A centrifuge for TUKS

Prof SW Jacobsz
Dept Civil Engineering
University of Pretoria
sw.jacobsz@up.ac.za

IN THE APRIL 2011 edition of the SAICE magazine (*Civil Engineering* April 2011 p 46) we reported on the successful funding application that the Department of Civil Engineering at the University of Pretoria (UP) had made to the National Research Foundation for a geotechnical centrifuge. Now, one year later, we are pleased to report that the geotechnical centrifuge has been delivered, installed and commissioned in the civil engineering laboratories at UP, or TUKS, as the university is popularly known.

The purpose of a geotechnical centrifuge is to accelerate small-scale soil models to high accelerations to create a realistic stress distribution within the model that is analogous to the full-scale situation. For example, a model with a scale of 1:50 needs to be accelerated to 50 times earth's gravity, or 50G. These requirements necessitate a powerful centrifuge. The TUKS centrifuge is the first geotechnical centrifuge in sub-Saharan Africa and is currently the largest in the southern hemisphere.

The centrifuge obtained by TUKS is referred to as a 150G-ton instrument, which means that it is capable of accelerating a model weighing up to 1 ton to 150 times earth's gravity. The centrifuge was manufactured by the French company Actidyn, located just outside Paris. The centrifuge model platform measures 0.9 m x 0.8 m with unobstructed headroom of 1.3 m. The radius, measured from the centrifuge axis to the model platform, is 3 m. This means that, at an acceleration of 150G, the model will be travelling in a circular orbit at 240 km/h! The model is counterbalanced by an automatically adjustable counterweight, which shifts to ensure that the machine remains in perfect balance during testing. Fine-tuning the balance of the centrifuge is accomplished by sliding weights located in the centrifuge arms.

The centrifuge was transported from France by sea and was delivered to Durban harbour from where it was transported to Pretoria by train. From the freight depot it was transported to UP by a crane truck. The 16-ton machine was offloaded in front of the heavy machine laboratories where it was hauled into position under an existing crane beam before being lifted and then lowered into the civil engineering laboratory basement. Getting the centrifuge into the laboratory was a major logistical exercise and was accomplished with the assistance of a rigging company. Once safely in the laboratory basement, the centrifuge was winched into the heavily reinforced concrete enclosure constructed to house it.

In addition to partial funding from the National Research Foundation to purchase the centrifuge, the university has received tremendous support from industry to create the infrastructure necessary to house the instrument safely. Due to the dangers associated with accelerating models weighing up to 1 ton to 150 times earth's gravity, the centrifuge was installed in a heavily reinforced concrete chamber. The containment walls were designed to absorb an impact associated with catastrophic failure of the centrifuge's hinges, implying an impact load from 1 ton mass released at 240 km/h!

The reinforced concrete chamber was designed by Jones & Wagener Consulting Civil Engineers and was constructed by Stefanutti Stocks at no cost to the university. In addition, the reinforcement steel was donated by Steeledale Reinforcing, the special shuttering by Wiehahn Formwork and Scaffolding, and the special high-slump concrete by Lafarge (an impressive cube strength of 70 MPa was measured at 28 days!). The electricity supply to the centrifuge was designed by Claassen Auret Incorporated, and the cooling system by Spoormaker & Partners. The Department of Civil Engineering would like to express its sincere gratitude to these companies for their tremendous support of this venture.

The centrifuge chamber is closed off with a curved door, manufactured from stainless steel by the technical staff of the civil engineering laboratories. The purpose of this door is to complete the circular circumference of the centrifuge chamber, and its function is therefore primarily aerodynamic in nature. Due to its light construction, a second steel-reinforced containment wall was constructed outside this door to ensure the safety of persons working in the centrifuge laboratory. A roller shutter door prevents access to the main centrifuge door during operation.

The centrifuge is powered by two electric motors with a combined maximum power consumption of 120 kW. As all the heat from the drive motors will be released in the centrifuge chamber during operation, a cooling system of equal capacity was installed. Cold air is introduced to the centrifuge chamber via a circular opening in the roof, and air is extracted from the floor of the chamber before being cooled and circulated back into the chamber.

Testing of soil models on the geotechnical centrifuge is accomplished with the aid of remote-controlled actuators, and observations are made using a state-of-the-art data acquisition system. The centrifuge is equipped with electric slip rings, as well as hydraulic and pneumatic lines, via a slip ring stack rated to 10 bar. This can be used to control various types of actuators to carry out many kinds of experiments during physical model studies on the centrifuge.

The data acquisition system was developed and manufactured by the Centre for Offshore Foundations Systems located at the University of Western Australia in Perth. The system has a total of 24 channels, which can log a variety of instrument types up to a frequency of 1 MHz for short periods. Data logged at slower frequencies, or data from, for example onboard cameras, can be streamed in real time via a fibre-optic rotary network connection or a standard wireless link to the data acquisition computers located in an adjacent control room.

The control room is equipped with two relatively high-specification personal computers for data acquisitioning and image processing, as well as a standard computer from which the centrifuge is controlled. A 42" video monitor is also available from which events within the centrifuge model can be observed, in addition to a video projector which can be used to project images against a large screen in the main centrifuge laboratory for teaching purposes.

The total floor space of the centrifuge laboratory amounts to approximately 250 m^2, of which the centrifuge takes up around 30%. A model preparation room, equipped with an independent dust extraction facility and a height-adjustable sand hopper, is also available. A press for

The reinforcing steel being fixed into position for the centrifuge chamber

The centrifuge being off-loaded at the University of Pretoria the consolidation of clay samples is currently being obtained.

The primary aim with the centrifuge laboratory is to provide a research tool which will be used for model studies by staff and students of the university. Collaboration with the Departments of Geology and Mining Engineering (and others) is envisaged. Two Masters students and a number of under-graduate final year students are currently in the process of designing centrifuge models which will be tested as part of their research. Projects which are currently in the planning phase include the following:

- the modelling of a soil-nail retaining wall, investigating the mobilisation of nail forces as excavation progresses, and the effect of moisture ingress behind the shotcrete face;
- studies into the behaviour of thin-walled large-diameter pipes; and
- a study to investigate the degrading of small-strain soil stiffness to obtain the correct stiffness for the design of conventional spread footings.

It is hoped that the facility will help to attract graduate students interested in carrying out model testing as part of their research during Masters and PhD studies. In addition, collaboration with other universities and other institutions, e.g. the CSIR and the Council for Geoscience, will be encouraged.

The geotechnical centrifuge will also be available to companies who would like to carry out testing of physical models for commercial purposes. Persons interested in more information are welcome to contact Prof SW Jacobsz at the Department of Civil Engineering (sw.jacobsz@up.ac.za). □


The centrifuge installed in its enclosure