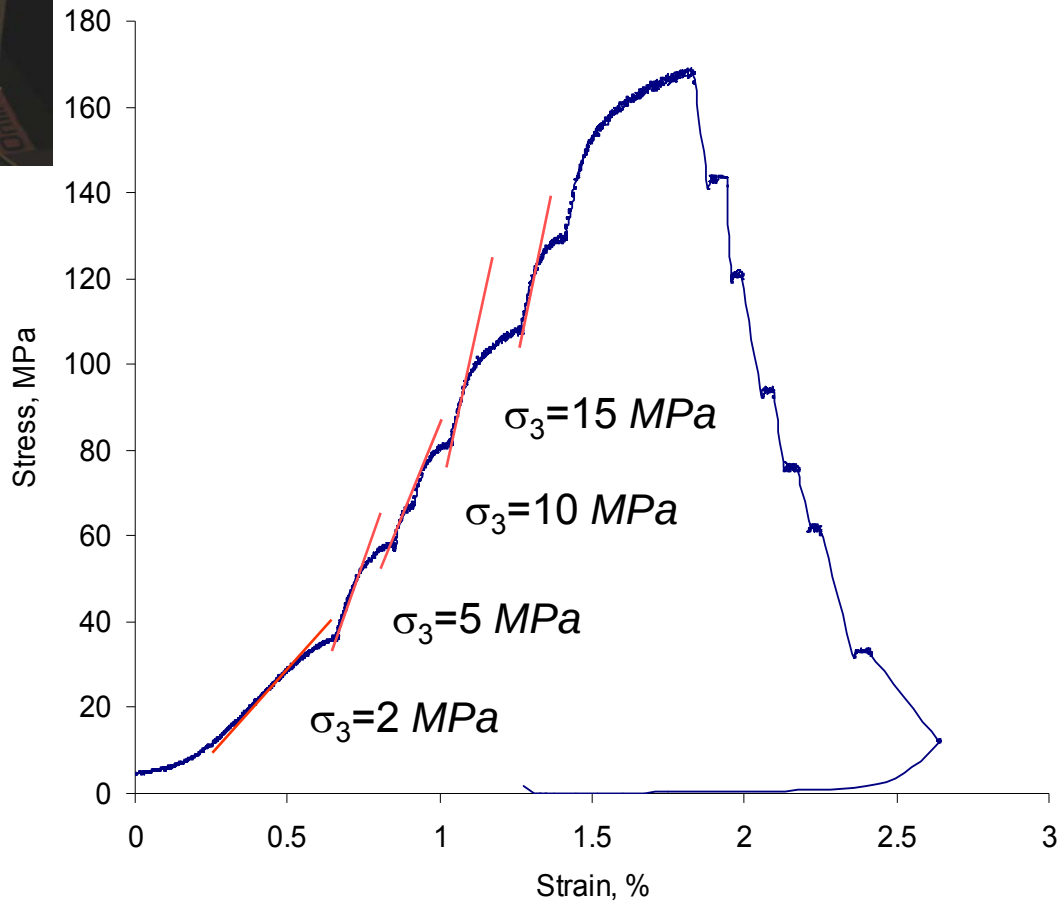
Stress-strain curve illustrating how elastic modulus changes with confining pressure



Rock Mechanics

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- Rock test sample preparation
- RDP Howden 1000kN stiff press
- Shear rig
- Tensile test machine/ 500 t press
- Creep rig

Used for research and commercial testing

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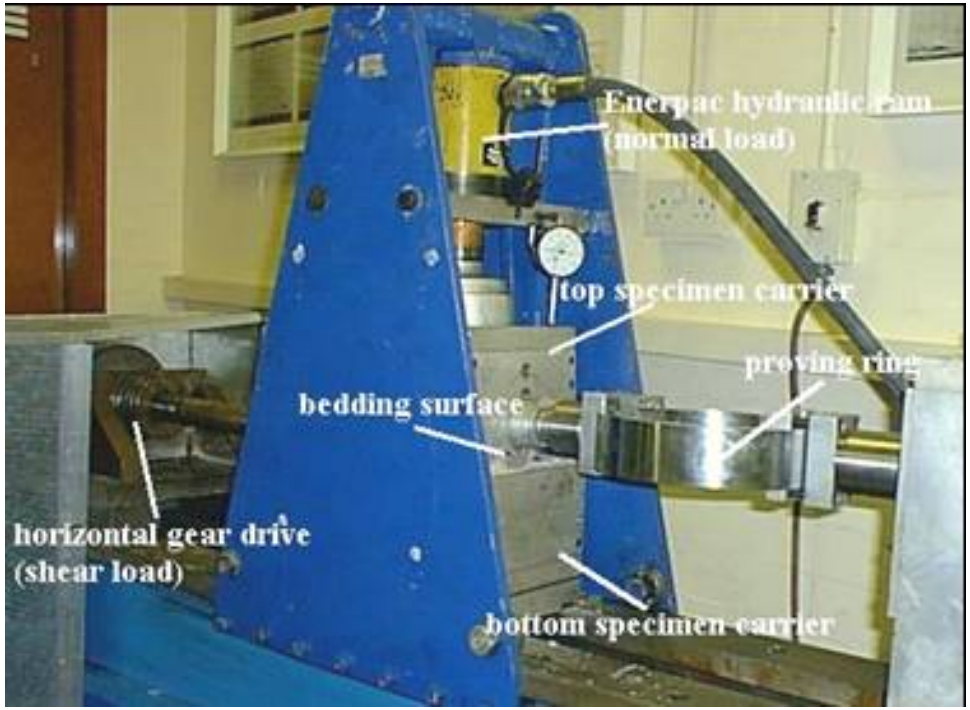
Dennison 20t tensile rig

Shear rig



Rock mechanics lab

- Rock test sample preparation
- RDP Howden 1000kN stiff press
- Shear rig
- Tensile test machine/ 500 t press
- Creep rig

Used for research and commercial testing

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Time Dependency Testing

- New Testing Rig
- 100 tonne capacity
- Temperature control
- 2 Vertical, 3 horizontal displacements
- Automatic logging

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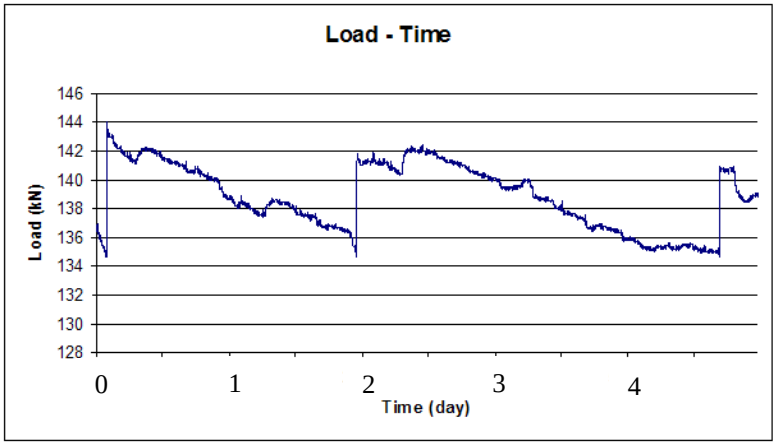
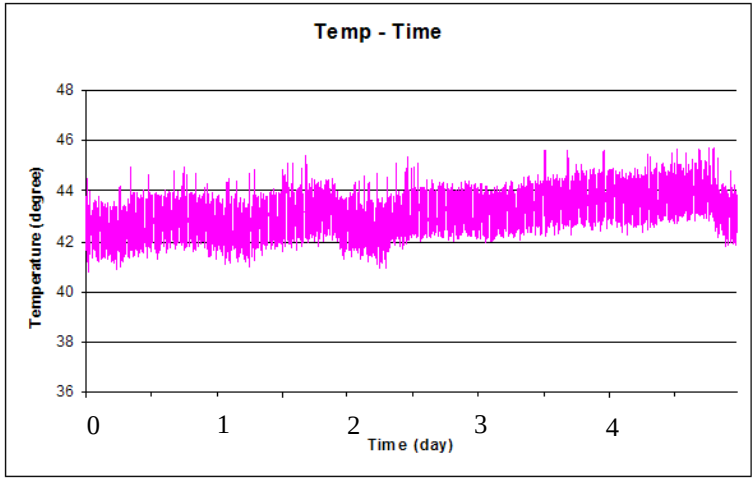
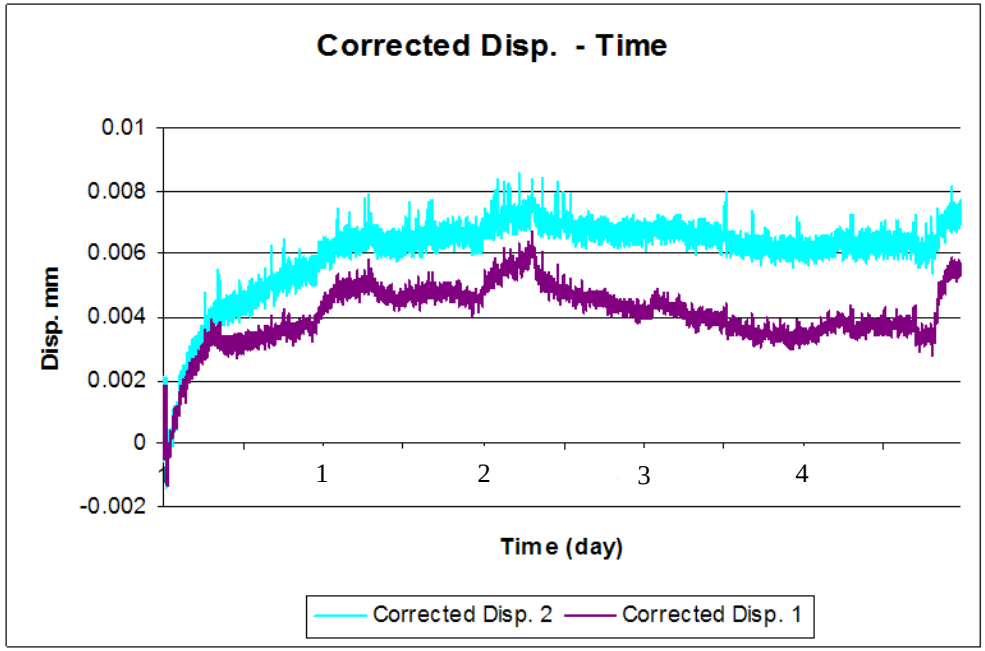
Time Dependency Data







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Numerical Modelling of Rock Excavations

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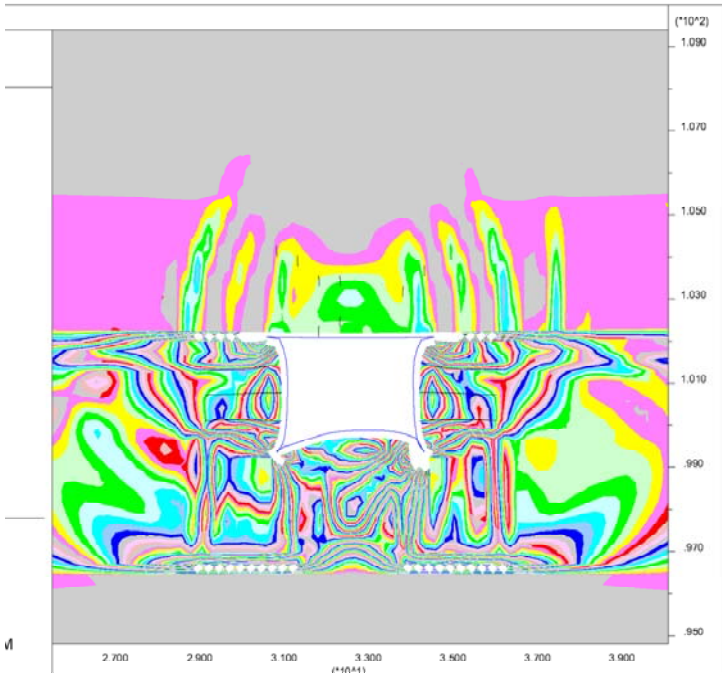
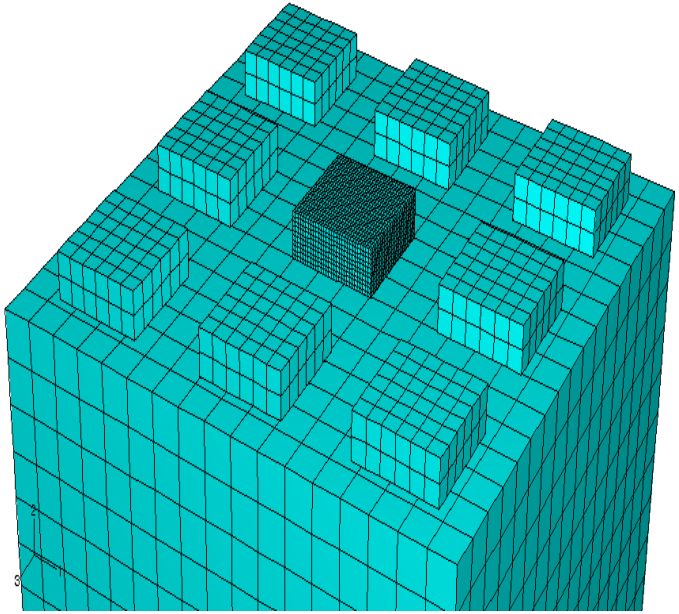
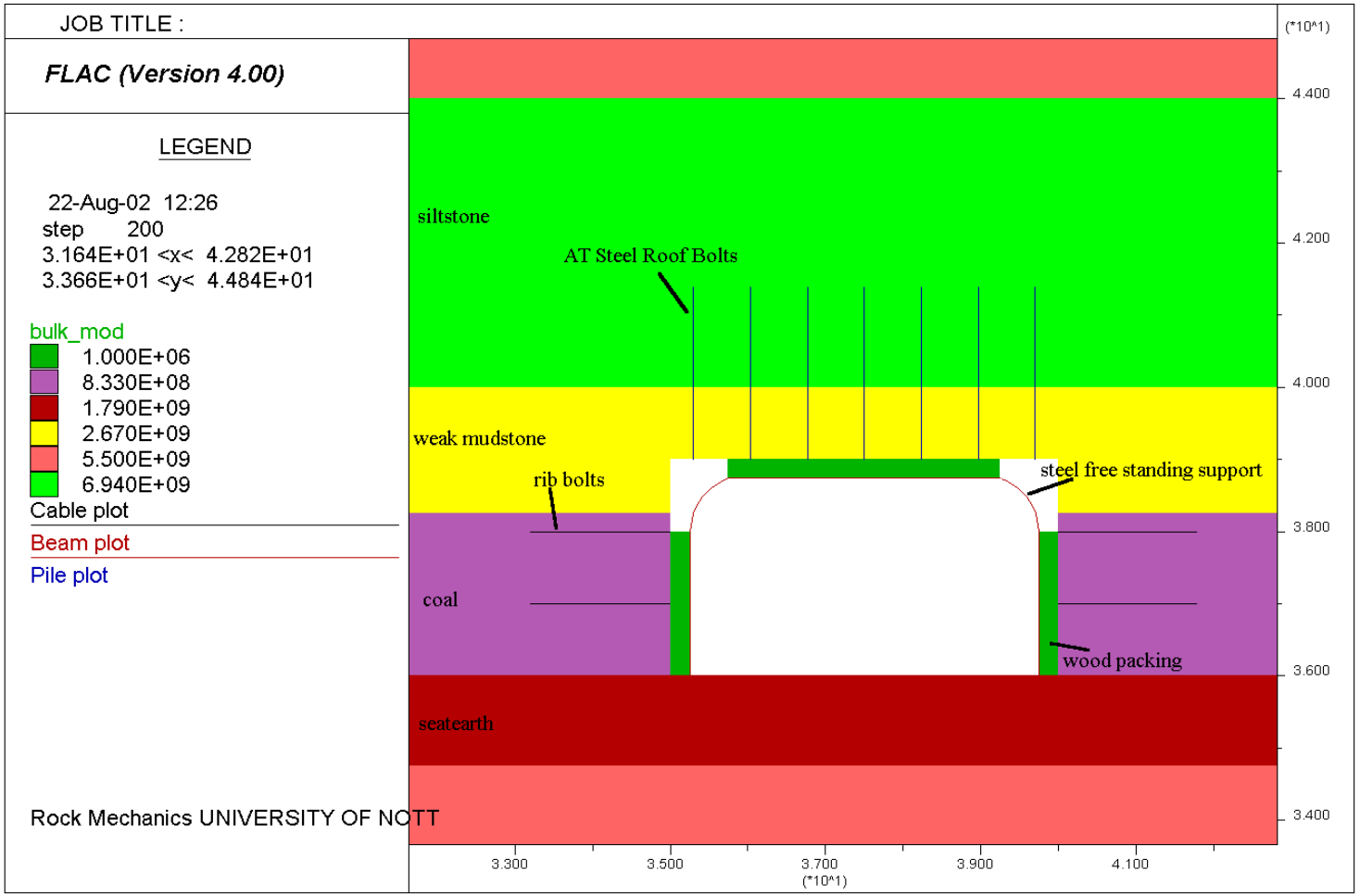
Highly deformed coal mine roadway



Partial extraction layout 3D model



Modelled using FLAC - a commercial finite difference code



FLAC allows the user to set up excavations in rock, insert support elements, both free - standing and internal to the rock mass (bolts), specify rock bed thicknesses and rock mass properties, and also specify external loads resulting from field stresses.

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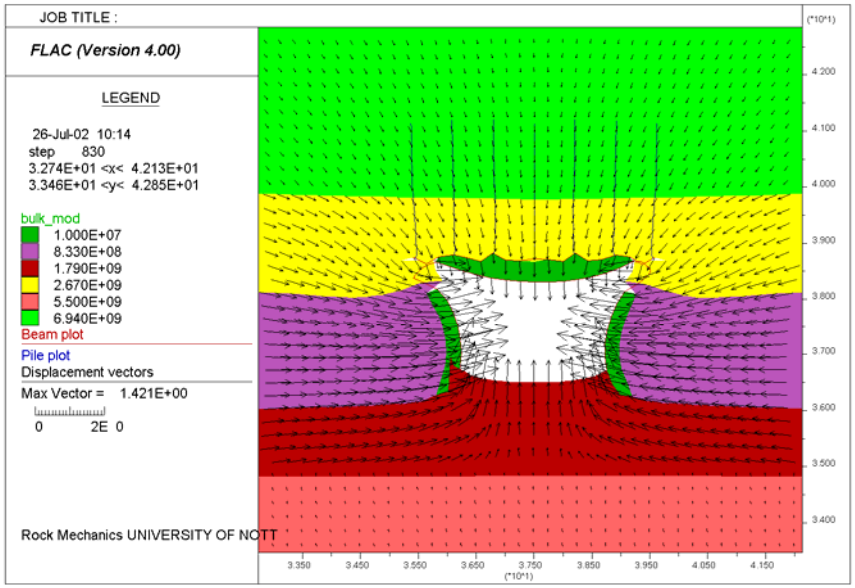
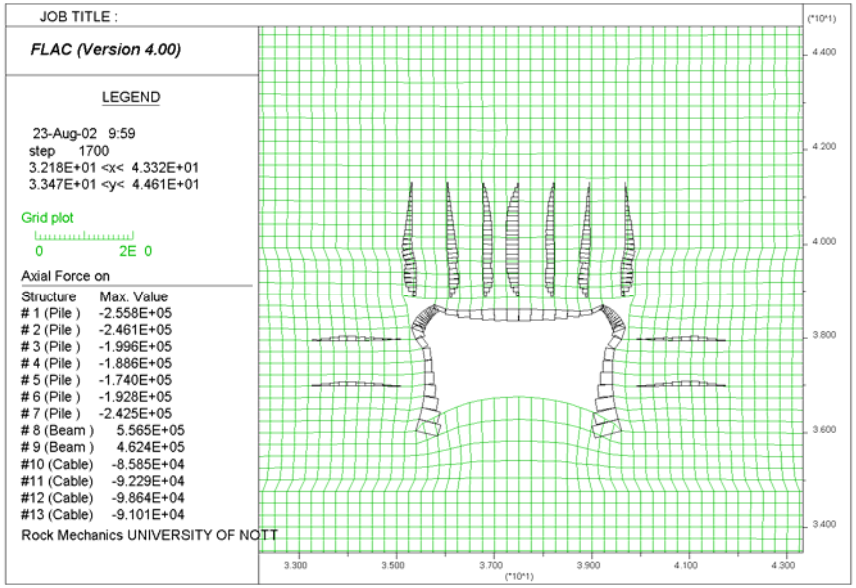
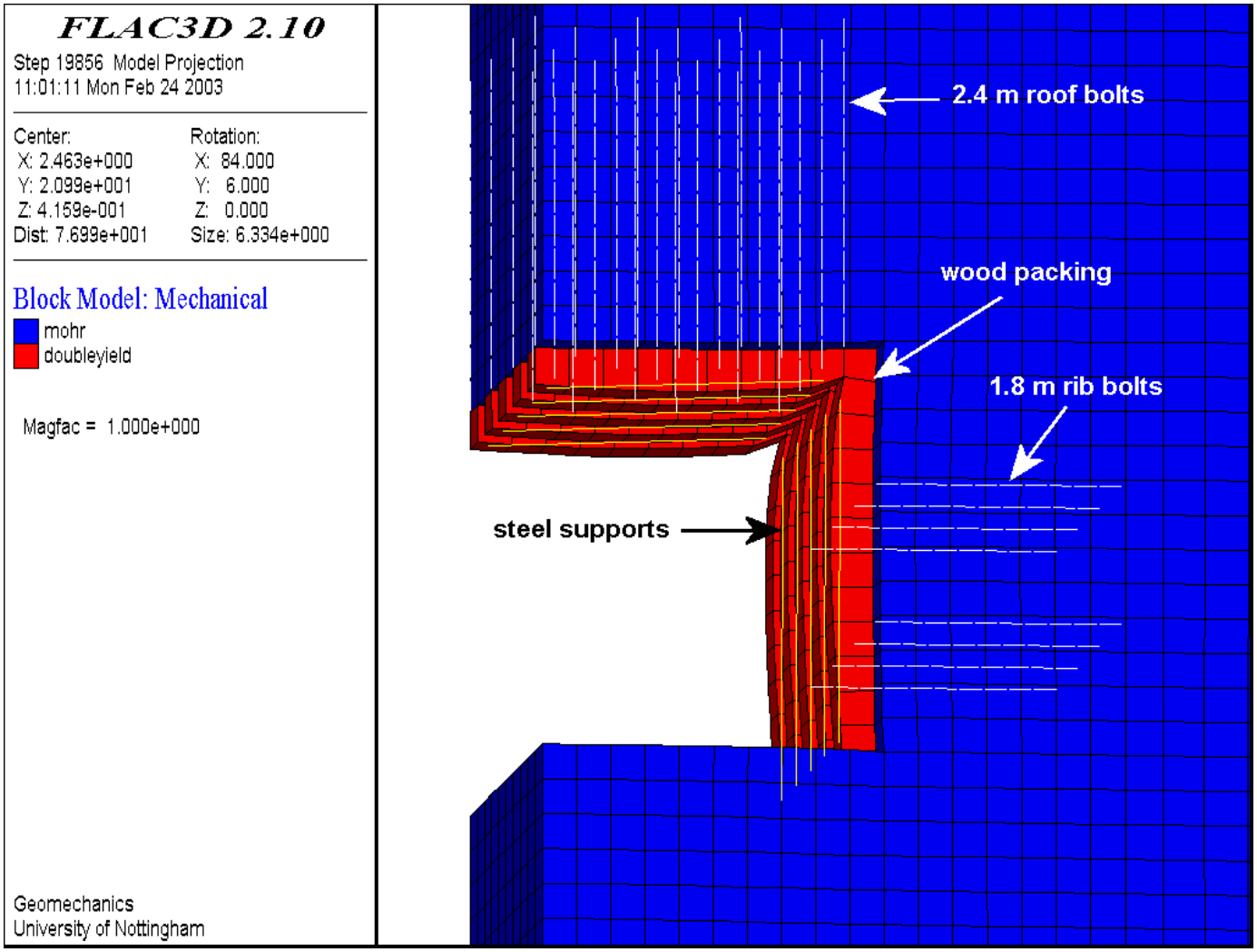


FLAC outputs can be in the form of stress concentrations strain, or displacement vectors

Modelling a “mixed” support system using FLAC to establish the supporting role played by both steel standing supports and rockbolts





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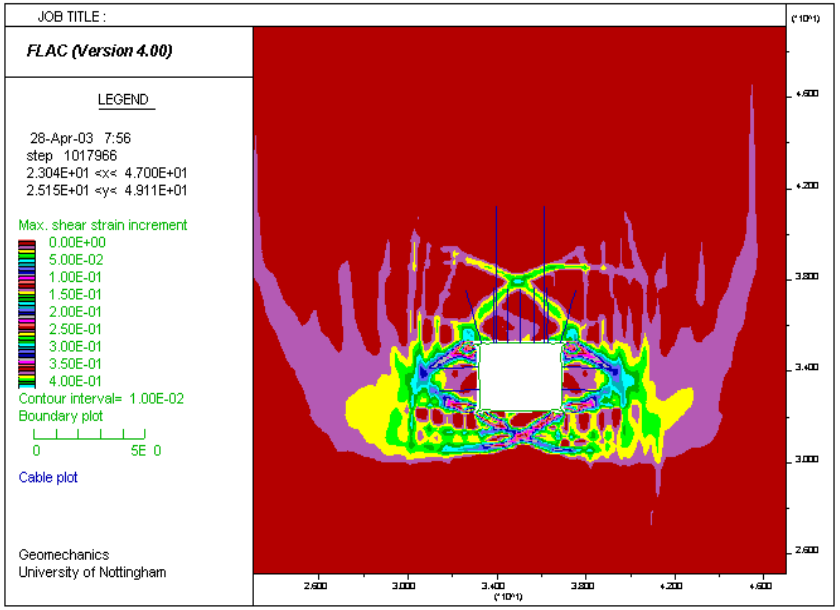
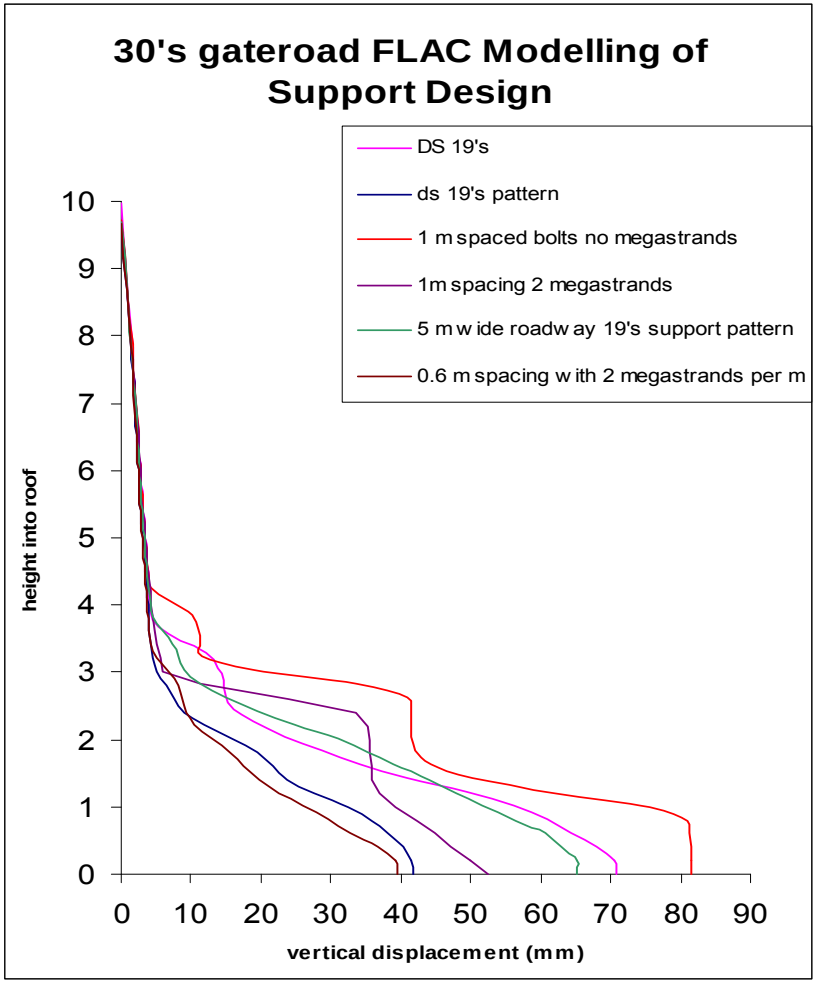
Sensitivity Studies





Modelling the effects of changes in support density and excavation width

Comparing modelled results with actual displacements

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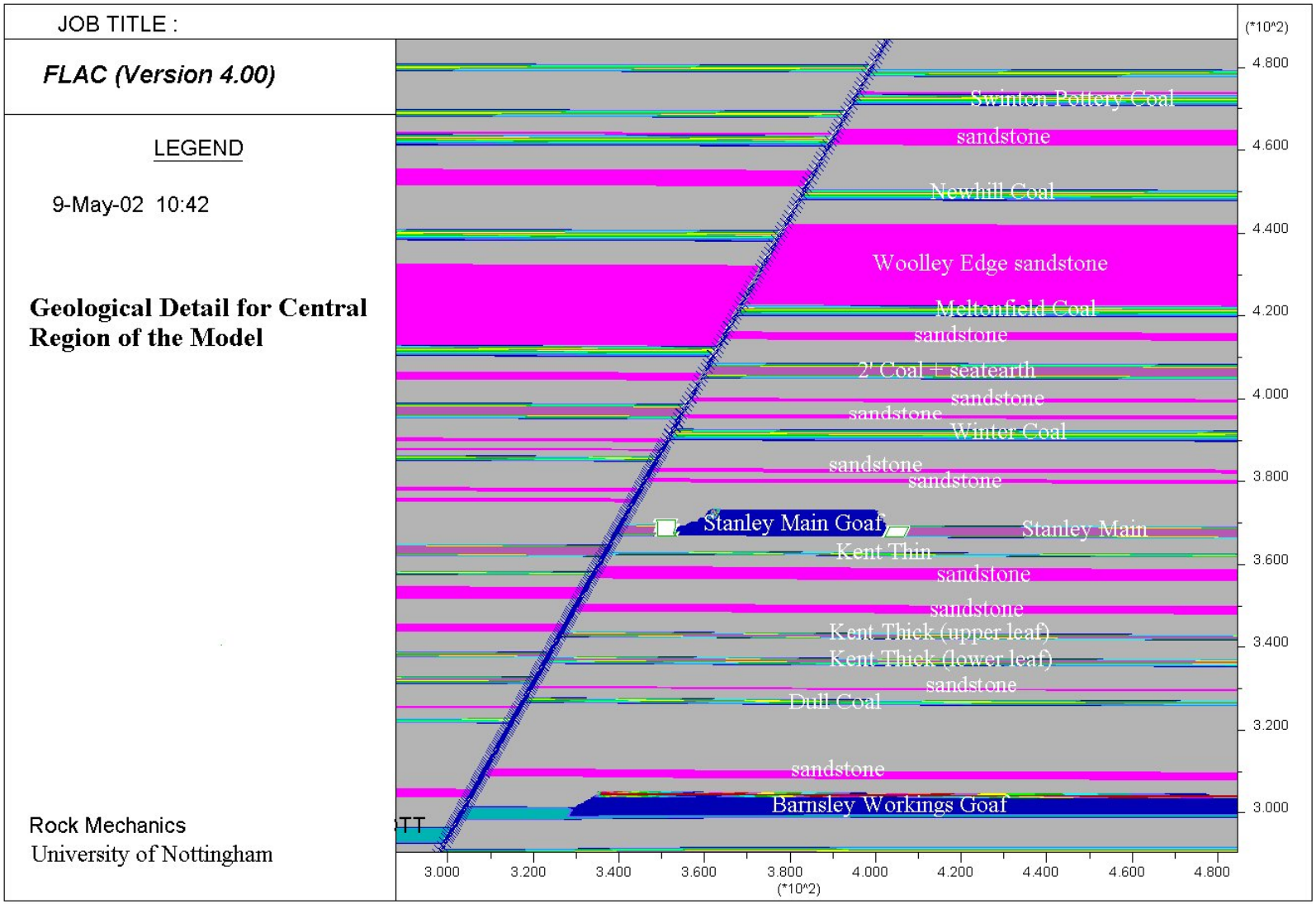

FLAC can also be used to identify flow paths for water of methane through rock masses affected by longwall mining

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JOB TITLE :

FLAC (Version 4.00)

LEGEND

9-May-02 10:42
step 24010

Shear Strain Plot

Contour Interval 2mm/m

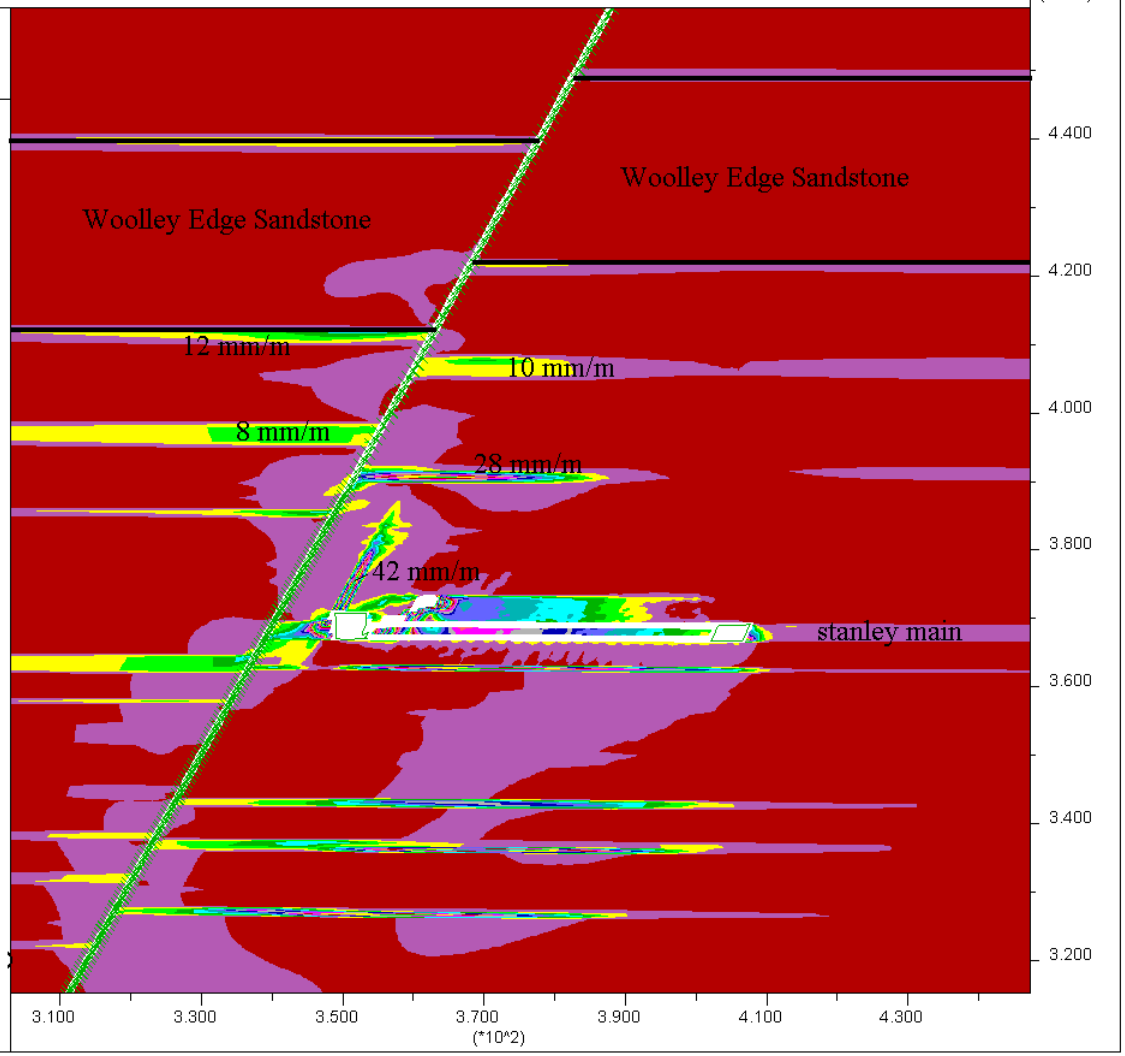
shear strain < 2mm/m

Boundary plot

0 2E 1

Interface ID#'s

Rock Mechanics
University of Nottingham



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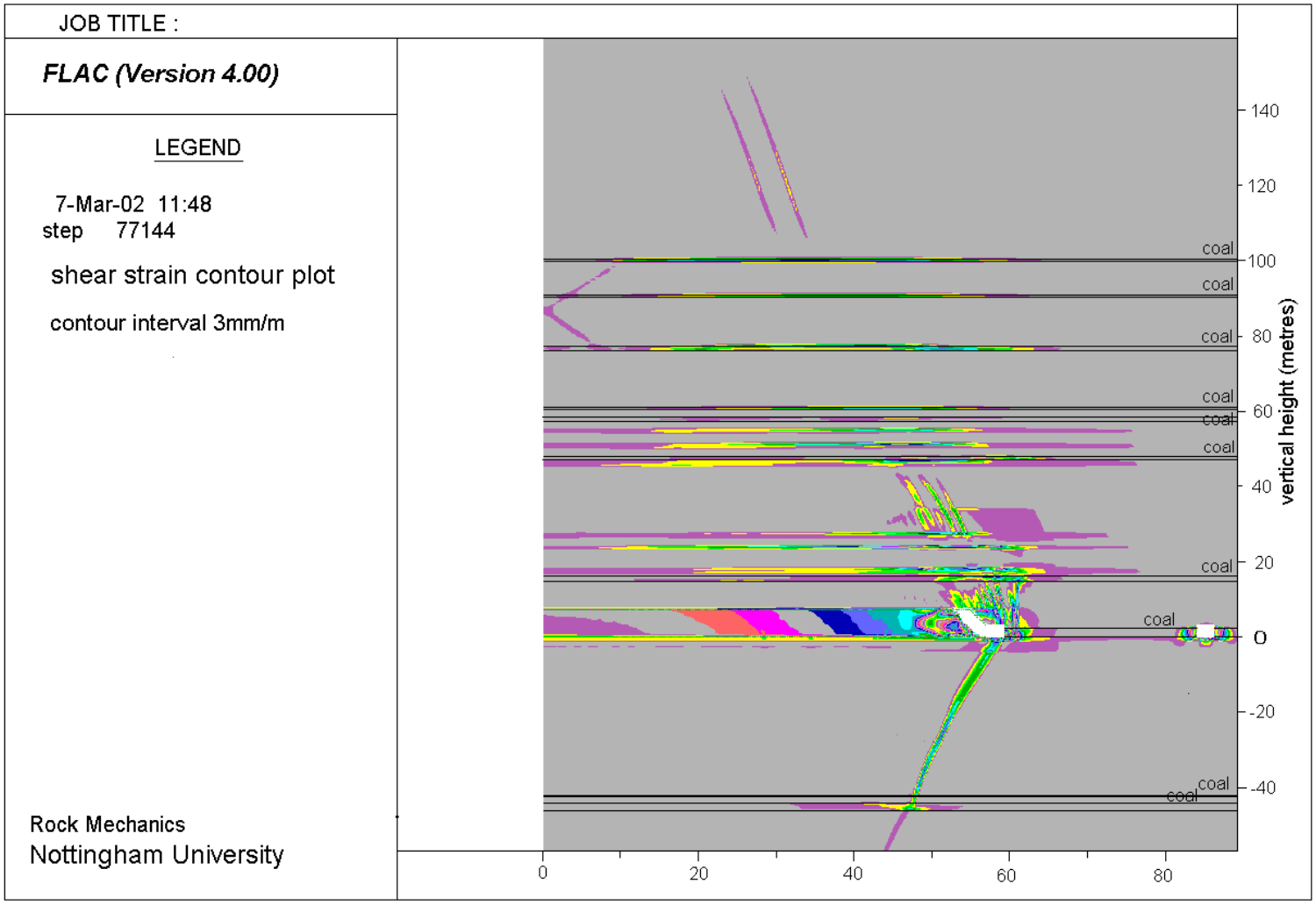

Shear Strain >3mm/m developed around the collapsed goaf and tailgate

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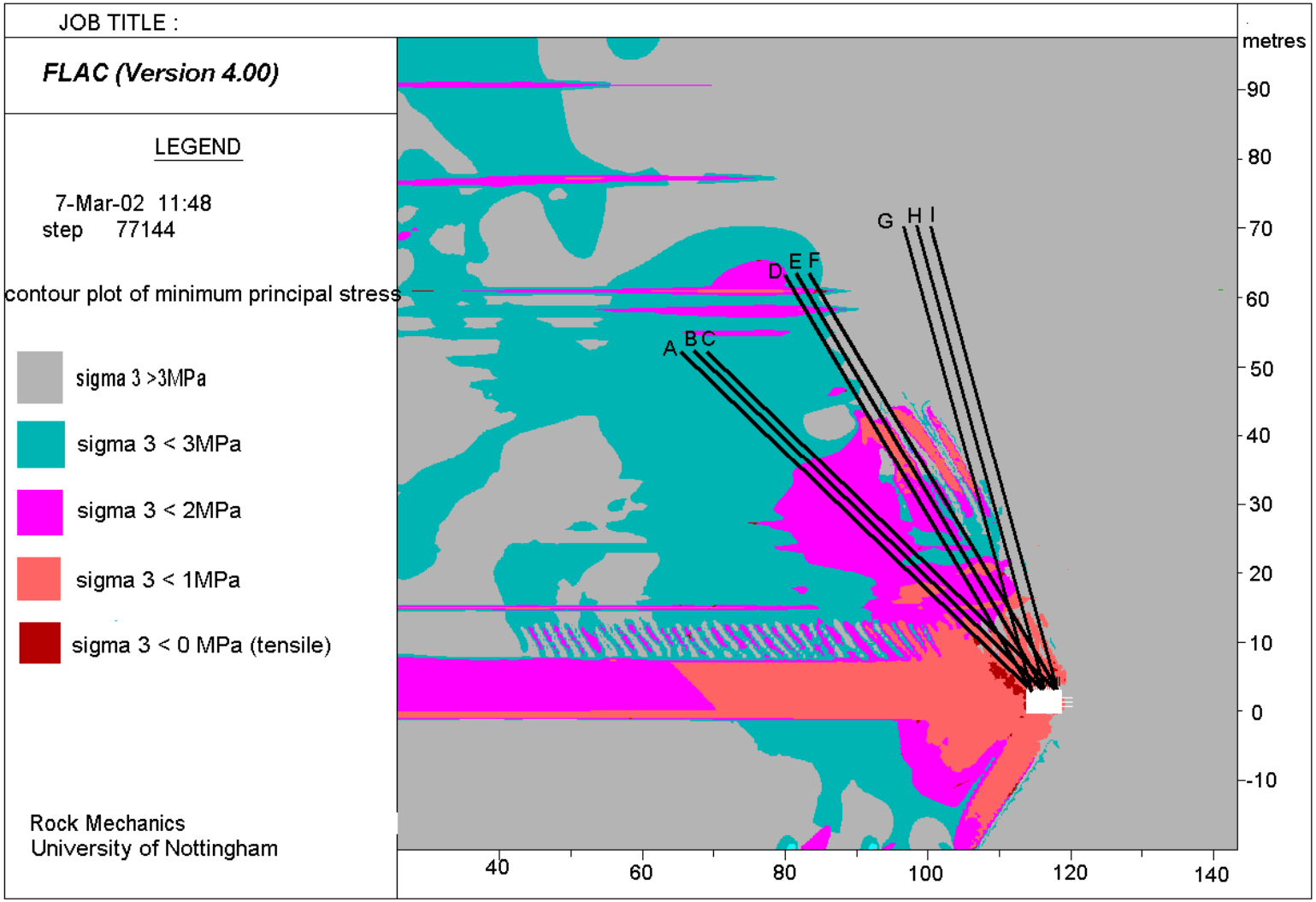

Confining stress contours with positions of gas standpipe boreholes

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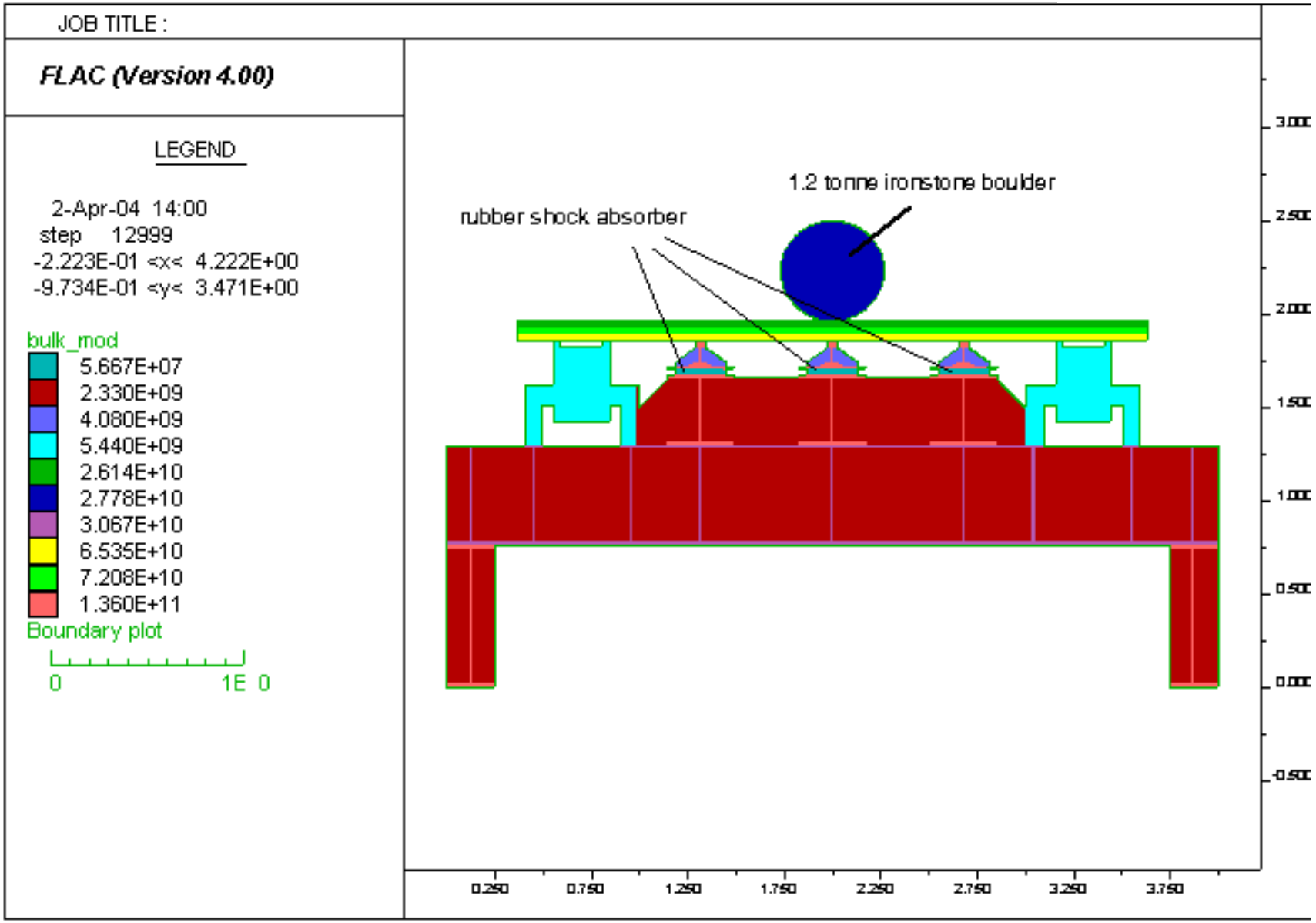
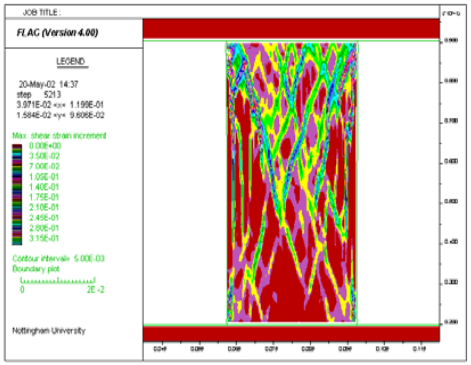


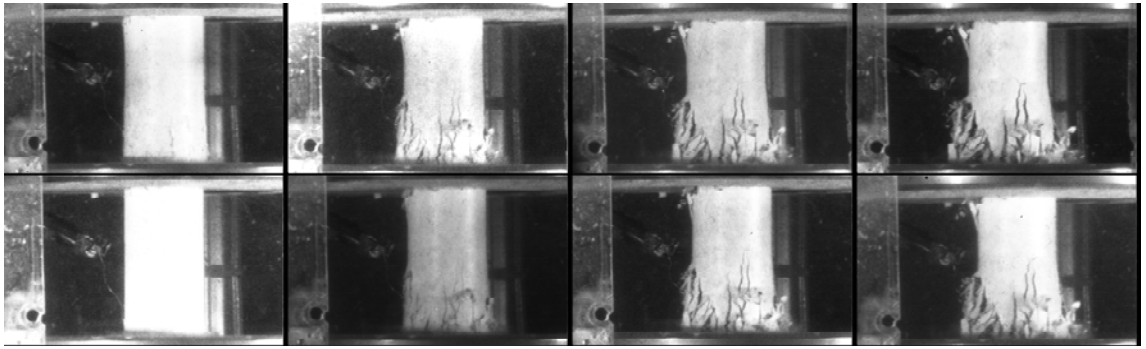
Steel Conveyor and Boulder Model

Impact Breakage of Rock

High speed camera system
100,000,000 frames/second



FLAC numerical representation of fracture development



Crack propagation from dynamic impact of cylindrical rock specimen

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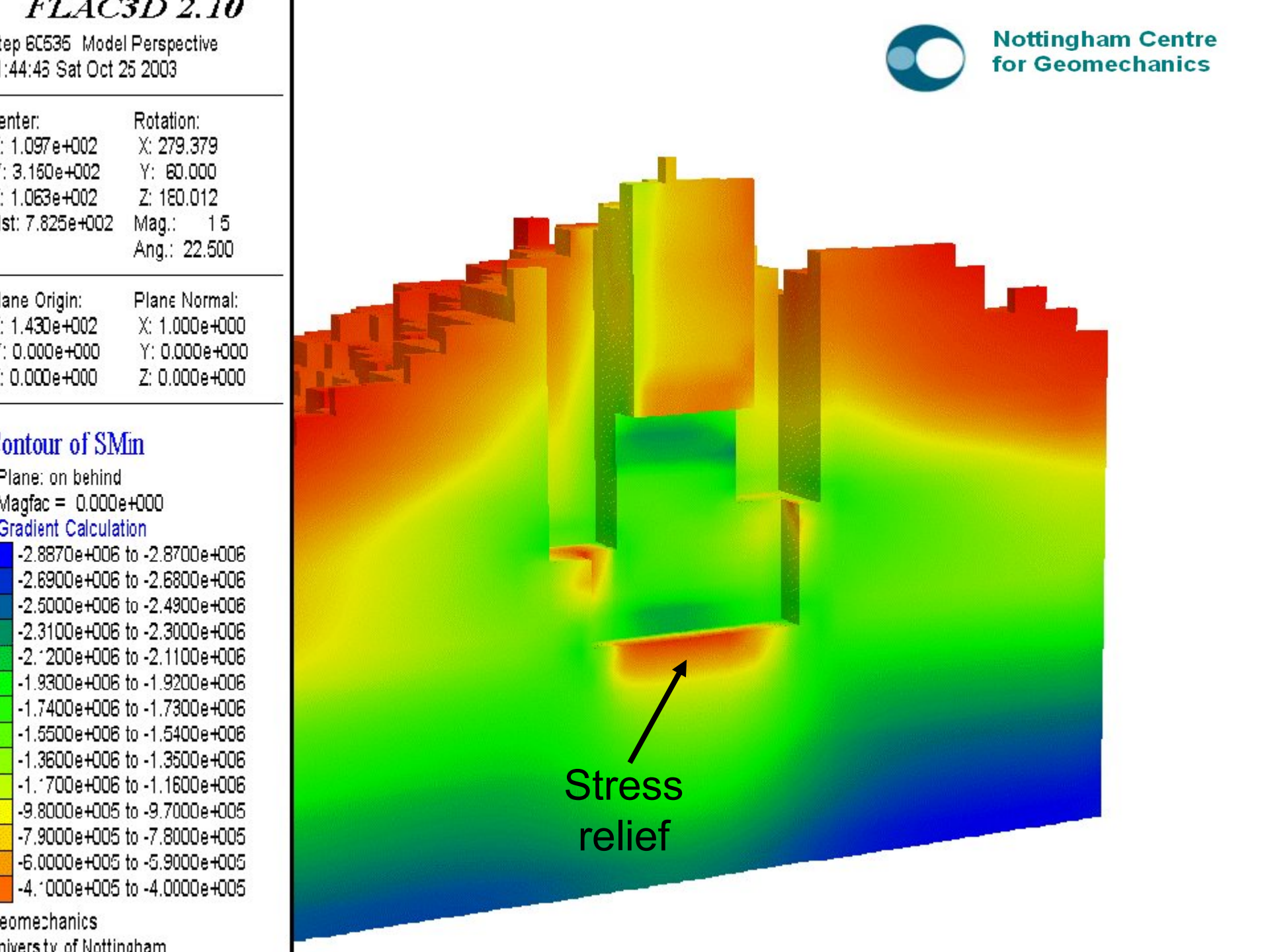
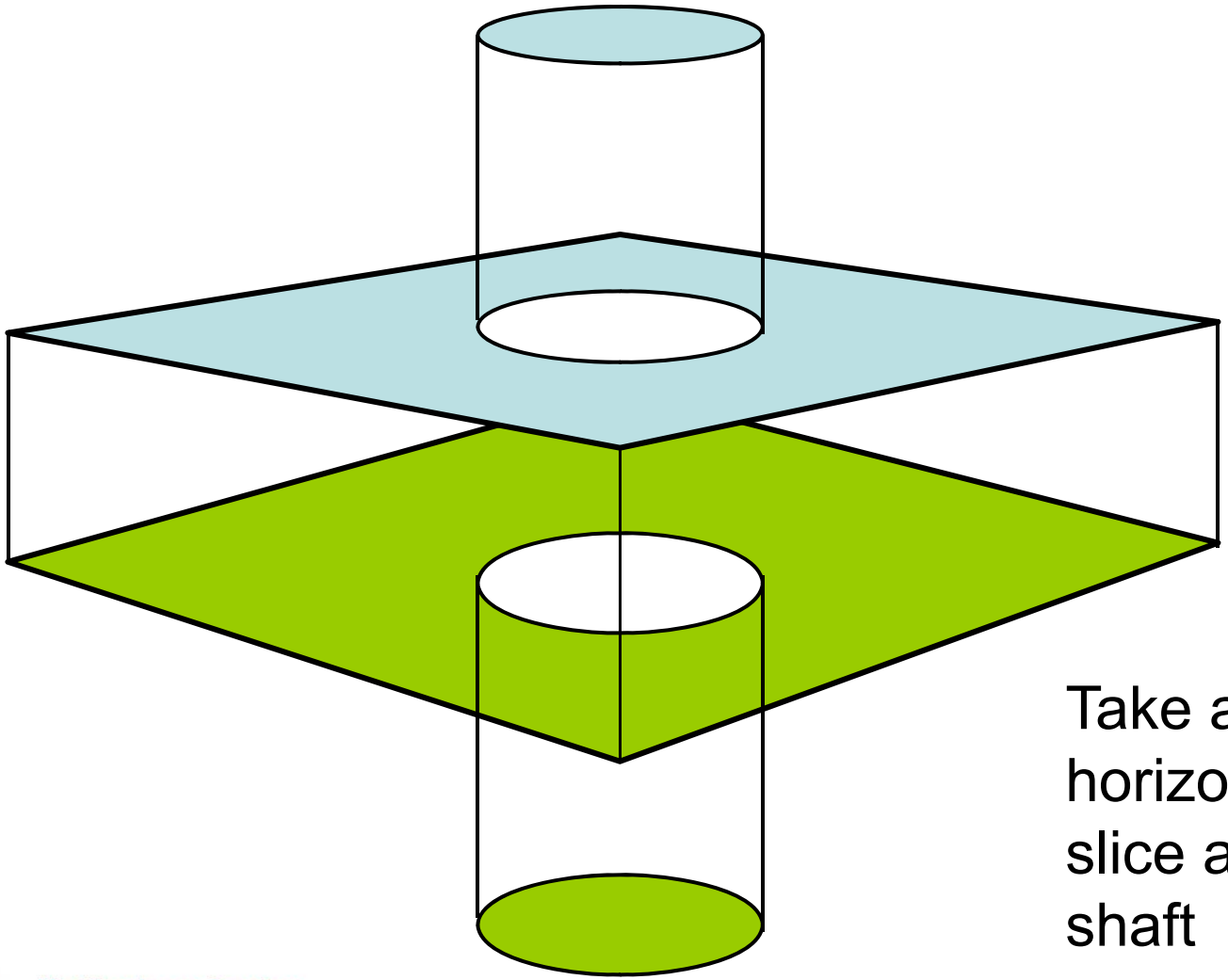

FLAC3D 2.10
ep 60535 Model Perspective
:44:46 Sat Oct 25 2003
enter:
: 1.097e+002
: 3.150e+002
: 1.063e+002
st: 7.825e+002
Rotation:
X: 279.379
Y: 60.000
Z: 180.012
Mag.: 1.5
Ang.: 22.500
lane Origin:
: 1.430e+002
: 0.000e+000
: 0.000e+000
Plane Normal:
X: 1.000e+000
Y: 0.000e+000
Z: 0.000e+000
ontour of SMin
Plane: on behind
Magfac = 0.000e+000
Gradient Calculation
-2.8870e+006 to -2.8700e+006
-2.6900e+006 to -2.6800e+006
-2.5000e+006 to -2.4800e+006
-2.3100e+006 to -2.3000e+006
-2.1200e+006 to -2.1100e+006
-1.9300e+006 to -1.9200e+006
-1.7400e+006 to -1.7300e+006
-1.5500e+006 to -1.5400e+006
-1.3600e+006 to -1.3500e+006
-1.1700e+006 to -1.1600e+006
-9.8000e+005 to -9.7000e+005
-7.9000e+005 to -7.8000e+005
-6.0000e+005 to -5.9000e+005
-4.1000e+005 to -4.0000e+005
eomechanics
niversity of Nottingham
Nottingham Centre
for Geomechanics
Stress
relief

Layout of Shaft Model



Take a 2D horizontal slice across shaft

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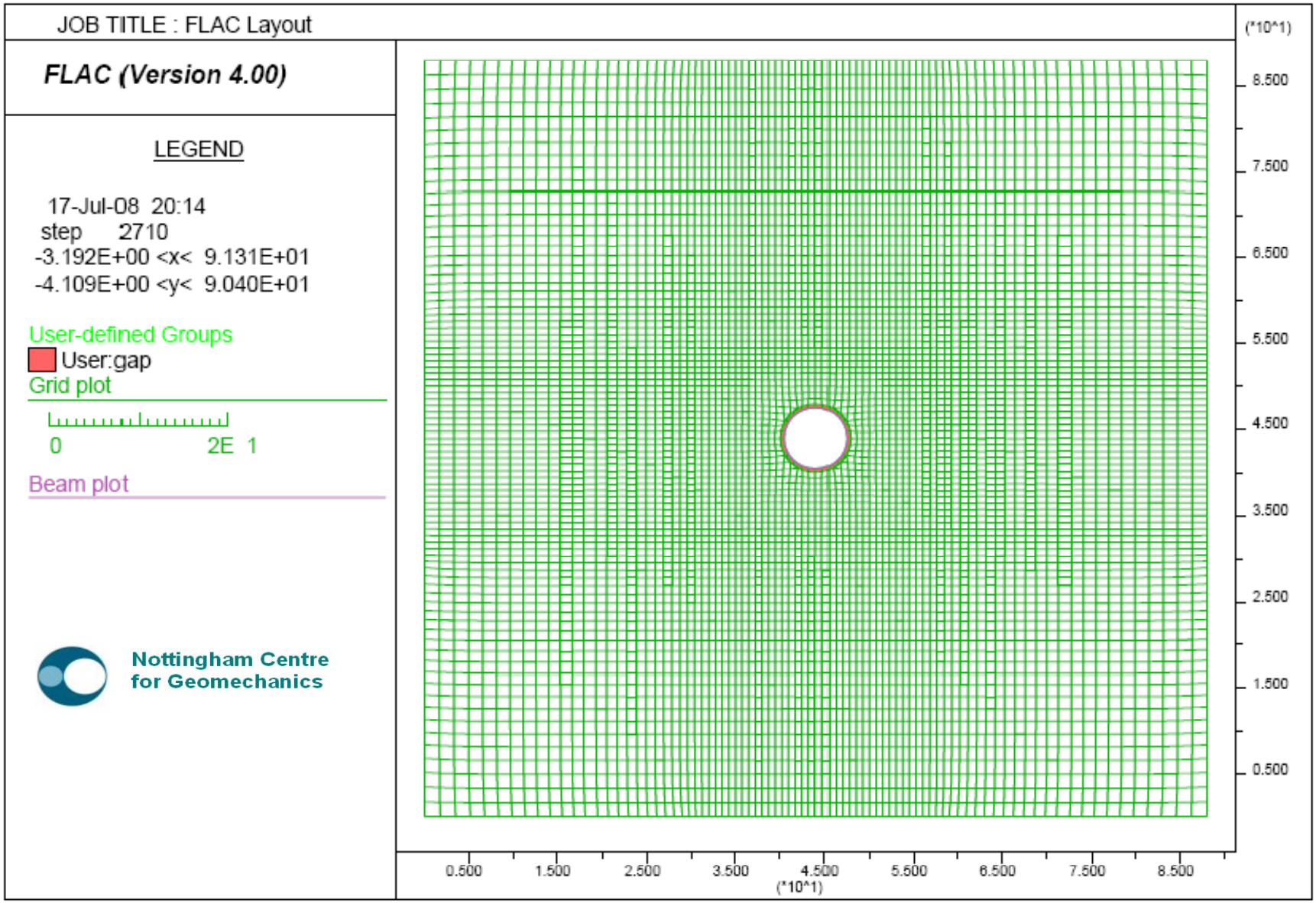
Layout of Shaft Model



FLAC Grid

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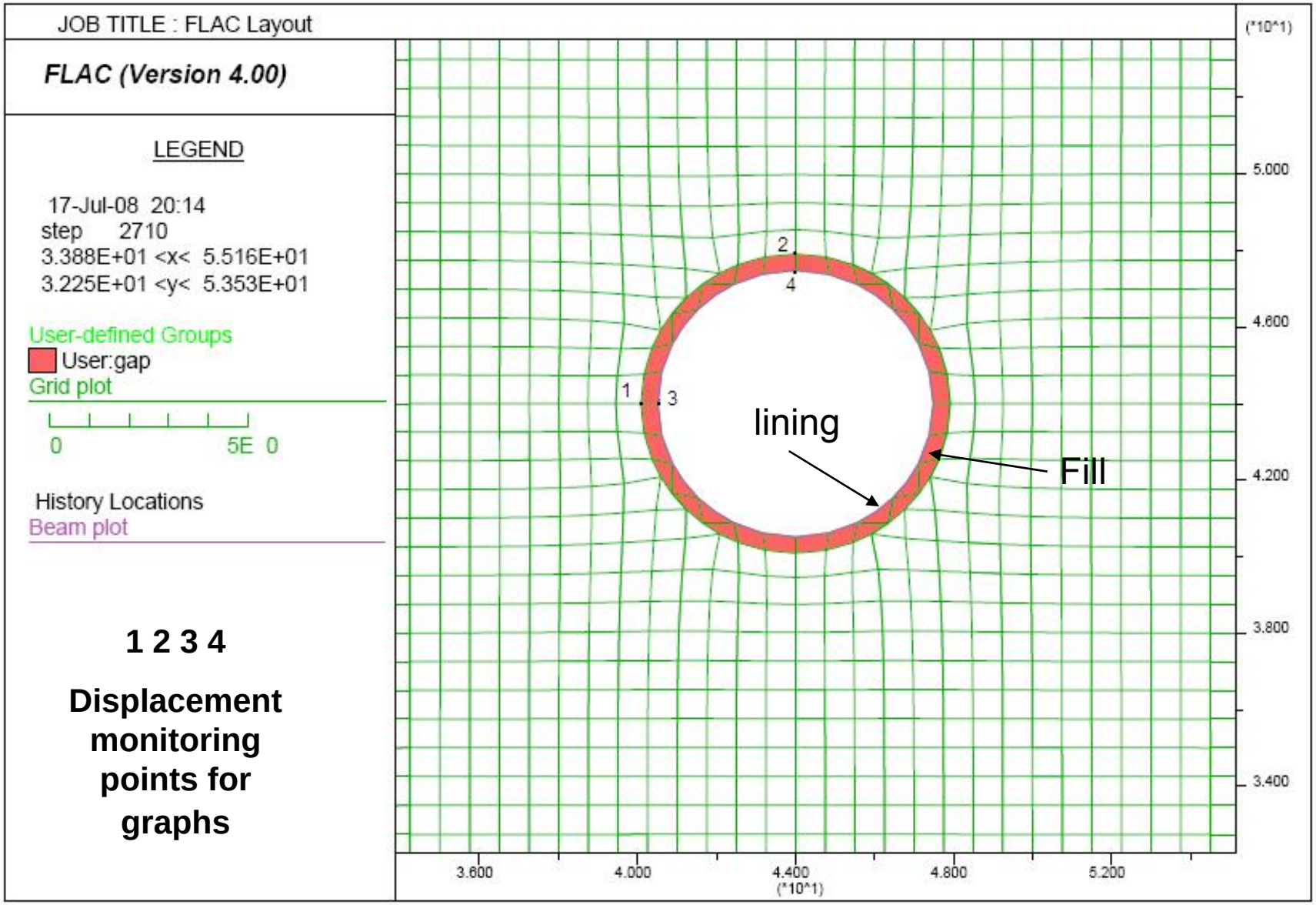

Input Parameters for Rock Type

- Stiffness
  - Modulus E = 1 – 6 GPa
  - Poisson's ratio v = 0.35
- Strength
  - Cohesion 0.1 – 5 MPa
  - Friction Angle $10 – 35^0$
- Stress
  - σ_{xx} 14.24 MPa
  - σ_{yy} 16.51 Mpa

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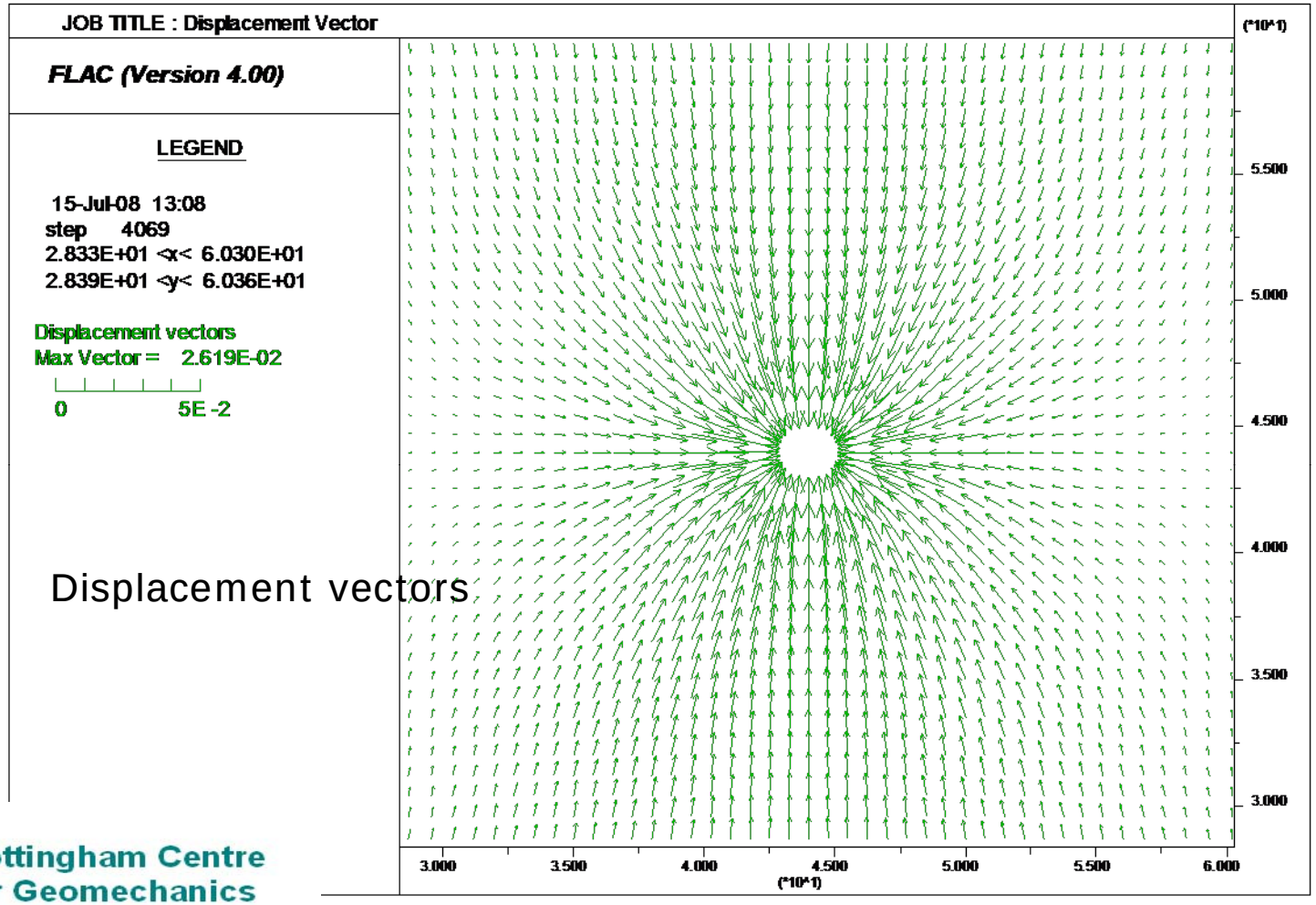
Example Model in Yield



Displacement vectors

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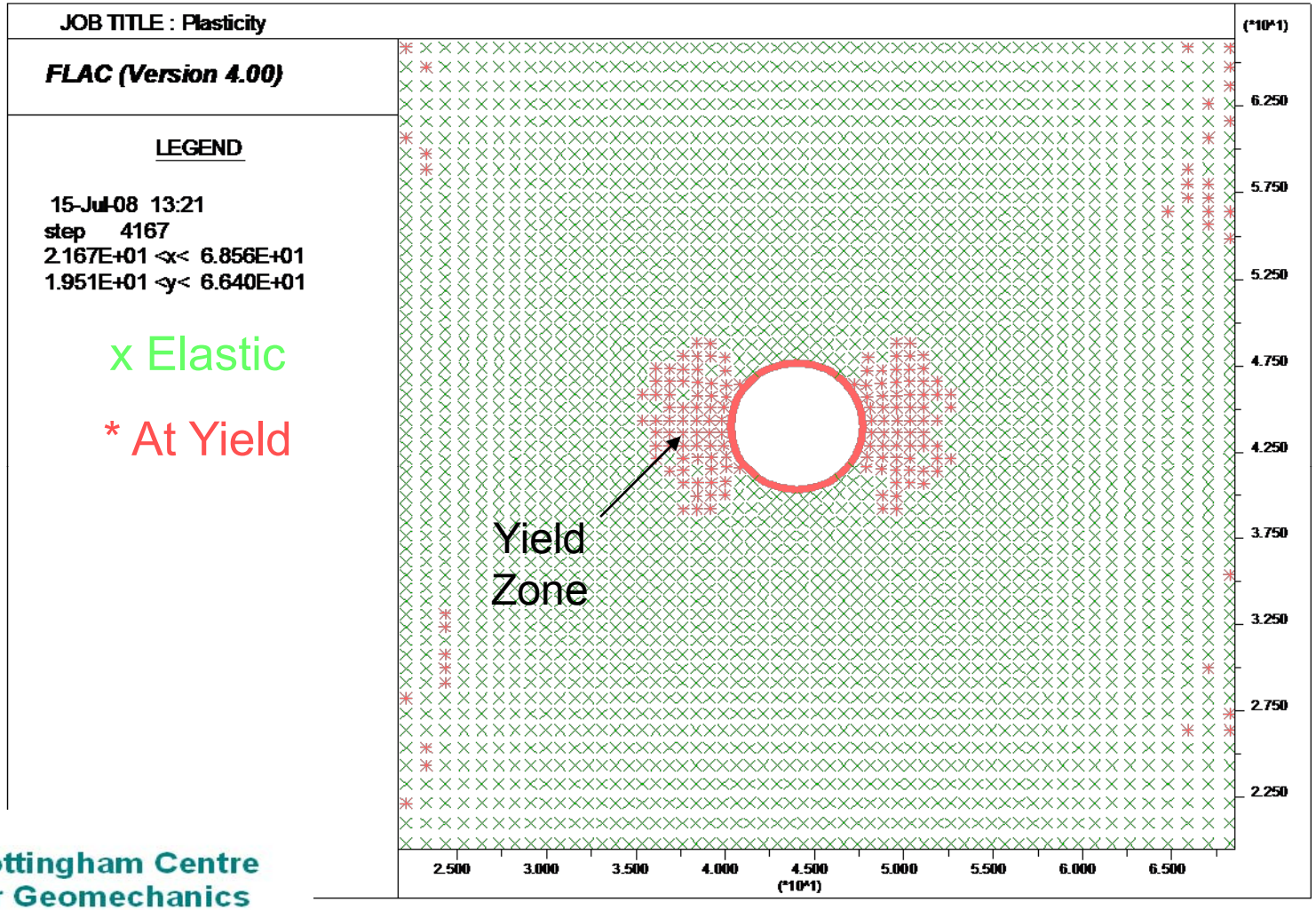
Example Model in Yield



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Research funding

- **RFCS**
  - EU Research Fund for Coal and Steel
  - provides 60% funding for projects
  - requires partnerships to be established across national boundaries
  - preference to projects with members from industry
  - coal focus
- **EPSRC**
  - Govt. funded Research Council
  - 100% funding
  - ring-fenced for the university sector, but very competitive
- **Industrial**
  - very welcome, but generally very short term
  - strategic relationships to promote large scale multi-disciplined research
  - income from commercial work, especially rock testing
- **Scholarships**
  - some potential help from scholarships
  - self-funded research students

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What research are we doing today?

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IMPREX Project

Objective

RFCS Funded project with the objective of improving coal recovery from otherwise sterilised reserves such as roadway pillars and remnants

Deliverable

Feasibility study recommending an economic safe extraction method & potential location/s

Partners

UK Coal, Rock Mechanics Technology Ltd, plus German and Polish partners

Selection of an Extraction Method

A typical Auger system

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Problems

- Continuity
  - feast and famine of research work (and funding)
- People
  - attracting the best skills in return for low pay and lack of security
  - uncertain prospects of an academic career
  - keeping our good people long enough to complete the research
- Maintaining our hardware and software
- Delivering all the outputs

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Thank you.

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