ETH Zurich Geotechnical Centrifuge Centre

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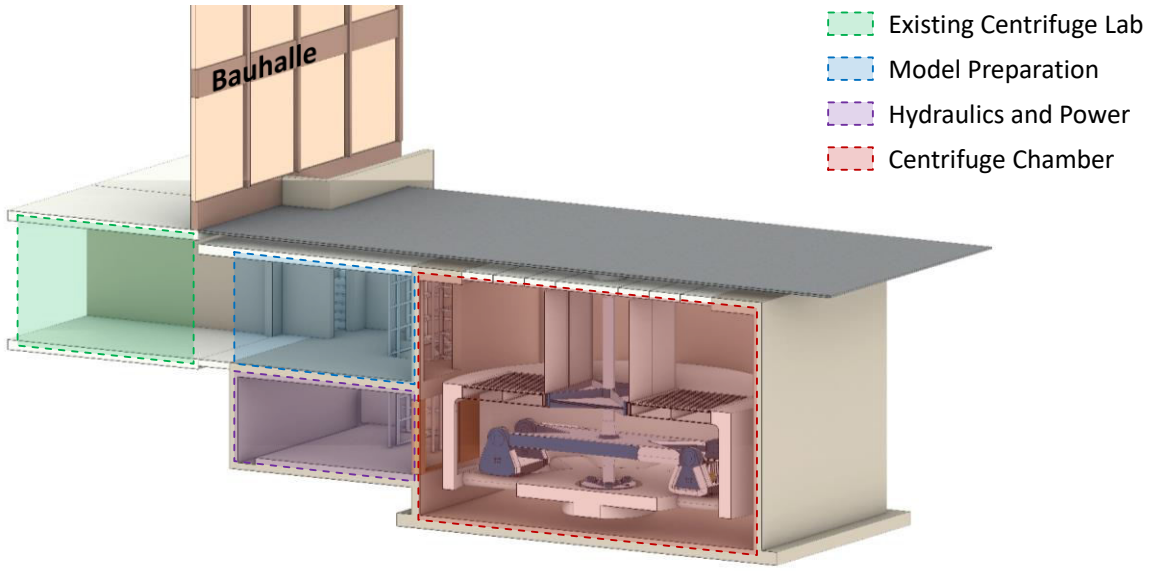
Introduction

Physical modelling is indispensable to derive insights on the key factors affecting the performance of geotechnical systems, to properly validate numerical models, and to evaluate the efficiency of innovative solutions (proof-of-concept). The ETH Zurich Geotechnical Centrifuge Centre (GCC) encompasses two geotechnical centrifuges, a 9 m diameter (500 gton capacity) beam centrifuge and a 2.2 m diameter (440 gton capacity) drum centrifuge, a cutting-edge earthquake simulator, a Miniaturized Tidal Generator (MTG), and a variety of actuators, tool platforms, and highly specialized devices and sensors. Our experimental infrastructure is predominantly used for research and teaching purposes. On demand, we also offer highly-specialized consulting services to the industry.



The ETH Zurich Geotechnical Centrifuge Centre (GCC).

Key Technical Spefications

Beam Centrifuge	
Manufacturer	KRUPP, refurbished by IGT and Hagenbuch AG
Year established	2023 ETH Zurich (1985 RUHR University Bochum)
Radius to base of soil container	4.125 m
Capacity	500 gton (5 tons @100g, max G-level: 250g)
Bucket area	1.25 m x 1.25 m
Major equipment	Earthquake simulator (capacity 0.7 tons @100g) Miniaturized Tsunami Generator (MTG) Automated sand raining system 3DOF Robotic loading system (under construction)

Drum Centrifuge	
Manufacturer	Broadbent
Year established	1999
Radius to base of soil container	1.1 m
Capacity	880 gton (2 tons @440g)
Channel dimensions	0.3 m x 0.7 m (H x W)
Major equipment	Combined (VHM) Loading Apparatus Climate chamber Rock avalanche simulator

Beam Centrifuge

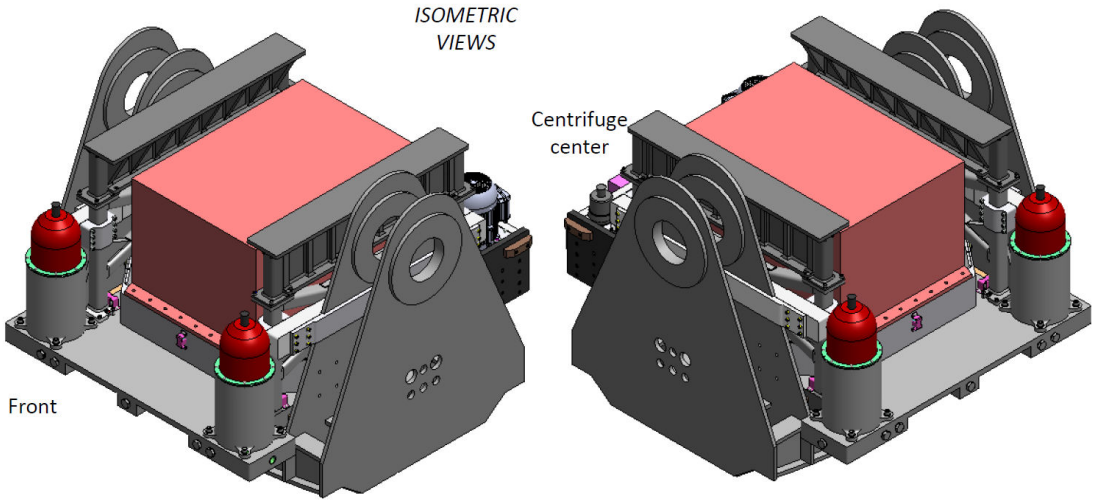
The beam centrifuge consists of an arm supporting two swings, in which the model and the counterweight are installed. It is connected to the chamber with a bottom and a top bearing, ensuring higher stability of operation. The centrifuge is not brand new, but rather an example of how existing equipment can be reused for research. The centrifuge was constructed by KRUPP and was originally installed in RUHR University Bochum, were it was under operation for over 20 years. Decommissioned in Germany, it was acquired by ETHZ and has been fully refurbished in terms of hydraulics, electronics and control systems.

KRUPP geotechnical beam centrifuge refurbished and installed at ETH Zurich.

With an effective diameter of 8.25 m, the centrifuge can be accelerated up to 250g carrying a payload of 2 tons (or equivalently 5tons at 100g). Its 500gton capacity is the largest in Europe and one of the biggest in the world. A key advantage of the beam centrifuge is that the model can be installed without 90^{o} rotation (as in the drum centrifuge), thanks to the swing which rotates progressively with the increase of the g-level. As a result, the model base is always perpendicular to the acceleration vector. Each swing has a platform of 1.25 x 1.25 m, where the soil container is placed. The setup offers the possibility of a soil container of up to 2 m length (extending 0.375 m from the platform on each side), allowing testing large models corresponding to up to 500 m length (at the maximum g level).

Earthquake Simulator

Custom-designed for the KRUPP centrifuge, the Actidyn BC-5810 earthquake simulator is capable of delivering horizontal seismic ground motions of any target waveform (including recorded and artificial motions) at up to 0.5 g peak ground acceleration on packages of up to 700 kg over a wide frequency band, at a maximum centrifugal acceleration of 100g. This new earthquake simulator is specially-designed to be easily mountable on the KRUPP centrifuge swing, without the need for extensive interventions. Moreover, it features an open design at the edges, allowing the installation of longer boxes, extending from the 1.1 x 0.8 m (length x width) table on both sides. This special feature offers the possibility to install a soil container of up to 2 m length (extending from the platform on each side), which can be crucial for testing structure-soil-structure interaction between neighbouring structures.



Schematic of the Actidyn on-board earthquake simulator.

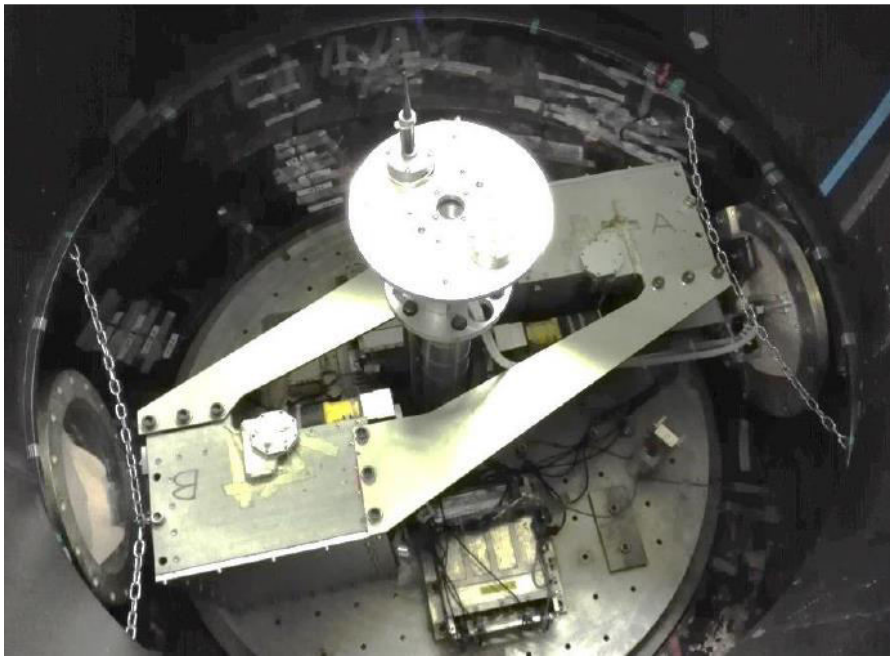
The table is supported by a set of preloaded rectangular elastomeric bearings (a sandwich of several elastomer and metallic layers), designed to withstand very high compressive loads. Local accumulators are installed at the edges of the earthquake simulator, aiming to provide compact packaging that minimizes piping lengths and pressure drops when high flow rate and pressures are required. The system is controlled with a SignalStar MATRIX digital controller from Data Physics Corp. The external hydraulic power supply includes a hydraulic pump, an oil reservoir, a set of accumulators, and an automatic control system. The high pressure output and low pressure return lines are routed to the centrifuge arm through a set of high pressure hydraulic rotary joints.

Drum Centrifuge

Established by Prof. Sarah Springman in 1999, the geotechnical drum centrifuge consists of a main channel, in which the model is built or placed, and a tool platform, where actuators and sensors can be mounted together with the data acquisition systems. With a diameter of 2.2 m, 0.7 m height and 0.3 m depth, the channel can be accelerated up to 440g carrying a payload of up to 2 tons. A key advantage of the drum centrifuge is that the entire channel can be filled with soil, creating a model deposit of 5 m length, which corresponds to a prototype of 2 km length, over 100 m depth and 300 m width. Smaller models can be tested using strongboxes, prepared outside and placed on the channel.

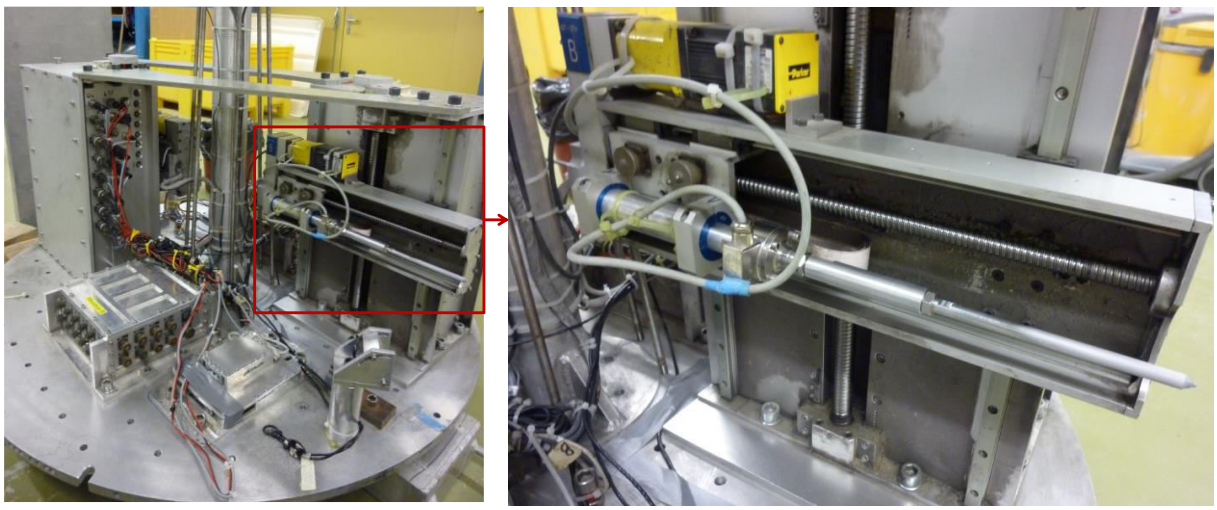
The rotation of the channel and the tool platform is provided by an external and an internal shaft, respectively. The tool platform can spin together with the channel, or independently. This allows stopping the tool platform during a test, allowing changes or adjustments of actuators and sensors mounted on the platform without stopping the test. In such a case, a shield is lowered to protect the stationary platform from the spinning channel. Communication between the on-board computer and

the control room is provided by sets of electrical slip rings. An additional slip ring is mounted on the tool platform over the internal shaft, allowing supply of water to the spinning model from an external source.



Broadbent geotechnical drum centrifuge with two cylindrical strongboxes installed.

Besides the data acquisition system and the on-board computer, the tool platform is equipped with vertical and horizontal servo-electric actuators. In combination with the ability of the platform to rotate independently from the drum channel, the system allows actuation in 3 degrees of freedom (vertical, horizontal, and lateral). The actuators are equipped with load cells and laser displacement transducers to control and measure the results of the test. Depending on the specific needs of the test, different tool platforms are available, containing other types of actuators and instruments.



Tool platform (left) and zoomed-in detail of one of the actuators.