

Adoption of the 'fall cone' as the standard method of determining the index parameters and shear strength in South Africa

**Report Progress:
June 2022 – November 2022**



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GEOCALIBRE
GEOTECHNICAL CONSULTANCY

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CONTEXT

The project was submitted to and approved by RAEng and the start date was March/April 2021. The funding was transferred to the lead university, Central University of Technology (CUT, SA). The memorandum of understanding (MoU) between University of East London (UEL) and CUT (lead university, SA) took eight months to be finalized. The UEL has requested an extension of eight months for their part of the project due to this delay in the agreement. CUT signed the final version of the MoU on 5 November 2021 while UEL signed on 23 November 2021.

The research activities have since continued at both CUT and UEL. CUT have been involved in the organization and presentation of new training workshops which was presented in November 2022 and will be presented in a series of workshops in line with the South African Institution of Civil Engineering (SAICE).

GeoCalibre and Letaba Lab have assisted the CUT in its material acquisition and testing, as well as training of students to become proficient engineers.

This report is a review of the progress from June 2022 to December 2022.

Project Goals

- Conduct full-scale proving trials, facilitating extensive translation of the modified fall cone (FC) technology developed through Royal Academy of Engineering IAPP2\100195 TASMIP project – single point test for determination of index parameters for a wide range of clayey soils across the Free State and beyond;
- Deployment of the FC technology – and refinement if needed – for measurement of suction-controlled undrained shear strength clayey soils, within the confines of stochastic and probabilistic models which then avails determination of reliable characteristic strength value, as stipulated in EC7, SANS, and BS EN 1997;
- Verification of method through correlating modified FC outcomes and CU/UU triaxial results to estimate characteristic values from these tests.

Three specific objectives are:

- Verify that the technology (modified FC) holds true for the majority of South African soils
- Presentation of the verified technology and its advantages to the South African geotechnical sector, policy makers and professional bodies for the eventual inclusion in the SANS.
- Streamlined the technology to offer stochastically independent undrained shear strength and index parameters.

Specific outcomes include:

- Fall cone as standard method for determination of index properties of soils in South Africa
- Determination/estimation of the characteristic value as required by the standard code
- Conference proceedings
- Accredited journal papers
- Bachelor and PG degrees
- Workshops
- Community/student engagement

Collaboration Visit

Mr SG Waters and Prof Elizabeth Theron visited the UK partner (University of East London – Dr Assadi Langroudi) in London during the month of November 2022. This planned visit was a useful engagement for the parties to strengthen the collaboration in their research and the project. The visit was partly funded by in-kind contributions of the CUT and partly from the RAEng funding.



Figure 1 - Arrival of CUT team in Heathrow Airport

This visit was very beneficial for project. The researchers could discuss the problems experience with the research and determined innovative solutions. Strategic plans for various articles and conferences could also be planned for the remaining 12 months of the project. The team have even determined suitable future projects of which they could expand.

The visit entailed Mr Waters and Prof Theron working for four weeks with Dr Assadi Langroudi in his geohazard laboratories. The CUT team also met several other

researchers at the UEL that are involved in similar fields or who can contribute to new research projects (including more focus on deep-learning systems).

The team worked on some of the following testing methods. Many of these tests could contribute towards the adoption of the fall cone method and will also feed into new projects that can be expanded for significantly more research outputs. The visit served as a medium for developing a junior researcher (Mr Waters) through mentorship of Dr Assadi Langroudi.

The course of the visit primarily focused on running multiple kinds of laboratory tests that will be used in 2023 to make analytical comparisons of many engineering properties to evaluate the fall cones effectiveness.

Scanning Electron Microscope (with EDX)

The Scanning Electron Microscope was used to observe the detailed images of the soil particles of these specimens. It is a type of electron microscope that produces images of a sample by scanning the surface with targeted beams of electrons. The electrons interact with the particles in the sample which produce various signals that provide information about the surface topography and composition of the soil sample. Energy Dispersive Spectroscopy (EDS) or Energy Dispersive X-ray analyzer (EDX) might be used as a stand-alone system combined with a separate Scanning Electron Microscope (SEM) or in the form of integrated systems

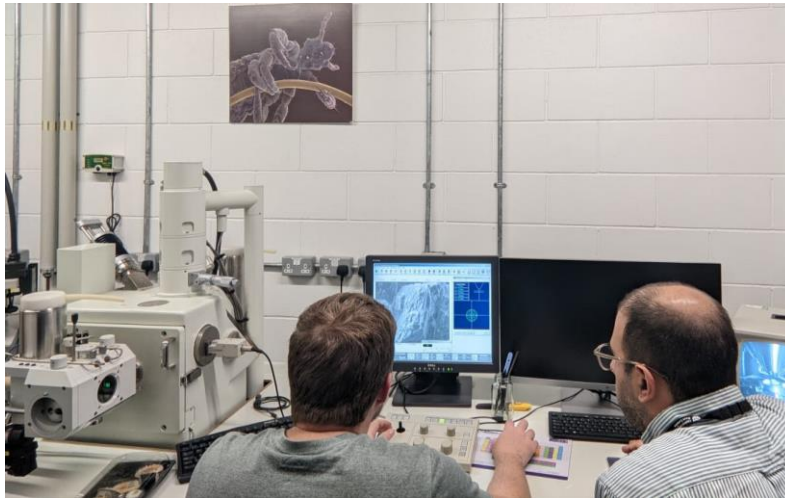


Figure 2 - Dr Langroudi and Mr Waters using the SEM apparatus



Figure 3 - Mr Waters preparing the samples through carbon coating to use in the SEM apparatus

X-ray powder diffraction (XRD)

X-ray powder diffraction (XRD) is an analytical technique used for identification of the phase of a crystalline material. This provides information on the dimensions of the materials. The analyzed material is finely ground soil samples. The X-ray

diffractometer is a sophisticated system designed to generate X-rays, optically focus them onto a sample, scan with precise angular control, and monitor the relative intensity of the diffracted beam as a function of 2θ (i.e., actual angular deviation from the incident beam). Monochromatic radiation is necessary for XRD analysis using a powder diffractometer. The X-ray tube emits intense characteristic $K\alpha$ radiation from its metal target. Shorter-wavelength (higher energy) radiation has the advantages of lower attenuation in air and less absorption by the sample. Longer wavelength radiation, however, produces better resolution of peak maxima, which is particularly advantageous for the large d-spacing of expansive phyllosilicates. The most commonly used radiation for soil mineralogy analysis is $\text{CuK}\alpha$ ($\lambda=1.54\text{\AA}$) because it is a reasonably good tradeoff with respect to energy and peak separation. $\text{MoK}\alpha$, $\text{FeK}\alpha$, and $\text{CrK}\alpha$ are higher- and lower-energy alternatives, respectively.

3D microscope

A three-dimensional microscope was an important tool to observe the shape and size of the soil particles. These features of the particles are important for interpreting the potential engineering properties like agglomeration, absorption of moisture, capacity for void ratios etc.



Figure 4 - Mr Waters using the 3D microscope to observe and record particle topography

Unconfined Compressive Strength (UCS)

Unconfined Compressive Strength (UCS) stands for the maximum axial compressive stress that a cohesive soil specimen can bear under no confining stress. Unconfined compression test is quick, cheap method to measure the shear strength of clayey soil.



Figure 5 - Several UCS samples prepared for testing

3D Printing

In an attempt to improve the use of some test procedures, the team has focused some of their efforts on developing better components. The first attempt at producing a better mould and piston for UCS has allowed the team to plan possible future projects with improved components (as was done previously with fall cone containers).

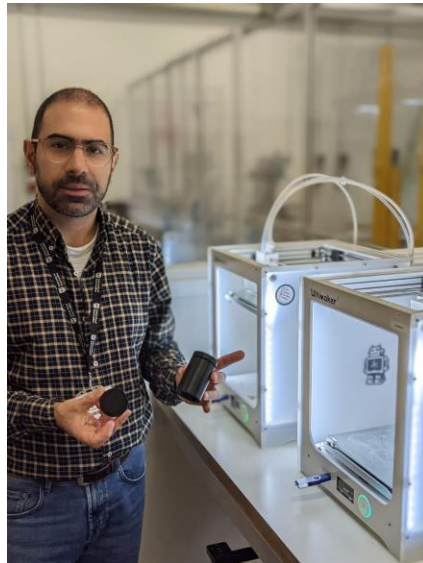


Figure 6 - Dr Langroudi standing with the printed UCS mould

pH Determination

A simple but effective test was the pH determination of the various clays which could show the chemical reactions acting within the materials that could strengthen the bonds between particles in C-H-L gels.



Figure 7 - pH Determination of various clays

These tests were also used in the assessment of organic growth in lime cake stabilized soils. This growth is being investigated on its effect on the stabilization of the soils and strength properties (amongst other engineering properties).

The CUT team is returning to South Africa on 2 December 2022. The projects will be able to continue with improved strategies since the visit and the vision for the RAEng project has been realigned for the last year to be very successful.

The Annual General Meeting (AGM) SAICE Bloemfontein Branch of 2022 hosted a free CDP lecture on “ASSESSMENT OF THE SUITABILITY OF THE FALL CONE METHOD FOR DETERMINING THE LIQUID LIMIT OF SOUTH AFRICAN SOILS.” It was presented by Prof. Theron. Many students from both the CUT and the UEL attended the workshop in addition to several industry partners from South Africa. This workshop will be the first of four potential workshops as part of the SAICE initiative. See annexure for presentation.