Uni Eiffel Geotechnical Centrifuge

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Owner: University Gustave Eiffel
Location: Bouguenais, Nantes Campus of the Uni Eiffel, France

Introduction

The Centrif-UGE is devoted to physical modelling in geotechnics. By increasing the centrifuge forces applied on a small scale model of a geotechnical work, the stress field existing on full scale (prototype) geotechnical work is reproduced. The model is installed in the Centrif-UGE's basket (~1.5m^3 of volume). A set of scaling laws have been established (e.g. Garnier et al., 2007, doi.org/10.1680/ijpmg.2007.070301) for different applications. The instrumented small scale models are useful in the scientific approach for observing, understading, testing proof of concepts and comparing with numerical analysis.

The Centrif-UGE is versatile and offers a large domain of applications, concerning mainly soil-structure interaction (SSI):

- Piles, monopiles, piles group effect, helical piles under vertical/horizontal monotonic/cyclic loading;
- Off-shore anchoring systems for Oil & Gas or Marine Renewable Energy;
- Shallow foundations (e.g. in slope vicinity);
- Soft soils reinforced with vertical rigid inclusions;
- Construction of adjacent embankments on soft soils ; Reinforced earth structures (soil-nailed wall; geosynthetic layers)
- Tunnels: effect of excavation on surface settlement;
- Unsaturated soils;
- Ground vibration isolation;
- Cantilever wall;
- Seismic loading, soil liquefaction (not detailed in this document);
- Macrogravity testing of medical apparatus or aeronautical devices

The Uni Eiffel Geotechnical Centrif-UGE has been opened in 1985. It is a 200g-ton beam centrifuge with a 5.5m radius. Associated equipements are also available such as a 1D earthquake simulator and a four axis remote operating robot system. and a variety of actuators, tool platforms, and highly specialized devices and sensors. The entire laboratory is on one level with the centrifuge, which facilitates the preparation and transfer of the models. Our experimental infrastructure is predominantly used for research, but also on demand, we also offer highly-specialized consulting services to the industry.

The Uni Eiffel Geotechnical Centrif-UGE.

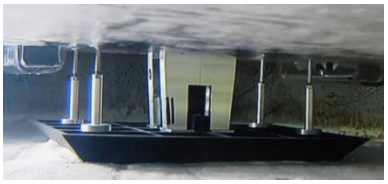
Key Technical Spefications

Beam Centrifuge	
Manufacturer	Actidyn Active Dynamics
Year established	1985, inaugurated by the Minister of Research H. Curien
Radius to base of soil container	5.5 m
Capacity	200 gton (2 tons @100g, max G-level: 100g)
Bucket area	1.4 m x 1.15 m (Clearance height: 1.5 m)
Major equipments	Earthquake simulator (capacity 0.4tons @ 80g) 4-DOF robot Automated sand raining system Miniature geotechnical investigation tools (penetrometer, pressure meter, cane test, T-Bar) Hydraulic and electric servo actuators Sensors set (~230) acquisition chains Consolidometers for test massif preparation Transparent face containers Roll-motion simulator Mobile tray for investigating the load transfer behavior towards rigid inclusions In-flight saturation

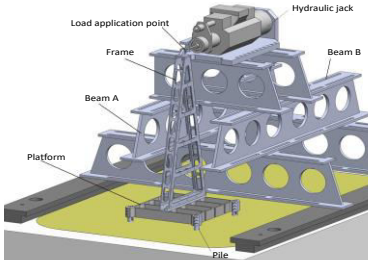
Geotechnical Centrif-UGE

The beam centrifuge consists of an arm supporting the swinging basket, in which the model is installed. The counterweights position is adjusted for equilibrating the centrifuge. Rotary joints, slip rings and fiber optic joint allows the transmission of the energy (oil pressure, electricity, air), the control and data from the rotating part towards the fixed one, including the control room. A special building houses the centrifuge and a total of 1100 m² are devoted to this activity: rooms assigned to model preparation (pluviation of sand, consolidation of clay), material conservation, mechanical and electronic workshop areas, as well as soil mechanics laboratory. The Geo-Centrifuge is one of the Ifsttar's exceptional facilities belonging to GERS Department (Geotechnical Engineeering, Environment, Natural Hazards and Earth Science Dpt.)

Installation of a hydraulic jack



Sliding foundation for off-shore Pipe Line End Termination (50×g tests for Subsea7)



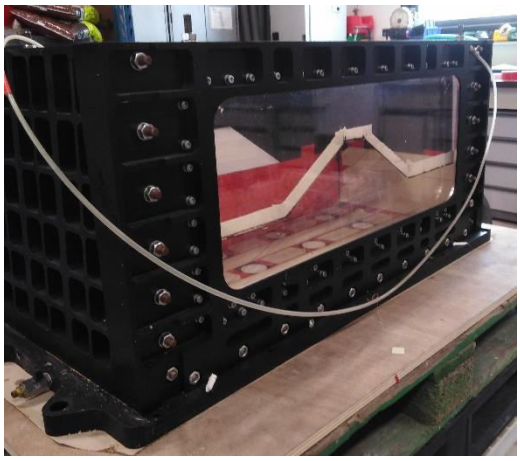
Model of wind-turbine Jacket piles (100×g tests for Regional Project Chargeol)

Earthquake Simulator

Centrifuge modelling no longer needs to prove its relevance in the field of earthquake engineering, as the growing application of this experimental approach in research demonstrates its worldwide acceptance. Since 2006, earthquake simulation tests have been conducted at the Uni Eiffel Nantes campus.

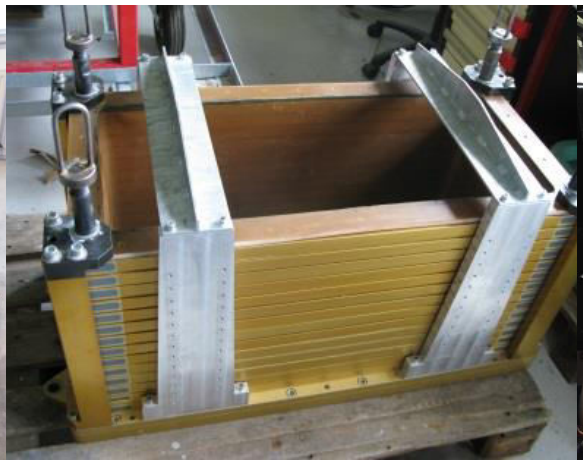
The embedded 1D earthquake simulator simulates bedrock acceleration during earthquakes, enabling analysis of the seismic response of reduced-scale models. The key feature of the Uni Eiffel facility in Nantes is its capability to simulate both sine inputs and multi-frequency seismic inputs (natural or synthetic), which can be applied to a maximum payload of 400 kg at 80 g.

Actidyn on-board earthquake simulator

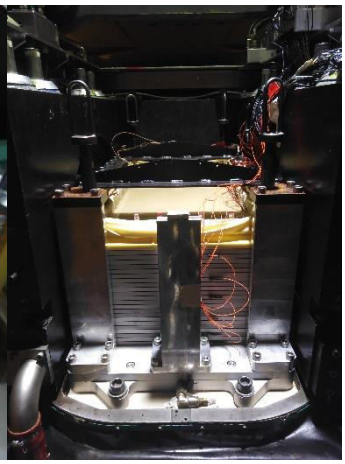


Rigid container/Strong box

Flexible boxes: Equivalent shear beam container 01



Flexible boxes: Equivalent shear beam container 02



Flexible boxes: laminar container

In addition to the earthquake simulator, several devices devoted to the dynamic tests on reduces scale models have been developed :

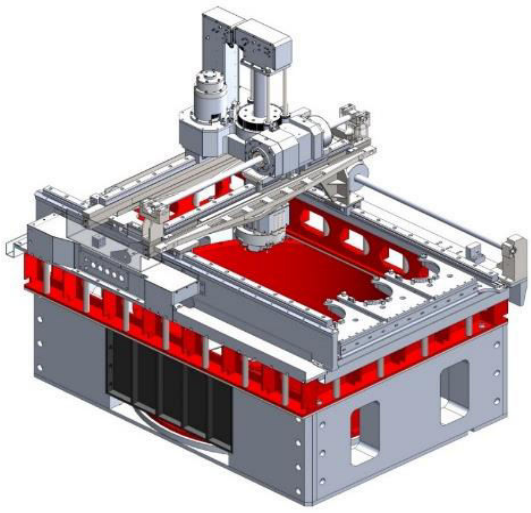
•2 equivalent shear beam (ESB) boxes with flexible sidewalls (inner dimensions 800mm×340mm×410mm (L×W×H))
•laminar container which minimize the effect of the container on the dynamic behavior of the soil column (inner dimensions 719mm×379mm (L×W). The height of the laminar container can be adjusted depending the number of shearing rings.)

•rigid container which a transparent window which allows the direct observation and image analysis of the behavior of the model (inner dimensions 800mm×340mm×400mm (L×W×H))
•1g and in-flight saturation systems for liquefaction studies
•Bender element system to characterize the shear wave velocity of the soil column
• Fast camera and DIC/PIV analysis platform.
The earthquake simulator expands the scope of research that can be conducted with the Uni Eiffel centrifuge tool to include geotechnical earthquake research such as liquefaction phenomena, remediation systems, dynamic behavior of various types of foundations (such as caissons, shallow and deep foundations), shallow tunnels, and slopes.

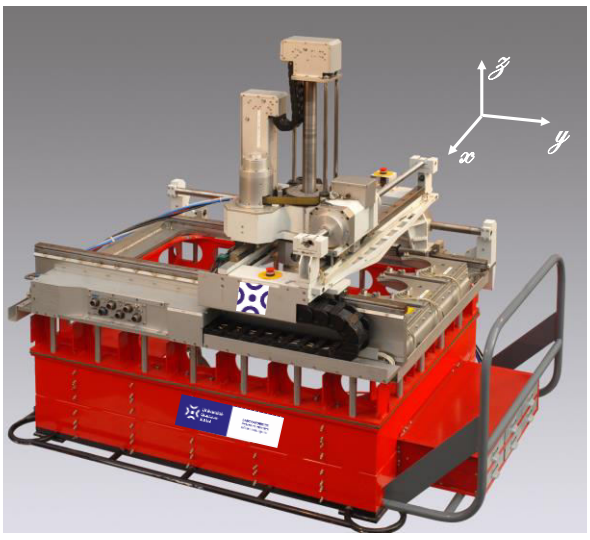
A fast data acquisition system with multiple channels that can support a wide range of sensors type enables reliable analysis of the dynamic responses of various configurations.

4-DOF Robot

Put into service in 1999, the only one of its kind in the world at the time, the teleoperator is a robot designed to carry out tests in the Uni Eiffel's geotechnical centrifuge, under an acceleration of 100 times the earth's gravity, carrying out operations without stopping the centrifuge.
The gantry-type robot with four degrees of freedom, three in translation and one in rotation, is installed above the model and has a magazine and a tool changer. The TOP can pick up any one of the three tools in the magazine and position it at 1/10 mm at any point in the container at a speed between 0 and 80 mm/s under a maximum centrifugal acceleration of 100g.
With the appropriate tools, all types of actions that were previously impossible to perform without stopping the centrifuge become possible, such as excavation, construction and compaction of embankments, installation of piles by drilling or driving, loading of structures.
Its evolution in space and the succession of actions to be carried out can be controlled manually or by programming from the control room, via a numerical control which is duplicated to be able to use the robot either in the test preparation room or in the centrifuge.
The tools have a standard interface allowing electrical (3 circuits) and fluidic (2 LP and 2 HP) connections to instrument the tool or to connect a particular hydraulic device: The location of an object by means of an integrated laser and its gripping can be provided for the execution of a particular action.



Scheme oft he robot for cicular container application



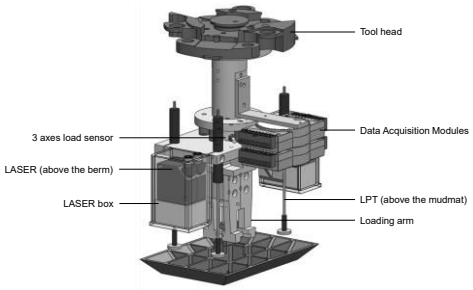
The Robot on ist mobile support

CPT tool

T-bar tool

Trench tool

Pincer and loading tool

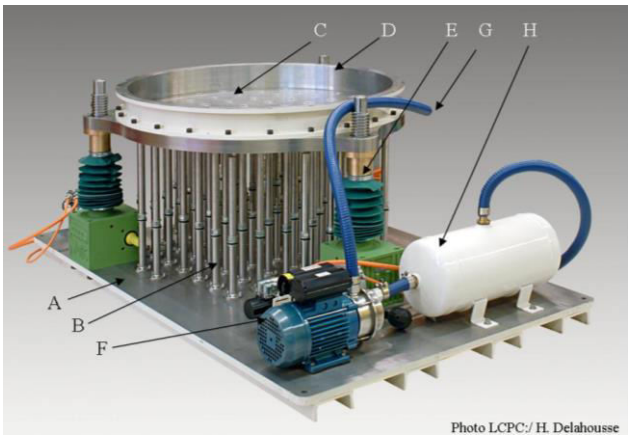


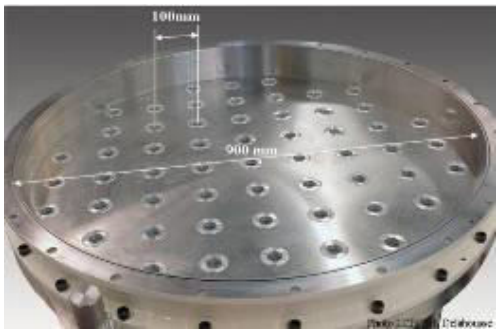
Tool developped for PLET sliding foundation

Other devices

Mobile Tray Device

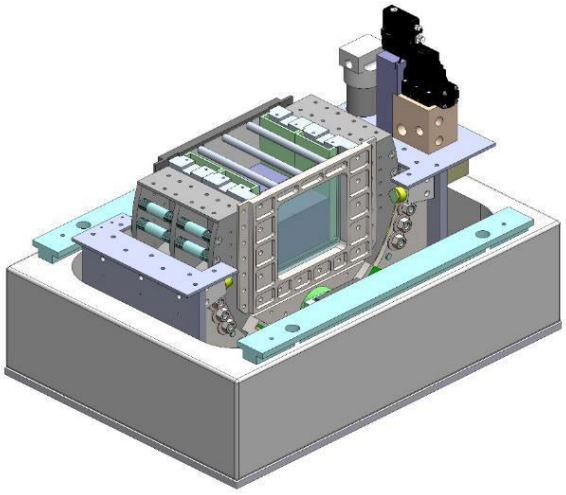
The MTD simulates the vertical settlement of soft soil, inducing the punching of the Load Transfert Platform (e.g. sand layer) by the (up to) 61 Rigid Inclusions *French National Project ASIRI (2005-12)*.

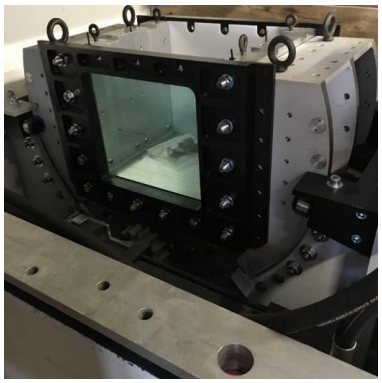




Rolling test device

It simulates the rolling movement of ore cargo during maritime shiping, in order to study the liquefaction induced phenomena (Eranet Martec Liquef Action, 2014-2018).





Max. g-level : 80, max. angular velocity 60°/s, max. rotation angle of rolling ±25°

Awards

2000 Best paper. GeoEng conf., Melbourne

2001 First Coulomb Lecture CFMS

2003 Best Paper Award, Int. J. Phys. Modelling in Geotechnics

2004 Best Paper Award, Int. J. Phys. Modelling in Geotechnics

2007 Best Poster Award, XIV Eur. Conf. Soil Mechanics & Geotech. Engng. Madrid

2008 Kérisel Price, CFMS

2010 Kérisel Price, CFMS

2014 Best Paper Award, Honourable mention. Geosynthetics International

2015 Best Paper Award, Int. J. Phys. Modelling in Geotechnics

2018 Kérisel Price CFMS

2018 «Prêmio Costa Nunes da ABMS». Best Brazilian Ph.D Thesis

2019 Hall of Fame Paper, Offshore Technology Conference. n° 7796, Cluckey, Morrison, Corté, Garnier, 1995.