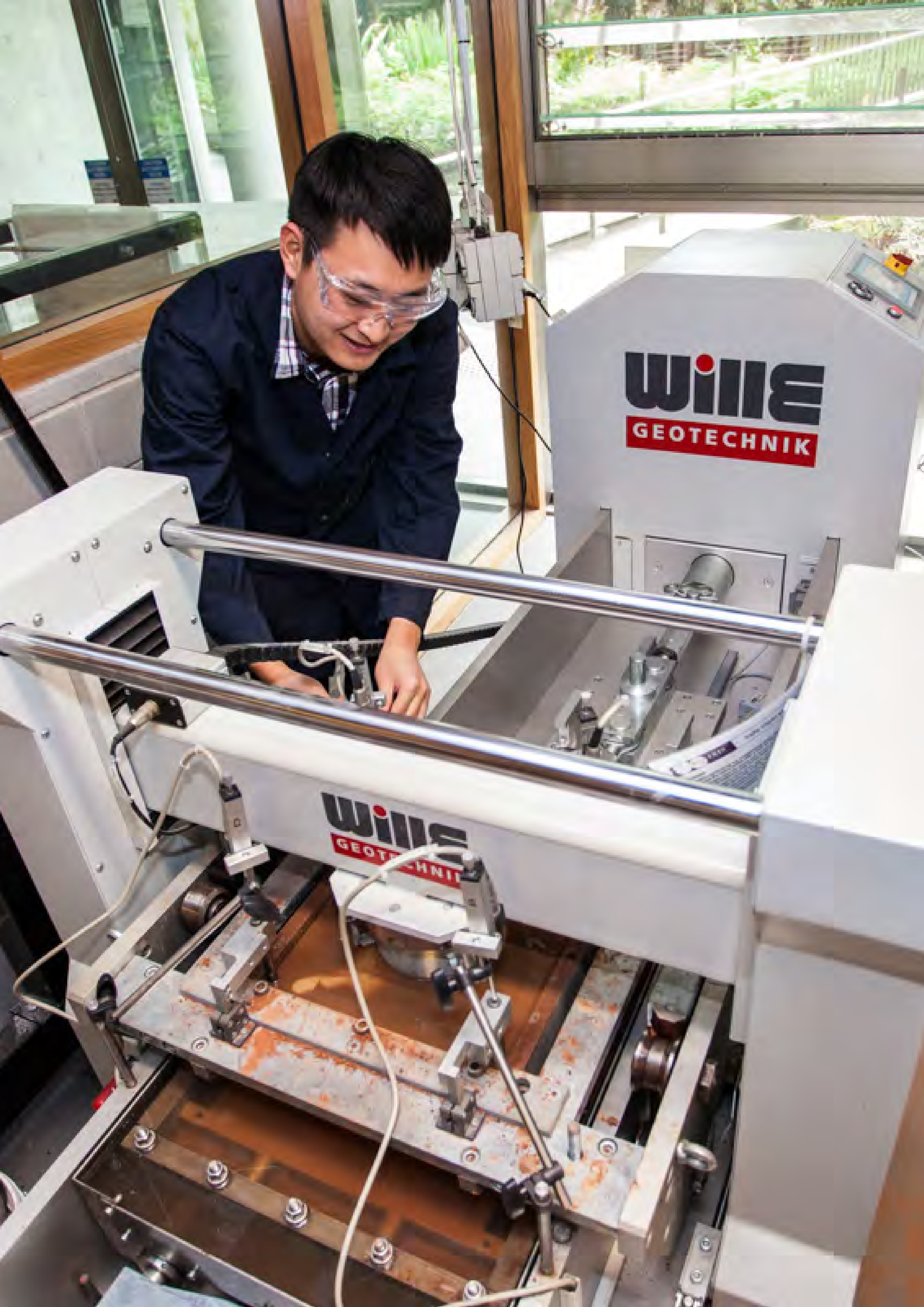
THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

CREATE CHANGE

GEOTECHNICAL ENGINEERING CENTRE

Testing, training and numerical modelling capabilities

2019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GEOTECHNIK

Capability **Summary**

The Geotechnical Engineering Laboratories within the Geotechnical Engineering Centre (GEC) in the School of Civil Engineering at The University of Queensland (UQ) continue to develop a wide range of world–leading testing facilities.

We have a culturethat promotes professionalism and creativity in all users of the laboratories. We aim to collaborate with other universities and industry partners to ensure the establishment of laboratory services relevant to meeting research and testing needs in Geotechnical Engineering.

Our facilities include custom-built equipment that covers a wide variety of soil and rock testing, and a capability to produce high-quality results for use in journal and conference papers, undergraduate and postgraduate research, and a growing number of commercial projects.

We are open to partner with Universities and Industry locally and internationally, including a push into South America in the tailings field, with projects in Chile and Brazil, and potential expansion into Colombia and other countries with important mining production.

Catering for change in geotechnical and geoenvironmental engineering for next generation of sustainable mining and civil infrastructure

GEC Industry Partners and Funding	
2007–2011	Golder, and matching UQ funding, totalling up to $400,000 per year.
2012–2017	Golder, Rio Tinto, AngloGold Ashanti, BHP, McArthur River Mining and Wagstaff Piling, and matching UQ funding, totalling up to $1.2 million per year.
2018–2022	BHP, McArthur River Mining, Alfa Laval, AngloGold Ashanti, AusiMM, Aurecon, BASF, KCB, Jellinbah, KCB, Mining3, ReoCo, Wagstaff Piling, and others, and matching UQ funding, totalling up to $900,000 per year.
LOP Management and Industry Sponsors	
2017–2019	Management of the Large open Pit Project LOP II (by Professor David Williams and Dr Mehdi Serati) valued at $2,05 million and involving Industry Partners AngloGold Ashanti, Barrick Gold, BHP, De Beers, Debswana, Newcrest, Rio Tinto, and Vale (www.lopproject.com).
2020–2022	Management of the Large open Pit Project LOP III – Open Pit of the Future (by Professor David Williams and Dr Mehdi Serati) valued at $4 million and involving over 10 Industry Partners (www.lopproject.com).

Teaching and **learning**

Unique Geotechnical Engineering Dual Major Programs

The GEC introduced in 2012 Geotechnical Engineering Dual Major Programs available to Civil and Mining Engineering undergraduates, which are unique in Australia. These include about one-third of the program devoted to Geology, Soil Mechanics and Rock Mechanics Courses, which are taught to the combined Civil and Mining Engineering cohort and are taken up as Elective Courses by others. The combined graduation is up to 70 graduates per year.

Postgraduate Research

The Geotechnical Engineering Centre supports up to 40 research higher degree students and currently offers three Courses to the Master of Engineering Coursework Program in Civil Engineering.

Research capability

The GEC's Geotechnical Engineering Laboratories offer a wide range of high-level soil, rockfill and rock testing capabilities for postgraduate research, undergraduate thesis projects, and commercial testing.

The efforts of the laboratory and academic staff are reflected in the extensive number of conference and peer-reviewed journal papers published, the number of PhD and MPhil degree students under supervision, continuous contributions to undergraduate student professional development through thesis projects, and extensive commercial testing. In addition to standard soil and rock sample preparation and testing facilities, the laboratory has developed unique soil and rockfill testing systems as listed on the following pages..

Research expertise

The Centre carries out applied research in:

- Mine waste management, rehabilitation, and closure.
- Ground improvement and reclamation.
- Waste utilisation.
- Tunnel support.
- Rock fracture mechanics.
- Design parameters for soil and rock structures.

The impacts of the applied research carried out by the Centre include:

- Improved land reclamation.
- Improved mine closure.
- Reduced risk of piping of dams.
- Improved tunnel support.
- Improved soil and rock design parameters.
- Improved tailings dam design and operation to reduce the risk of tailings dam failure and facilitate closure.

Learn more about geotechnical engineering research at UQ.

Soil testing capabilities

High stress consolidation testing

Purpose-built consolidation cell with 150 mm diameter by 150 mm high, and a maximum vertical stress of 10 MPa. Suitable for particle sizes up to 19 mm. The device is suitable for testing rockfill and mine waste rock to loading equivalent to up to 600 m of overburden.

Large-Scale Triaxial Testing

For testing soil specimens up to 100 mm in diameter and up to 200 mm high, up to 1,000 kPa cell pressure, under, saturated or unsaturated conditions.

Slurry consolidation testing

Purpose-built consolidation testing of soils from a slurry state, including tailings and dredged sediments. Dimensions of 150 mm diameter by 410 mm high, with a maximum vertical stress of 500 kPa (up to about 60 m depth of tailings). Instrumented with top and base load cells, and pore water pressure transducers at the base and 40 mm intervals up the side of the cell.

Large soil direct shear and pull out testing

Large direct shear apparatus for shear strength and pull-out testing involving coarse-grained materials and geotextiles with 300 mm x 300 mm cross-section and 200 mm high. The machine can apply maximum normal stress of up to 4,000 kPa (for 150 mm specimens). The device is suitable for particle sizes up to 37.5 mm, and shear and pull-out testing of geotextiles.

Instrumented Column Testing

Column, and associated moisture, suction, temperature, salinity and gas sensors, and data logger, was developed at UQ as a "standard test" for assessing the settling, self-weight consolidation and desiccation of tailings slurry. It measures 1.2 m high by 200 mm diameter, is constructed in sections for ease of pouring and sample deconstruction, and can be deployed in laboratory-simulated desiccation and re-wetting, and under atmospheric conditions in the field, with a weather station.

Large-Scale, Instrumented Field Column Testing

Large-scale field columns and associated moisture, suction, temperature, salinity and gas sensors, and data logger, for assessing covers for potentially contaminating waste rock.

Soil Water Characteristic Curves

This test simulates drying/wetting of tailings under applied pressure (suction) in order to measure moisture vs suction values on samples of 75 mm diameter and 25 mm height.

Instrumented large columns

Large columns for testing sediments and mine tailings from a slurry, including settling, self-weight consolidation, desiccation and re-wetting. Sensors include moisture, suction, temperature, salinity, gas, piezometers, inclinometers, and data loggers to replicate wetting/drying long term periods.

Filtration Cell

To apply controlled air pressure onto tailings samples in order to dry them out and collect the water coming out of them.

Electromagnetic and Hydraulic characterisation

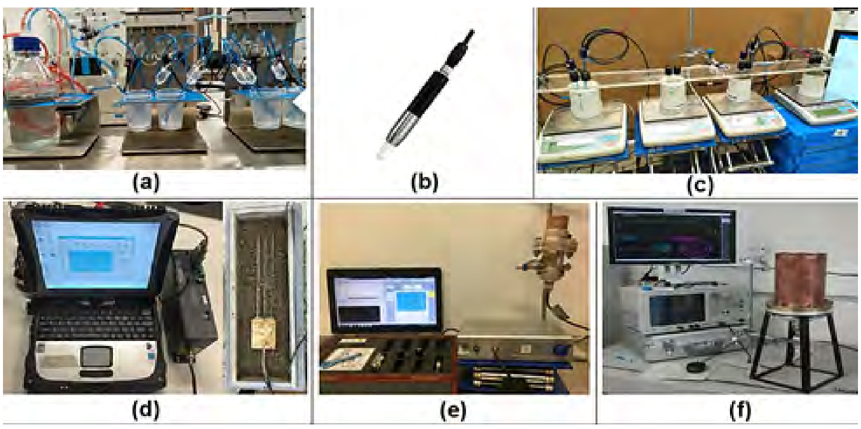
(a) T5x tensiometers (measures suction up to 160 kPa); (b) UGT Polymer tensiometers (Measures suction up to 1,500 kPa); (c) Setup for measuring unsaturated hydraulic conductivity functions of soils; (d) Time domain reflectometry (TDR) setup comprising of pulse generator, sensor, and computer ; (e) Stabilized time domain reflectometry (STDR) comprising of pulse generator (SEQUID), calibration kit, coaxial cell, and computer; (f) Vector network analyser (measures complex dielectric spectrum with a frequency range of 50 MHz – 3 GHz).

Soil direct shear box and Consolidation

Saturated and unsaturated direct shear testing on 60 mm x 60 mm and 100 mm x 100 mm samples. Maximum shearing capacity is 1000 kPa (equivalent to up to 60 m of overburden). Consolidation can be performed by 75 mm and 71 mm diameter rings for up to 1,000 kPa at different loading rates.

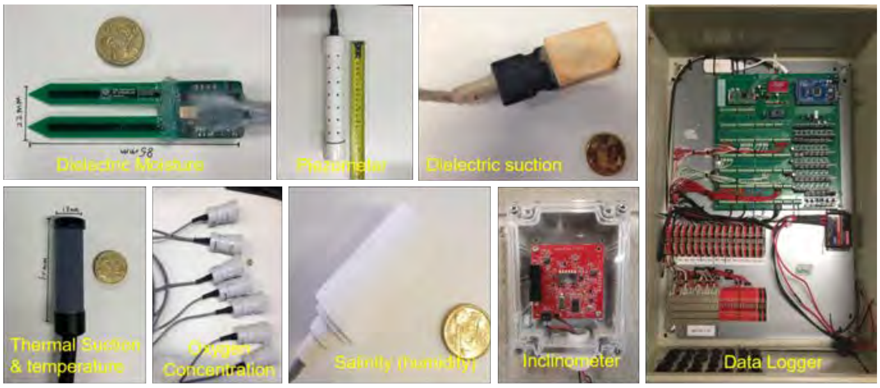
Vane Shear

Vane shear test with 12.5 mm and 40 mm diameter vanes.



Sensors

Among the GEC's research and laboratory activities is the developing of sensors for monitoring moisture, suction, temperature, salinity and earth pressures within soils. Processes such as hydraulic sorting and settling of slurries, consolidation, and desiccation of soils have been studied successfully with the in-house wide ranges of GEC's sensors. We can also provide holistic solutions to monitor in-situ, continuously and in real-time the soils/tailings, water and atmosphere conditions. The GEC instrument is cost-effective as it is manufactured and calibrated in-house at UQ, reducing the marketing and overhead costs that the proprietarily equivalents (if any) require. The real-time and historical data is ready to be visualised and analysed from a password-protected webpage.

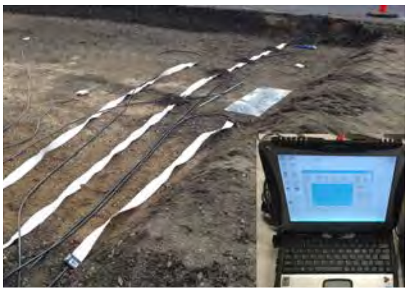


The environmental chamber provides well-controlled heat, water, dry air, and wet air to simulate the effect of sunlight, rain, temperature, and humidity on the weathering of waste rocks and coatings. This device is particularly useful to examine the acid-forming process over a long time.

Monitoring of in-situ moisture and density of Geo-material

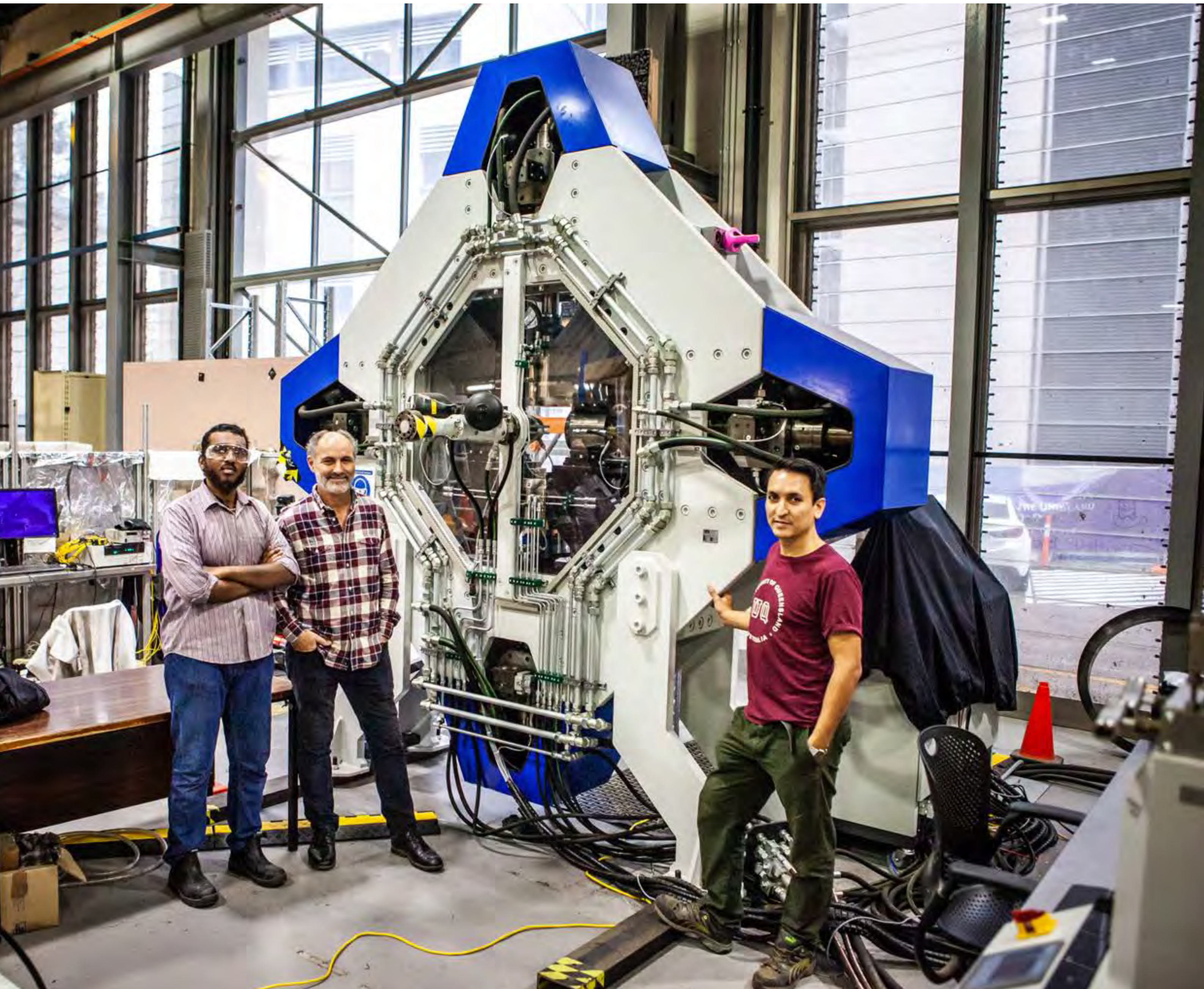
The GEC's Time domain reflectometry (TDR) device measures soil water content and dry density in a non-destructive way. The whole set up consists of a pulse generator (TDR100), sensors, transmission line and computer. The method can assess transverse moisture distribution and the corresponding density change under loading. Rod probes (30 cm) or long flat ribbon cables (6 m) sensors are installed to obtain point-wise or profile of soil state variables.

Careful calibration of moisture, suction and salinity sensors against targeted soil/tailings is important as they measure these properties indirectly. Sensor calibration apparatus is designed to calibrate soil sensors in the samples against repeated drying and wetting scenarios before they are deployed in situ. The calibration curve provides key information to interpreting the field data in the most accurate way.



Learn more about our instrumented column testing of salt uptake from compacted bauxite residue into a cove.

Rock testing **capabilities**



Since 2015, the GEC has experienced an increasing research and commercial demand for an expanded rock testing capability.

To satisfy this demand, the GEC has developed a cutting-edge National Hybrid True Triaxial/Biaxial Load Testing Facility centred at UQ. This includes a True Triaxial Testing System and a Biaxial Testing System, supported by a stereo (3D) ultra-high-speed and high-resolution camera facility capable of running at up to 1,000,000 frames per second, a Stereo Digital Image Correlation (DIC) software platform, Hoek triaxial cells of various diameters, and rock preparation equipment including coring, cutting and grinding machines. The Center has also access to UQ's and School of Civil Engineering's unique large range of existing servo-controlled loading frames, MTS actuators and hydraulic pressure supplies ranging from 20 kN to 10 MN, advanced high-speed processing computers (HPC), Scanning Electron Microscope (SEM) imaging, and Micro-CT scanning for consultancy and research in rock mechanics and rock fracture mechanics.

Rock preparation facilities

The GEC's cutting machine can cut rock samples of irregular shapes, rock cores, as well as surfacing and machining the ends of the cylindrical or cubical samples. This machine is micro-processor controlled; front panel with touch pad controls and has a cutting capacity of up to 90/115 mm of solid stock, for cut off wheels of up to 250/300 mm in diameter, and are twin T-slotted. The available grinding machine has two electronic motors and can be used for the vertical grinding and polishing of natural stones, concrete, as well as ceramic samples on two parallel sides. The coring device accepts sample sizes up to a maximum of 300x300x300 mm. Core barrels of dimeter 18-150 mm can be used with the machine, with a barrel length of approximately 400 mm.

Conventional Triaxial System (Hoek-Cell)

The available Hoek cells accept 1.5" diameter samples (38.1 mm sizes), BX sample sizes (42.04 mm), and NX sample size of 54.7 mm. Each cell can operate up to 70 MPa of confinement, and the length can be up to twice the diameter of the specimen.

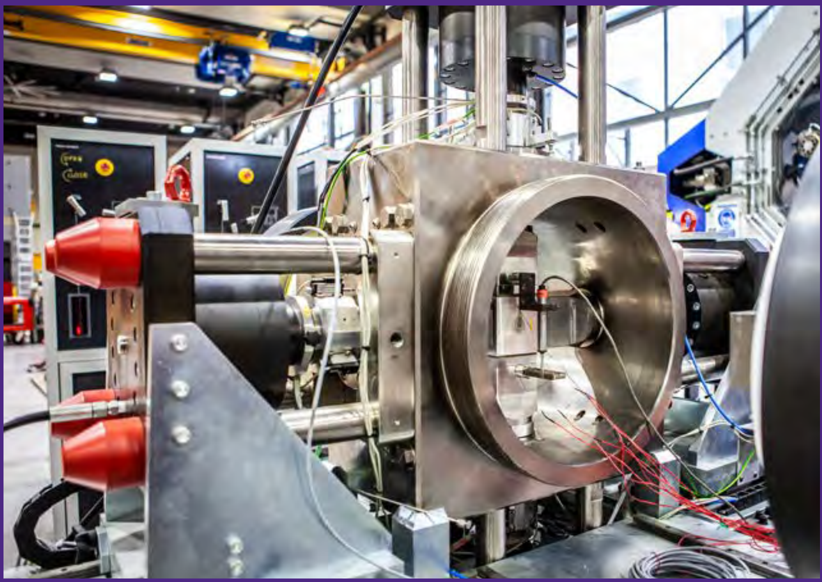
Stereo Ultra-High-speed camera facility

The GEC at UQ is equipped with a state-of-the-art stereo (3D) ultra-high speed and high-resolution camera facility capable of running at up to 1,000,000 frames per second, which makes it able to capture the high-speed fracture of brittle materials. With the aid of the 3D high speed photography and Stereo Digital Image Correlation (DIC) capabilities, quantitative measurement of static and dynamic deformation and cracking patterns in rock failure can be monitored.

Hybrid True Triaxial/Biaxial Load Testing Facility

The True Triaxial Testing system is capable of applying 21 MPa stress in three orthogonal directions on 200 mm cubic specimens (or up to 340 MPa on 50 mm cubed specimens). It is equipped with temperature (up to 100° C) and relative humidity control, has the capability for testing under saturated and unsaturated conditions, and will have state-of-the-art monitoring equipment including acoustic emission (AE) and ultrasonic for the assessment of progressive damage processes. The Biaxial Testing System can test slabs of up to 300 mm in-plane dimensions (i.e. 300 mm by 300 mm shells) and comes with 10 mm grips that makes it an ideal high-tech research testing rig for metals, fibre/resin composites, rocks and any other plate/shell materials. The Biaxial machine is equipped with 4 x 250 kN actuators that can each be operated in either compression or tension to provide a diverse range of biaxial stress conditions. Moreover, the Biaxial machine can provide cyclic motion and single or repeated impact loads by means of 1 x 10 kN out of plane hammer with up to 4 m/s impact speed.

The available rock true Triaxial testing device at the GEC can perform rock permeability testing at up to 10 MPa pressure and hydraulic fracking at up to 52 MPa on 200 mm, 100 mm and 50 mm cubic rock specimens in three directions.



Consulting

Our staff offer Expert Opinion and Peer Review related to areas of soil and rock research strength. Further to the aforementioned true triaxial, biaxial, high-speed rock fracture photography, shear strength, compressibility and permeability of geomaterials ranging from mine tailings and dredged slurries, through soil, weak rock to hard rock; the following testing capabilities exist at the GEC:

- Typical rock Unconfined Compressive Strength (UCS),
- Rock direct shear test,
- Brazilian Tensile Strength (BTS),
- Slake durability test,
- Point load strength index,
- Determination of rock fracture toughness, abrasivity, and elastic constants,
- Sieve analysis,
- Compaction and soil simple shear testing,
- Soil permeability tests under falling and constant head,
- Determination of Atterberg limits, and more ...

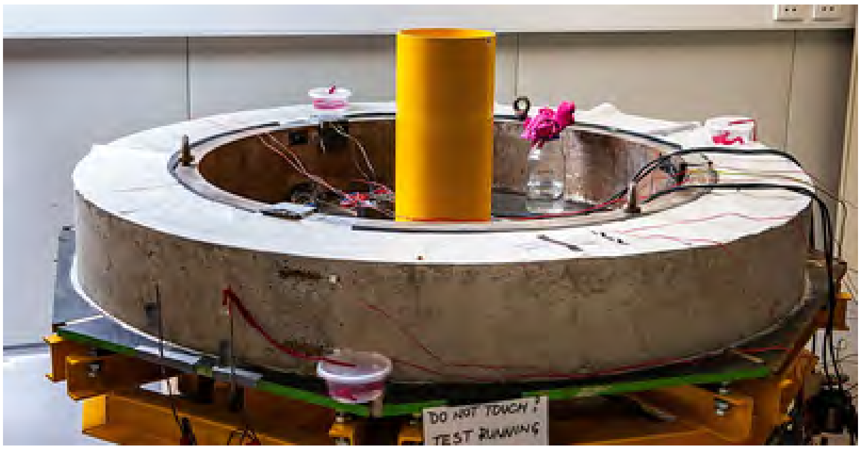
Please contact us to discuss your needs.

Learn more about our true triaxial load testing facility.

Shotcrete testing capabilities

Large Restrained Shrinkage Test

The large restrained shrinkage test is a method to estimate cracking tendency of concrete in large structures such as slab or shotcrete lining, which is up-scaled from standard test method ASTM C1581 and AASHTO T 334-08. The hydraulic jack in the test rig enables drying from top and bottom surface. The restraint is provided by an instrumented steel ring with 1,200 mm in outer diameter, 55 mm in thickness and 200 mm in height. The concrete ring specimen is 1,200 mm in inner diameter, and 200 mm in height and thickness of concrete ring can be set from 100 mm to 290 mm, application focused, providing different degrees of restraint.

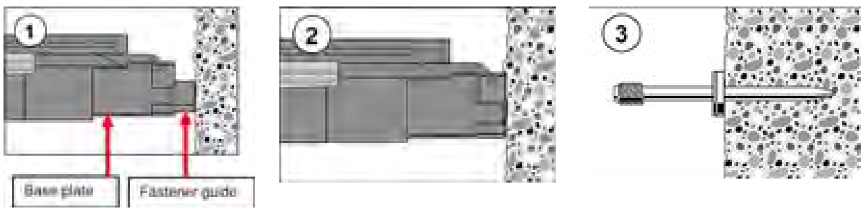


Shotcrete toughness testing facility

Round Determinate Panel (RDP) test method is capable of determining flexural and post-crack performance of fibre reinforced shotcrete. Toughness is expressed as energy absorption in the post-crack range using an Ø800/75 mm round panel supported on three symmetrically arranged pivots at the bottom and subjected to a central point load from the top. RDP test is often used to compare the effectiveness of additions of reinforcement fibres. There is potential to extend the diameter and enlarge the thickness of the panel to 1,200 and 150 mm, respectively.

Determination of the early strength of sprayed concrete with Hilti gun

The calibrated system consists of a stud driving gun and a tensile pull-out tester, which can determine early strength of shotcrete, especially for specimens with set accelerator. The results of a series of test are able to estimate strength development of shotcrete. Concrete strength can be converted from the ratio of measured pull-out load to penetration depth from calibration curves. It is capable of measuring concrete strength range from 2.0 to 16.0 MPa.



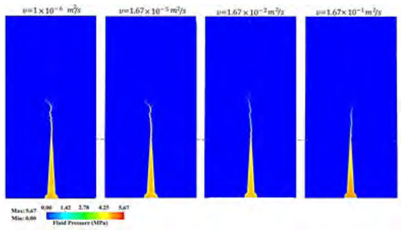
Numerical modelling capabilities

The GEC undertakes a wide range of applied research in the field, with application to solving real-world Civil, Mining and Environmental Engineering problems.

The research includes laboratory and field experimental work as well as numerical modelling and simulation that includes slope stability, settlement, fracking, and tailings dam run-out analysis. The numerical capabilities of the GEC were created out of the necessity to complement the existing capabilities of our laboratory facilities with strong theoretical capabilities, to obtain further understanding and predictive power of the phenomena commonly found in geotechnical engineering practice. It has been founded under a strong philosophy of continual comparison between experimental laboratory and field observations and simulation using advanced numerical modelling. Apart from the commercial licences available at the GEC, the numerical methods developed locally at the Centre are:

Discrete Element Modelling (DEM)

A meshless particle method created to represent the constitutive behaviour of soils and rocks. It can deal with large deformations as well as discontinuous behaviours such as fractures. Applications of DEM include the analysis of the bearing capacity of soils, prediction of structural failure, and post-failure risk assessment for slopes (i.e. evaluation of how far the detached soil will extend after failure).



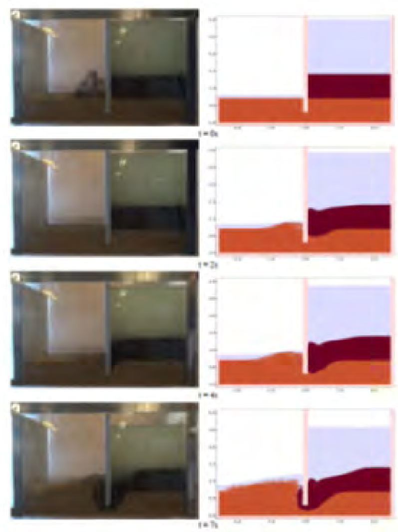
Results of hydraulic fracturing simulations, in which a highly pressurised LBM fluid fractures a DEM block that is properly calibrated

Lattice Boltzmann Methods (LBM)

Our choice for a Computational Fluid Dynamics (CFD) algorithm, LBM is capable of simulating the interaction between water and air with geomaterials, including soils and rocks. It is fully coupled with our DEM module. LBM is also used for its capabilities in modeling multicomponent fluid systems such as gas and water systems, as well as the interaction with solids such as rock. Potential applications of LBM include the aforementioned hydraulic fracturing simulations; the estimation of gas extraction from coal seams; and predictions of contaminant transport (such as mercury of radioactive pollutants) from mine sites.

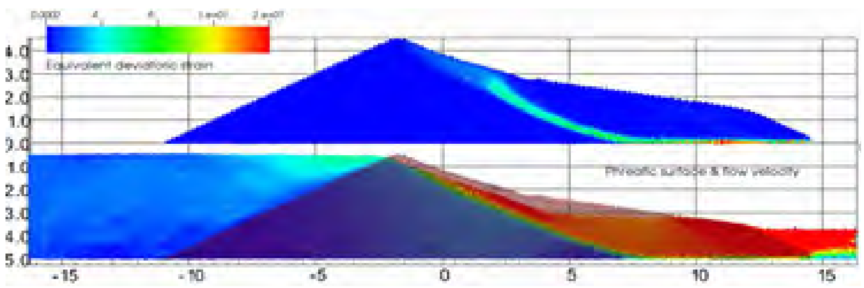
Smooth Particle Hydrodynamics (SPH)

The SPH method is a meshless Partial Differential Equation (PDE) solver. Our SPH implementation considers the coupled physics of groundwater with soil mechanics. SPH can also deal with large deformations to estimate the evolution of post-failure systems. This is an advantage over traditional Finite Element Analysis algorithms, which are limited to small deformation predictions. With this tool, risk can be categorised not only by the conditions that cause the onset of failure, but also in terms of the consequences of such failure.



Hydraulic heave SPH simulation compared with experiments. The blue colour represents water, the brown represents gravel and the orange sand. As can be seen, SPH matches experimental observations with adequate accuracy.

Right: Hydraulically loaded embankment dam with its initial condition showed on top and the post-failure condition showed at the bottom. SPH can predict both the failure and post failure situations, which is a clear advantage over Finite Element Analysis.



Research partners

Platinum Industry Partners

BHP

Gold Industry Partner

McArthur River Mining
A GLENCORE COMPANY

Silver Industry Partners

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BASF We create chemistry

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WAGSTAFF PILING

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ReoCo PERFORMANCE FIBRES

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GOLDER

PORT of BRISBANE Here for the future

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