CASE STUDY: VARIABLE DIRECTION DYNAMIC CYCLIC SIMPLE SHEAR

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The geotechnical engineering research laboratories at the ***University of Dundee*** *were established in 1997 and have grown significantly since that time. In addition to its undergraduate and postgraduate teaching and research activities, the group offers services to industry across a broad range of geotechnical engineering. The group is equipped with advanced facilities for geotechnical modelling and characterisation including a 7m diameter geotechnical centrifuge and the Scottish Marine Renewables Test Centre (SMART). These are supported with large 1g soil test beds and physical modelling facilities, which have been used to study offshore foundations (deep and shallow), pipelines, onshore vegetation-supported slopes, earthquake faulting and liquefaction. The applicability of the facilities at UoD for industry are recognised by their inclusion in the Scottish Enterprise Energy Lab (SEL facility 45). The REF 2014 ranked Civil Engineering research at the UoD top in Scotland and third in the UK for its quality and impact.*

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SCALING ISSUES IN CENTRIFUGE MODELLING

Centrifuge modelling is an advanced physical modelling technique for testing reduced scale geotechnical engineering models in the enhanced gravity field of a centrifuge. The main principle of centrifuge testing is the equivalence between the small scale model and the full-scale prototype via well established scaling laws. In order to scale the stresses correctly, the centrifuge test is performed at increased gravity forces equal to the number of times the model is scaled to. The outcome of the modelling is stress and soil behaviour similarity between the scale model and the full size field structure (Schofield, 1980). Centrifuge modelling has been applied to many disciplines, such as earthquake engineering, where soil models are prepared and tested under extreme seismic events, which can provoke large displacements failures and liquefaction.

Conventional centrifuge testing proposes the use of identical soil in the model and prototype. However, in some cases, such as centrifuge testing of stone columns as a countermeasure against liquefaction, the stone columns should be modelled using reduced scale particles, because prototype aggregate is too large in diameter for the model columns. For consistency, the surrounding soil must be scaled by the same rule. Moreover, the fine material should be capable of liquefaction, as it represents a liquefiable soil. Here, the proposed fine soil is a liquefiable coarse silt. However, before using large amounts of soil in a centrifuge model and testing it under earthquake motions, it is necessary to test the material under shearing to check its behaviour. (Apostolou et al., 2016)

BEHAVIOUR OF SILT UNDER SIMPLE SHEARING ON VDDCSS

The chosen material used for further investigation as a scaled reference was coarse silt A50 Silica. According to geological reference and case studies silt is a material that can liquefy (Carr et al., 2004), (Sartain et al., 2014). Thus, it was investigated extensively in the lab to understand its behaviour under cycling loading.

A series of drained tests were carried out in order to assess the degree of contraction under cyclic simple shear, which may be interpreted as indicative of its potential to undergo liquefaction. The equipment used for the tests was the GDS Variable Direction Dynamic Cyclic Simple Shear System (VDDCSS) (Fig. 1). Simple Shear was preferred over a conventional direct shear device, as soil behaviour under simple shearing mimics

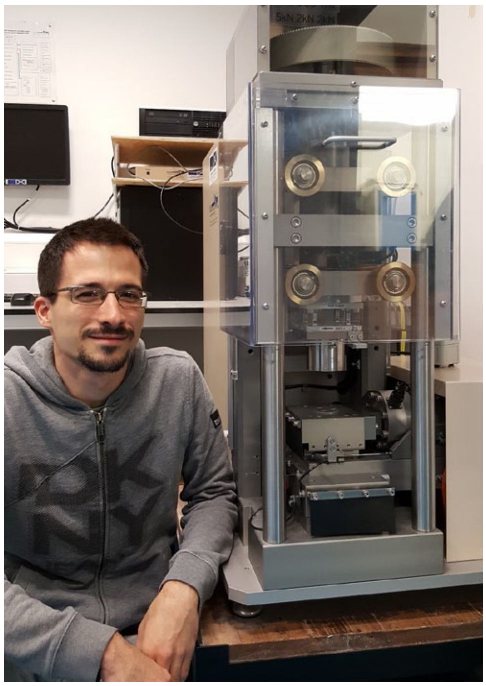

Fig 1. GDS Variable Direction Dynamic Cyclic Simple Shear System (VDDCSS)

better the soil stress response under seismic events in real field conditions. More precisely, a conventional shear box splits horizontally in halves during the direct shear test and as a result, it allows a specific plane of failure for the specimen. On the other hand, a soil sample in the VDDCSS is placed on the interior area of a number of rings, which can move freely to the desired direction, so the shear strains γ are distributed to the whole area of the sample (Fig. 2).

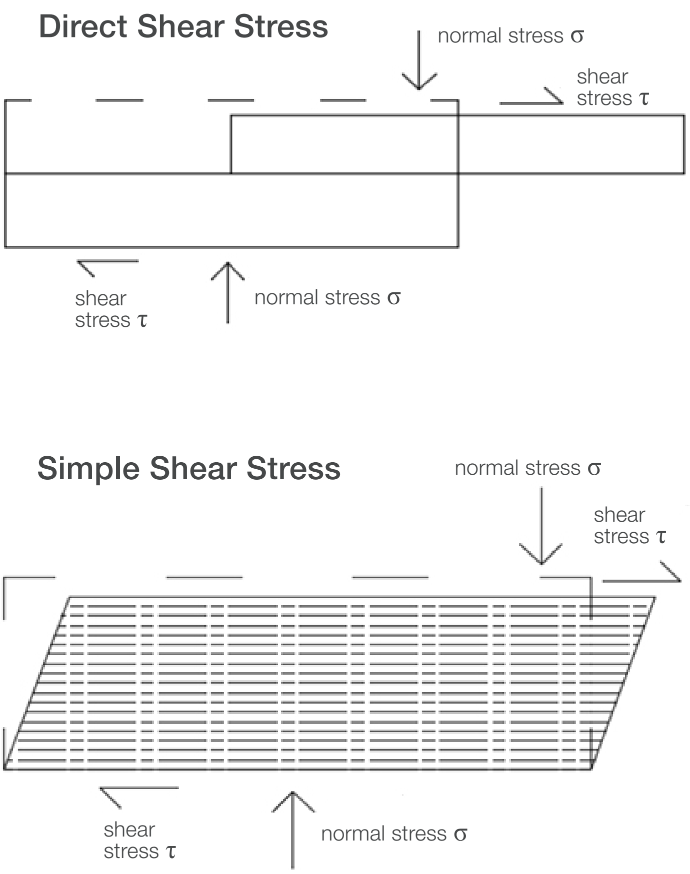

Fig 2. Difference between direct and simple shearing methods

The soil specimen for the VDDCSS equipment is prepared by air pluviation. A cylindrical sample of 70 mm diameter, 20 mm high, is prepared on a pedestal using a rubber membrane and a number of Teflon coated rings, which allow the shearing displacement of the specimen (Fig. 3). Then, the sample is docked on the centre of the device, where it can be deformed in simple shear horizontally. The VDDCSS allows the performance of simple shearing in two directions at the same time, but for the purpose of these tests simple shear was performed in only one direction.

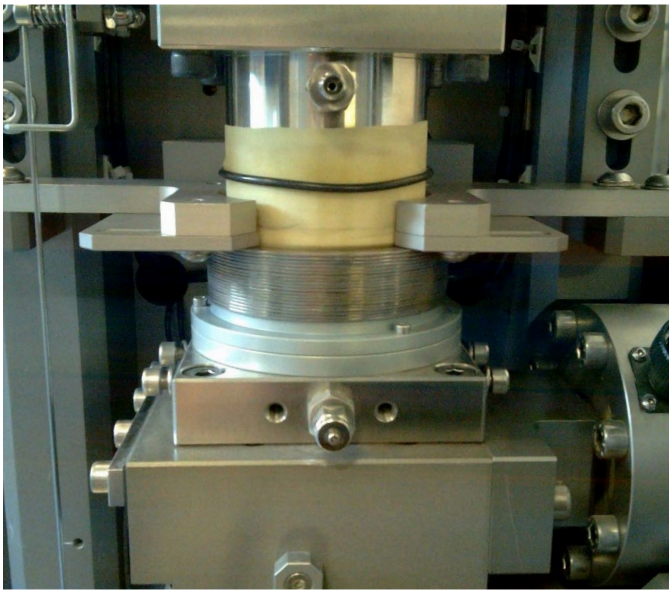

Fig 3. Placement of the coarse silt sample on the VDDCSS equipment

THE SIMPLE SHEAR TEST RESULTS AND CONCLUSIONS

Fig. 4 and Fig. 5 show the results from the simple shear tests performed at 4 different ratios of shear stress to effective stress (τ/σ'). The graphs show sample strain against number of cycles, with Fig. 4 showing tests performed at 0.8Hz and Fig. 5 showing the same tests but performed at 0.5Hz. It is observed that the dry coarse silt clearly contracts under shear stress when cycling in a range of shear ratios and cycle numbers and should therefore be appropriate for behaving as a liquefaction susceptible material and could replace coarser, liquefiable sandy soils when necessary for centrifuge testing. The fine material was then tested in the geotechnical centrifuge of the University of Dundee and the rise in pore pressures observed confirms the liquefaction potential of the silt and the reliability of VDDCSS results. (Apostolou et al., 2016)

Correlation Among Axial Strain - Shear Stress Ratio - Number of Cycles (0.8Hz)

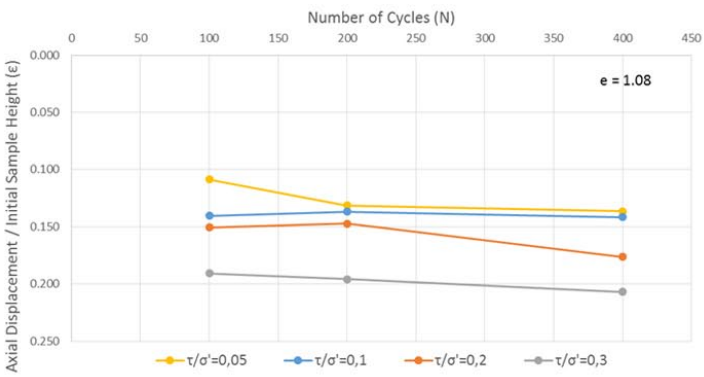

Figure 4. Axial strain (contraction positive) as a function of number of stress cycles applied, for different shear stress ratios (Frequency f = 0.8 Hz)

Correlation Among Axial Strain - Shear Stress Ratio - Number of Cycles (0.5Hz)

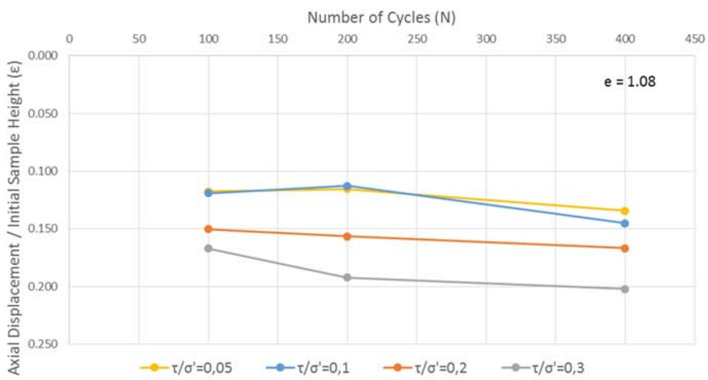

Figure 5. Axial strain (contraction positive) as a function of number of stress cycles applied, for different shear stress ratios (Frequency f = 0.5 Hz)

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“The cooperation with GDS Instruments was very satisfying. As already described, the use of a dynamic simple shear system was more than necessary and it is pleasant to know there is a company that understands the concerns and meets the requirements of a geotechnical engineering laboratory.

Also, understanding and operation of hardware and software of GDS equipment is easy and straight forward. In addition to that, the device allows the pre-selection of many parameters as input information before the test, which leads to a wide range of possible output data.
Thus, GDS will be definitely our first choice for any future lab equipment.” Efthymios Apostolou.

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