# Cambridge University
## Schofield Centre for Geotechnical Process and Construction Modelling

Director: Prof Gopal Madabhushi
Manager: Mr John Chandler
Contact: Ms Alessandra Cirani - schofield-centre@eng.cam.ac.uk
Website: https://www-geo.eng.cam.ac.uk/Contact/Schofield
Owner: Department of Engineering, University of Cambridge
Location: Cambridge, UK

### Introduction

The Schofield Centre (SC) for Geotechnical Process and Construction Modelling hosts equipment to facilitate physical modelling of geotechnical systems such as *e.g.*, shallow and piled foundations, open excavations and tunnels, engineered slopes, and retaining structures subjected to complex loading including mechanical, seismic, hydraulic, and thermal actions. Reduced scale models tested at increased gravity ensure stress similarity between homologous points in the model and in the prototype and permit to speed up all processes driven by transient consolidation associated with migration of pore water down gradients of pore water head. In a centrifuge model constructed at a linear scale of 1/N and tested at N*g,* consolidation time scales as $1/N^2$; if N = 100, less than one hour of model time represent one year of prototype time, making it possible to simulate, *e.g.*, weather cycles and seasonal variation of boundary conditions in feasible testing times. The centre comprises two geotechnical centrifuges, namely the 10 diameter, 150 g-tonne Turner beam centrifuge and a 0.8 m diameter 400 g-tonne mini drum centrifuge. The infrastructure is used mainly for research purposes but we also offer consulting services to industry.

### Key Technical Specifications

| **Beam Centrifuge** | |
|---|---|
| Manufacturer | Cambridge University Engineering Department |
| Year established | 1972 |
| Radius to base of soil container | 4.125 m |
| Max size of soil sample | 0. 855×0. 855×1.50 $m^3$ (L×W×H) |
| Bucket area | 0.855 $m^2$ |
| Capacity | 150 g-tonne (1 ton @150g, max g-level: 150g) |

| **Drum Centrifuge** | |
|---|---|
| Manufacturer | Department of Engineering, Cambridge (ANS&A) |
| Year established | 1995 |
| Radius to base of soil container | 370 mm |
| Maximum acceleration | 470 g |
| Channel dimensions | 0.12 × 0.18 $m^2$ (H × W) |

### Beam Centrifuge

The 10 m diameter and 150 g-tonne Turner beam centrifuge is the focus of centrifuge based geotechnical modelling at Cambridge. The beam centrifuge was built in the early 1970s to designs by Philip Turner, described here. The large capacity of this centrifuge together with its physical size give great scope for the building of novel experimental packages. Electrical and hydraulic slip rings are available for the passing of water, compressed air and power to packages, enabling to construct and use complex actuators. A large number of experiments have been carried out and a great deal of experience has been accumulated over the past 40 years, enabling modelling of such diverse situations as earthquake loading and climatic fluctuations. Present PhD projects include earthquake loading of geotechnical and structural systems, monopile foundations for offshore wind, piled foundations under complex loading, tunnelling and retaining walls.

Turner beam Centrifuge

**Drum Centrifuge**

A successor to the earlier Cambridge MKI minidrum centrifuge (now at Horoshima University), the 0.8 m diameter twin-shaft MKII minidrum centrifuge was developed in the mid-1990s to provide a relatively inexpensive and quick alternative to conventional larger-scale centrifuge model tests.

MKII minidrum centrifuge

With its small radius, the minidrum centrifuge is ideally suited to teaching applications and the modelling of processes where large quantities of soil are expensive to retrieve (*e.g.*, seabed pipelines). At a 1/400 scale, a prototype site of dimensions L×W×H = 850×70×50 $m^3$ can be modelled in the ring channel. A particular feature of the Cambridge drum centrifuges, pioneered by Andrew Schofield, is their twin coaxial shafts - they are, effectively, one centrifuge (the central turntable, carrying actuators or tools) rotating independently of the other (the ring channel, carrying the soil). This makes it possible to keep the soil spinning correctly, while carrying out the various stages of model preparation and actuator interventions in sequence by stopping and starting the central turntable. A feature (covered by a patent application) of both the MKI and MKII minidrum centrifuges is the ability to rotate the drum through ninety degrees without stopping the spinning drum. This allows soil and water to be added into the channel with the axis horizontal and subsequent model testing carried out with the axis vertical to eliminate the +/-1g variation in accelerations.

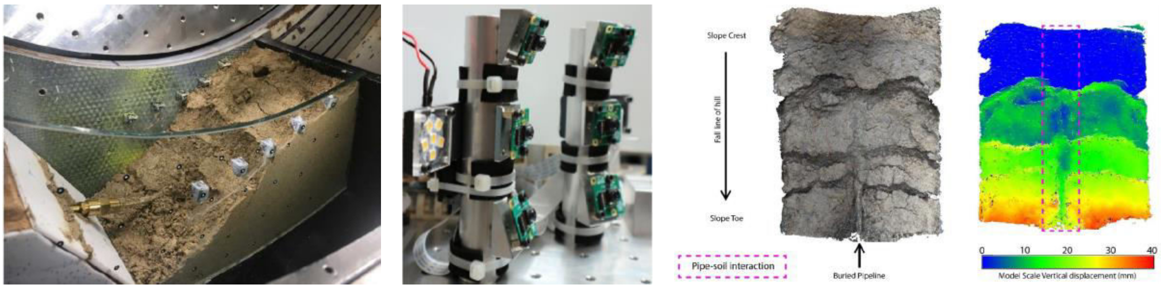
**Instrumentation and ancillary equipment**

Both centrifuges have fibre-optic communications and are equipped with several systems to perform experiments.

For the Turner beam centrifuge, data acquisition is carried out using on-board computers. It is possible to log up to 60 channels in any given test at a sampling frequency of 10 kHz. Two high-speed cameras are available to obtain high resolution images for Particle Image Velocimetry:

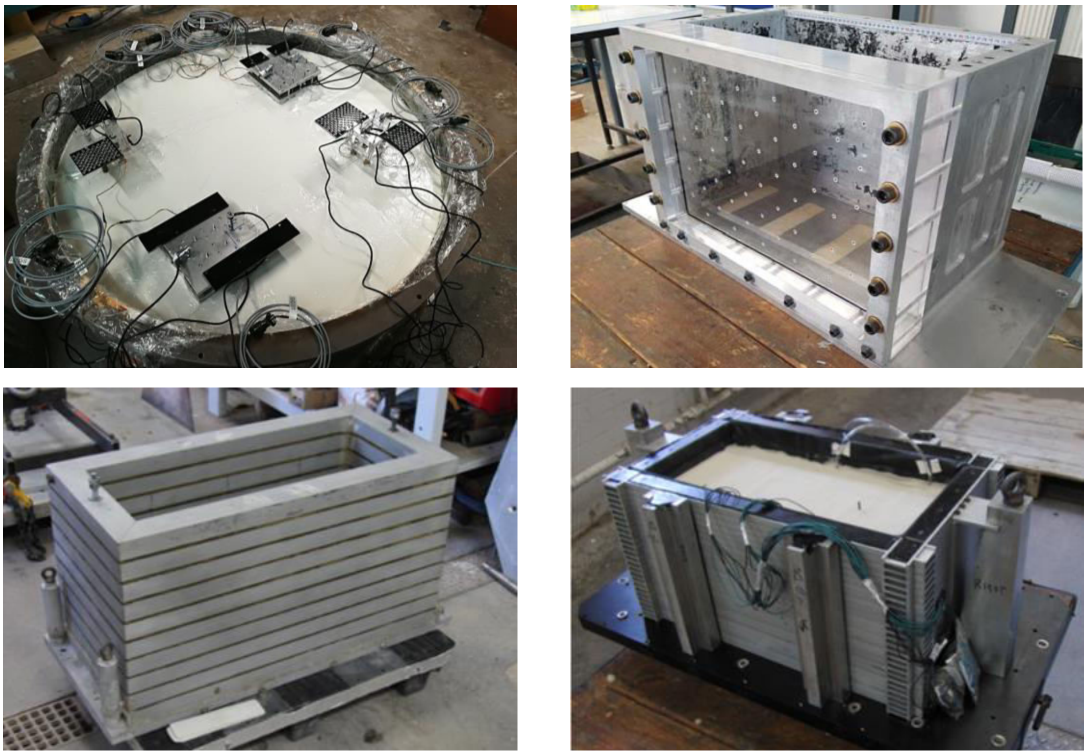
- 1.3 megapixel MotionBlitz Cube2 500 fps GigE high-speed monochrome camera; link
- 12 megapixel DaHeng Imaging MARS-1231 32 fps USB 3.0 monochrome camera; link

Raspberry Pi imaging systems have also been developed for use on both centrifuges.




Application of Raspberry Pi imaging to reconstruct model slope displacements.

Different containers are available to house soil models including cylindrical tubs with a diameter of 850 mm, several windowed strongboxes for PIV of varying size, several Equivalent Shear Beam (ESB) centrifuge strongboxes and one laminar centrifuge strongbox for earthquake testing, together with *ad-hoc* containers designed and built for specific projects.



Model containers

Quasi-static actuation systems include: one 10 kN 2D actuator with 500 mm horizontal travel and 300 mm vertical travel and 5 mm/s maximum displacement rate, one 10 kN 1D actuator with 300 mm vertical travel and 5 mm/s maximum displacement rate, and a range of electric linear actuators with capacities of 0.5-4.7 kN and strokes of 100-300 mm.

Two dynamic actuators are currently used on the Turner beam centrifuge, namely the Stored Angular Momentum (SAM) actuator, purely mechanical, and the more recently added Servo-Hydraulic earthquake actuator. The SAM actuator can apply powerful sinusoidal shaking motions at *g* levels of up to 100*g*. The peak dynamic force that this actuator can produce is about 100 kN. The Servo-hydraulic earthquake actuator can apply realistic acceleration time histories mimicking real earthquakes and can operate at *g* levels of up to 80*g*. This actuator can produce a dynamic force of 100 kN and operate in the frequency range of 10-200 Hz.


Stored Angular Momentum (SAM) actuator and servo hydraulic earthquake actuator

A number of ancillary utilities are available to prepare clay and sand soil models including one clay mixer, two 500 kN hydraulic presses for clay sample consolidation, one 250 MN pneumatic press for clay sample consolidation, a fully-automated 3-axis sand pourer, and an originally devolped CAM-SAT back-saturation apparatus.


Hydraulic presses for clay sample consolidation