UNIVERSITY OF SURREY

SAGE Laboratory

Surrey Advanced Geotechnical Engineering

WHAT IS THE SAGE LABORATORY?

The SAGE (Surrey Advanced Geotechnical Engineering) laboratory is a world-class geotechnical testing facility within the Department of Civil and Environmental Engineering at the University of Surrey.

The SAGE laboratory supports the University's broad expertise in geomechanics research and is designed for advanced testing of soils and scaled model tests of geotechnical problems.

Surrey's Geomechanics Research Group has been at the forefront of soil testing for many years. GDS Instruments (one of the leading soil testing equipment manufacturers) was founded by Dr Bruce Menzies, a Lecturer at the University. Surrey has also recently relaunched its successful masters course in geotechnical engineering (MSc Advanced Geotechnical Engineering) for 2015 to address the skills shortage in this area.

Our two key capabilities are:
Advanced soil testing: we carry out all types of soil testing including Triaxial testing with local strain measurements (bender element), Cyclic Triaxial, Resonant column and Dynamic Simple Shear.

Scale model tests: we conduct scale model tests for different geotechnical problems, such as the behaviour of offshore wind turbines under cyclic and dynamic loading, behaviour of pipelines crossing a fault, and other Dynamic Soil-Structure Interaction (DSSI) issues.

In addition, we can carry out vibration monitoring of small scale models using non-contact devices, and shaking table tests for small scale models. We also develop customised sensors (eg waterproof MEMS accelerometers) and bespoke experiments.

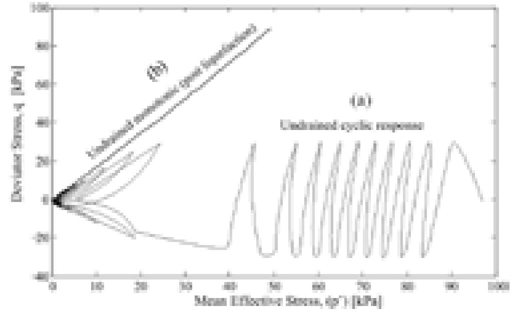
OUR CAPABILITIES – IN DETAIL

Advanced soil testing

Cyclic Triaxial apparatus
We carry out element testing of soil to understand its cyclic behaviour, including liquefaction susceptibility and multi-stage shear testing of the soil – for example we may conduct cyclic testing of soil to liquefaction and then apply monotonic loading (ie post-cyclic).

From cyclic triaxial test results, we can construct bespoke p-y curves (non-linear Winkler Springs for pile-soil analysis) for any soils taking all the points from the stress-strain relationship. While current codes of practice provide methodology to construct p-y curves for standard soils (such as sand, soft clay and stiff clay) using few data points from the stress-strain relationship, research undertaken at Surrey enables us to construct continuous p-y curves for a broader range of soils using all the data points. (Bouzid D.J, Bhattacharya S, Dash S.R (2013): Winkler Springs (p-y curves) for pile design from stress-strain of soils: FE assessment of scaling coefficients using the Mobilized Strength Design concept, **Geomechanics and Engineering**, 5 (5), 379-399).

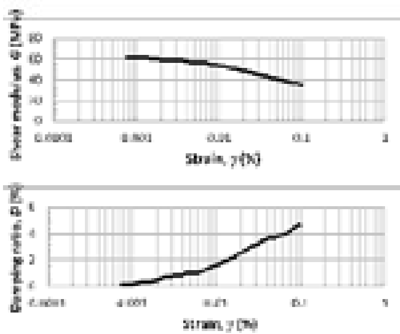
Cyclic Triaxial apparatus



Typical test result for Redhill-110 sand

Resonant Column apparatus
Using this apparatus, we carry out Shear Modulus and Damping characterisation of soils. Pictured are results of a test conducted to find out the dynamic properties of Redhill-110 soil.

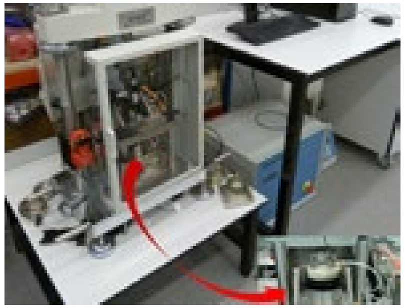
Resonant Column apparatus

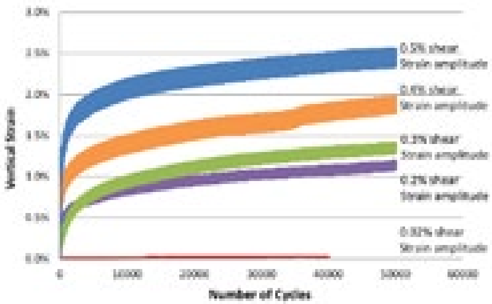


Dynamic properties (stiffness and damping) of Redhill-110 soil

Dynamic Simple Shear apparatus
We can carry out Cyclic Simple Shear tests on soils by applying hundreds of thousands of cycles.

Pictured are typical test results using this method for a silica sand (D. Lombardi, S.Bhattacharya, M. Hyodo, T. Kaneko: Undrained behaviour of two silica sands and practical implications for modelling SSI in liquefiable soils, Soil Dynamics and Earthquake Engineering, Volume 66, November 2014, Pages 293-304, ISSN 0267-7261, http://dx.doi.org/10.1016/j.soildyn.2014.07.010).

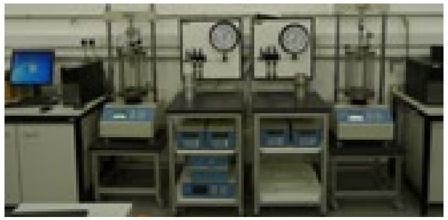

Dynamic Simple Shear (DSS) apparatus

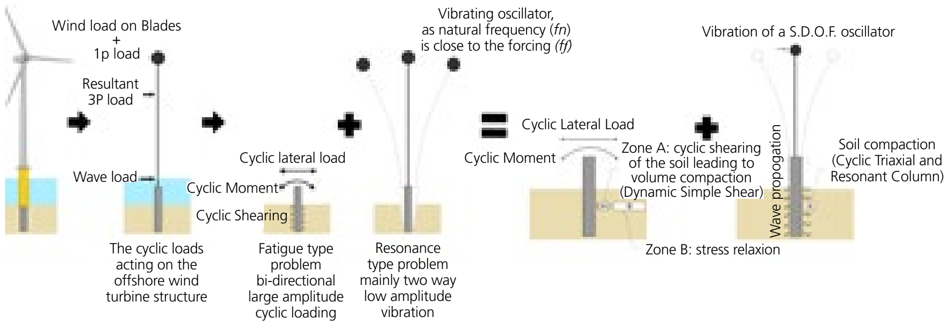


Typical results for a silica sand

Triaxial with local measurement (bender element)
Our monotonic Triaxial apparatus is equipped with bender element equipment and also allows us to carry out other local measurements.

These testing apparatus can be used to predict the long-term performance of dynamically-sensitive structures such as Offshore Wind Turbines.


Monotonic Triaxial apparatus equipped with bender element and local measurement



All of the above element testing can be used to study long term issues of Offshore Wind Turbines.

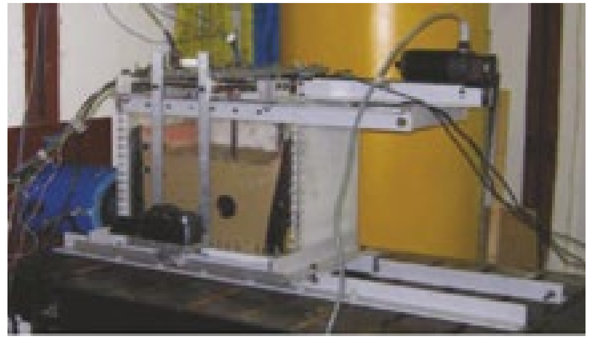
Physical modelling in geotechnical engineering


Large calibration chamber

Large calibration chamber
Featuring a transparent front and measuring 2.4m by 1.4m by 2.6m, this chamber can be used to carry out pile-soil interaction and many other Soil-Structure Interaction problems.

Small calibration chamber
Featuring a transparent front and measuring 450mm by 200mm by 400mm, this chamber can be used to carry out 1-g shaking table tests and small calibration tests


Small calibration chamber


The chamber in a 1-g test set-up to study pipe-soil interaction

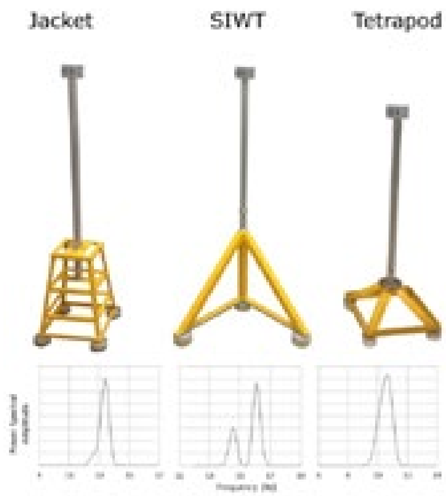
The results of research based on our physical modelling facilities have been published in the following journals:
Lombardi, D., Bhattacharya, S. (2014). 'Modal analysis of pile-supported structures during seismic liquefaction'. **Earthquake Engineering and Structural Dynamics.** Published online in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/eqe.2336

Domenico Lombardi, Subhamoy Bhattacharya, Fabrizio Scarpa, and Matteo Bianchi: (2015), Dynamic response of a geotechnical rigid model container with absorbing boundaries, **Soil Dynamics and Earthquake Engineering**, (69) 46–56.

Small scale wind turbine model tests
We construct small scale models of offshore wind turbines supported on different types of foundations in order to understand the dynamic soil structure interactions, as well as the long-term performance of the different foundations. In addition to standard measuring devices, we use non-contact devices such as a Laser Vibrometer to monitor the structure frequency during shaking.


Some typical wind turbine foundations


Measurement of twisted jacket using Laser Vibrometer



Typical frequency results for scaled wind turbines on different foundations

The results of research based on our small scale wind turbine model tests have been published in the following journals:

Bhattacharya S, Lombardi D, and Muir Wood D (2011): Similitude relationship for physical modelling of monopile-supported wind turbines. International Journal of **Physical Modelling in Geotechnics**, 11(2): 58–68.

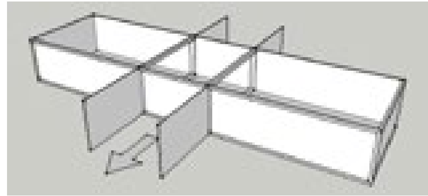
Bhattacharya S, Cox J, Lombardi D, Muir Wood D, (2012): Dynamics of offshore wind turbines supported on two foundations. **Proceedings of the ICE—Geotechnical Engineering**, 166(2):159–69.

S. Bhattacharya, N. Nikitas, J. Garnsey, N.A. Alexander, J. Cox, Lombardi, D. Muir Wood, D.F.T. Nash (2013): 'Observed dynamic soil–structure interaction in scale testing of offshore wind turbine foundations', **Soil Dynamics and Earthquake Engineering.** 54, 47-60. DOI:10.1016/j.soildyn.2013.07.012.

Examples of pipeline testing

Normal fault

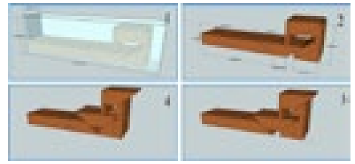

Behaviour of pipelines subjected to a land-slide or fault movement


Schematic view of the set-up

Reverse fault


Bespoke apparatus to study pipeline behaviour under reverse faulting


Pipeline deflection due to fault movement

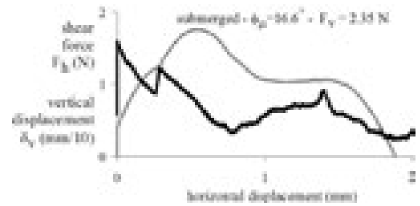

Schematic view of the model test

Examples of micro mechanical behaviour of soil

Inter-particle friction apparatus
Using new custom-made inter-particle friction apparatus we can carry out testing on an irregular surface under different normal load values.

Pictured are the results of research using this apparatus (Cavarretta, I., Coop, M.R. and Rocchi, I. (2011): 'A new inter-particle friction apparatus for granular materials'. Canadian Geotechnical Journal, 48, No. 12, 1829-1840, doi: 10.1139/T11-077).


Micro mechanical apparatus



Test results from 2011 research


Moving wall apparatus

Physical model of retaining wall
We can carry out shearing tests on granular material confined by a moving wall.

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