Center for Geotechnical Centrifuge Modelling

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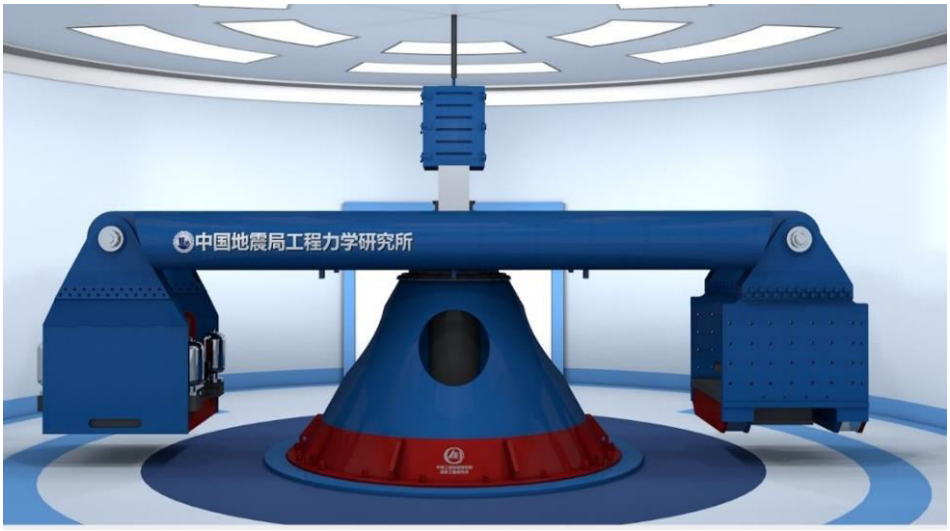
Introduction

Physical modelling of geotechnical centrifuge enables researchers to perform experiments with a holistic-level of complexity that is indispensable to derive insights on the key factors affecting the performance of geotechnical engineering, to properly validate numerical models, and to evaluate the efficiency of innovative solutions.

The Center for Geotechnical Centrifuge Modelling （CGCM） at IEM provides users, both national and international, with access to a 5.5-m radius geotechnical centrifuge for research on the performance of soil and soil-structure systems under earthquake, storm surge and cold current loading. The geotechnical centrifuge is equipped with a shaking table of 1500kg payload that enables the use of scale models to investigate nonlinear, stress-dependent responses of soil masses that are many times larger than is possible on the world's largest 1-g shaking tables.

The experimental facilities at CGCM include: (1) a 5.5-m radius multifunctional geotechnical centrifuge equipped by a 160-channel high speed data acquisition system, (2) a shaking table capable of triggering a soil model of 1500kg with a maximum acceleration of 30g, (3) a storm surge simulator capable of producing rainfalls with different intensities, (4) a cold current simulator capable of producing air current with temperatures ranging from -40 to 50 ° C, (5) various model preparation devices for sand pluviation, vacuum saturation, prestress consolidation, vacuum mixer, deair water, high viscous liquid and soil physical parameter tests, (6) an instrument research and development shop for developing measurement transducers, model containers and calibration apparatus, (7) the Geotechnical Modeling Facility building including workshops for visiting scholars and students.



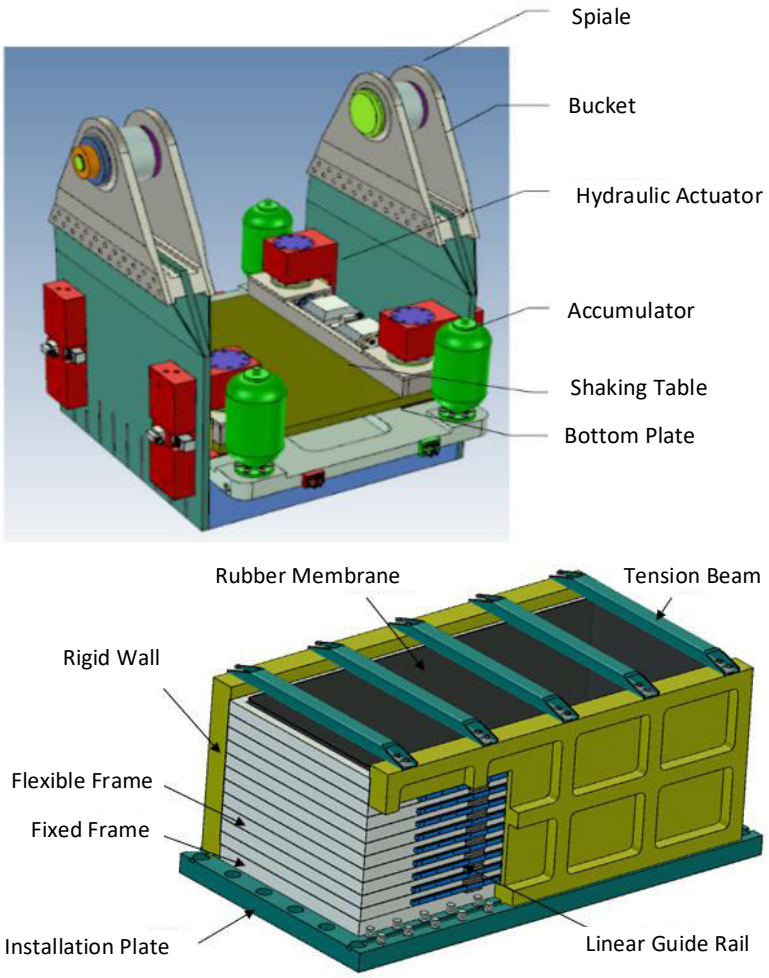


Fig. 1 IEM-40-300 geotechnical centrifuge with a shaking table of 1500kg model payload and a flexible shear beam container

Table **1** Primary **specification** of IEM-**40-300** geotechnical centrifuge

Geotechnical Centrifuge	
Manufacturer	Institute of Engineering Mechanics of CEA, China Academy of Engineering Physics (CAEP), Harbin Institute of Technology
Year established	2019 IEM, CEA
Capacity	300 gton (3 tons @100g, max G-level: 100g(S))
Centrifuge Acceleration	100 g
Max.Radius	5.5 m
Bucket area	2.2 m×2.0 m×1.8 m
Shaking payload	1500 kg
Shaking Acceleration	30 g
Max.Displacement	± 10.0 mm
Max.Velocity	1.50 m/s
Dynamic data acquisition instrument	160 ch
Shear container	1.5×0.8×0.7 m^3
Major equipment	A uniaxial shaking table (capacity 1.5 tons@30g) A storm surge simulator A cold current simulator High speed data acquisition system

	High speed camera system (2500fps) Fundamental soil test and microstructure analysis system Soil model preparation system Measurement and calibration system

5.5m Geotechnical **Centrifuge**

The beam centrifuge consists of an arm supporting two swings, in which the model and the counterweight are installed. This design philosophy of the symmetric enables reduction of unbalanced centrifugal force. Based on the test type and requirements, either a static test bucket or a dynamic test bucket can be installed. In addition, a pair of dynamic balance adjustment systems are incorporated into the rotating arm in order to maintain the unbalanced force induced by model deformation during the operation within the permitted range. This dynamic balancing system mainly is composed of counterweight block, servo motor, screw and ball linear guide.

Fig2. A photo of IEM-40-300 geotechnical centrifuge at IEM, CEA

With an effective radius of 5 m, the centrifuge can be accelerated up to 100g carrying a payload of 3 tons. Its 300gton capacity is the middle level in China. 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 1.8m×1.6m×1.0m, where the soil container is placed. In particular, the pin connecting the bucket and the rotating arm is equipped with joint bearings that allow for unrestricted rotation in multiple directions, thereby significantly reducing the vibrational impact of the shaking table on the centrifuge during the dynamic centrifuge test.

1500kg-payload Uniaxial Shaking Table

The horizontal uniaxial shaker is capable of triggering horizontal seismic ground motions of any target waveform (including recorded and artificial motions) at up to 30 g peak ground acceleration on packages of up to 1500 kg over a wide frequency band. It has an effective triggering capacity of 40gt (for driving soil and container) that is the largest in China. The integrated design of the horizontal uniaxial shaker and the bucket is to be easily mountable on the centrifuge. Moreover, the interior of the base of the bucket is designed as a hollow grid and the thickness of the lugs at both ends is quite limited, which minimizes the mass of the bucket.

The table is supported by a set of rubber shear bearings with greater vertical stiffness than horizontal stiffness, 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 shaker is driven by a unique synchronous drive technology that combines the power of two hydraulic power mechanisms to achieve greater shaking capacity. Two actuators are arranged on both sides of the table, eliminating the torsional motion of the table.

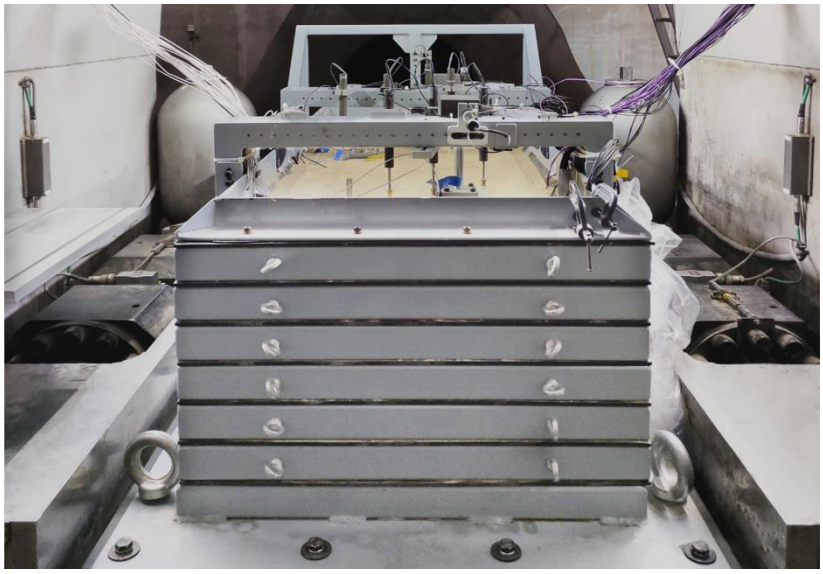


Fig3. A photo of the shaking table with a flexible shear beam container at IEM, CEA

Auxiliary Equipment Development

A laminar shear container with the dimensions of 1.2mx0.5mx0.6m was developed, featuring adjustable stiffness, large internal space, and obvious shear effect. Its single-layer frame is separated by laminated shear rubber, which can more reasonably reproduce the propagation law of seismic waves in the soil model. The inner side of the container is affixed with a rubber membrane for waterproof protection, and the bottom of the container is installed with permeable stones and drainage channels for model saturation and drainage. In addition, the model containers also include supergravity rainfall-earthquake multi-hazards coupled container and slope/high earth and rock dam-earthquake coupled container.

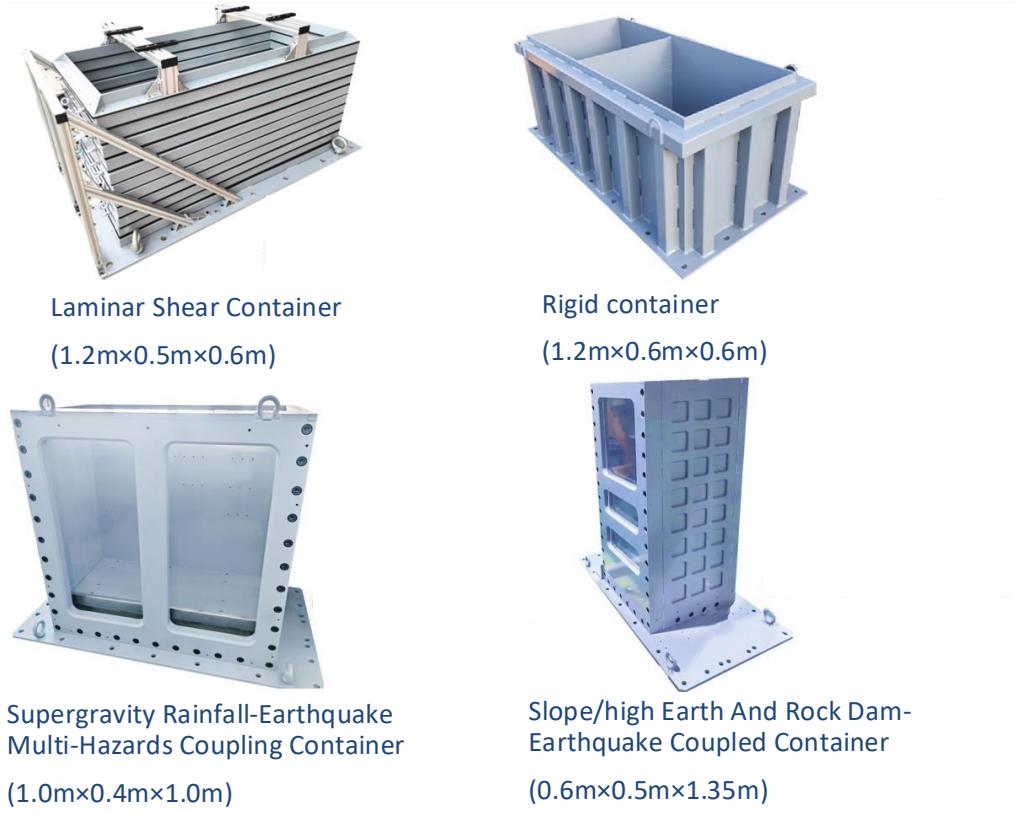


Fig4. Developed model containers for earthquake and storm surge tests

An advanced dynamic pore pressure calibration system with digital input of arbitrary waveforms was developed independently to meet the static and dynamic performance calibration requirements of pore pressure sensors. We have also developed a number of sensors for centrifuge test, such as pore pressure sensors and flexible contact earth pressure sensors, which have a broad frequency response, high accuracy, and long-lasting functional characteristics and have been applied by many colleges, institutes and engineering corporations.

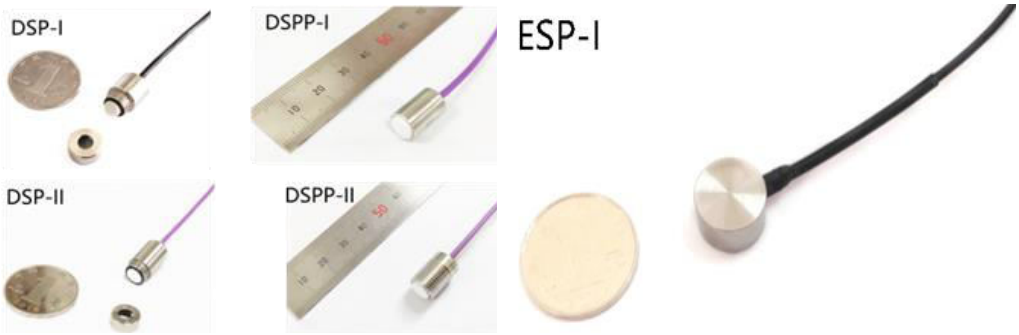


Fig5. Developed pore pressure sensors and flexible contact earth pressure sensors