Review of a dissertation

submitted for the degree of Doctor of Philosophy by
M.Sc. Jose Alejandro Duque Felfle,

entitled
Contributions to the experimental investigation and numerical description of soil cyclic behavior

Introduction

Soil behaviour under cyclic loading conditions is relevant to numerous engineering problems. The experimental database available from the published results is still very limited with respect to both, loading conditions and soil types. Constitutive models suitable for the description of the cyclic behaviour of soils belong to the most advanced models. Comparisons with experimental results reveal again and again new deficiencies and need for improvements. The submitted thesis is thus a valuable scientific contribution to this topic.

Composition of the thesis

The cumulative thesis is composed as a collection of seven papers published or submitted, respectively, in the leading international journals in the field of soil mechanics and geotechnical engineering. The papers cover both experimental and numerical subjects.

1. *Experimental investigation on Malaysian kaolin under monotonic and cyclic loading: inspection of undrained Miner's rule and drained cyclic preloading* (submitted for publication in Acta Geotechnica)

An extensive experimental study on the cyclic behaviour of a high plasticity silt mainly under undrained triaxial conditions. Observations of the influence of the stress state, stress amplitude and initial stress ratio on the accumulation of pore water pressure. A significant observation on the sequence of loading packages and its estimation using a modified Stewart's approach.

2. *Experimental investigation on Zbraslav sand under monotonic and cyclic loading: on the influence of cyclic preloadings* (submitted for publication in Acta Geotechnica)

An analogous paper to the previous one with tests on Zbraslav sand. A special focus on the effects of drained and undrained preloading.

3. *Inspection of four advanced constitutive models for fine-grained soils under monotonic and cyclic loading* (submitted for publication in Acta Geotechnica)

The tests results on kaolin clay from the database by Wichtmann and Triantafyllidis. Four conceptually different advanced constitutive models capable to include effects of the recent stress and deformation history. The results reveal several deficiencies in the existing models, although they can qualitatively reproduce many aspects of the experimental behaviour. Effects of the soil anisotropy have been also investigated.

4. *Characteristic limitations of advanced plasticity and hypoplasticity models for cyclic loading of sands* (submitted for publication in Acta Geotechnica)

Numerous aspects of the soil behaviour during cyclic loading are not correctly reproduced by the advanced constitutive models. A comparison between numerical and experimental behaviour is based on the published test results on Toyoura and Karlsruhe fine sands. A systematic classification of the parasitic effects and options for their remediation are provided.

5. *Improvement to the Intergranular Strain model for larger numbers of repetitive cycles* (Acta Geotechnica, 2020, Vol. 15, 3593-3604)

The hypoplastic constitutive model with intergranular strains is widely used for the modelling of cyclic behaviour of coarse grained soils. In order to better capture the recent stress history, an additional variable is introduced into the model. An improvement of the predictions of strain accumulation during cyclic loading has been achieved.

6. *On the behavior of monopiles subjected to multiple episodes of cyclic loading and reconsolidation in cohesive soils* (Computers and Geotechnics, 2021, Vol. 134, 104049)

A successful application of an advanced constitutive model for the case of offshore monopiles in a clayey soil (Malaysian kaolin). Comparison of the simulation results with centrifuge tests.

7. *Performance of tripod foundations for offshore wind turbines: a numerical study* (Géotechnique Letters, 2021)

Another application of an advanced constitutive model (hypoplastic model with intergranular strains) for an offshore foundation problem (tripod suction bucket). Experimental results of a centrifuge model as a comparative basis for the numerical analysis. Explanation of the "self-healing" effect.

Comments and Questions

The thesis represents an impressive research work with experimental, constitutive and numerical results. The contribution of the Mr. Duque in the all papers co-authored by further persons is clearly stated. It is not obvious why all recent papers have been submitted for the publication in one and the same journal (Acta Geotechnica). A wider journal range would be advantageous (and more convincing).

The following questions can be discussed by the applicant during the defence:

1. The own experimental basis on Malaysian kaolin (Paper 1) is of a high quality. Why the comparison of four advanced constitutive models (Paper 4) have been per-
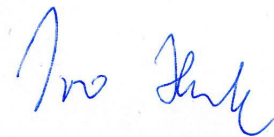
formed for a different material?

2. What are the differences in the behaviour between the Malaysian kaolin and the German kaolin (Wichtmann and Triantafyllidis)?

3. Are there significant qualitative differences between the cyclic behaviour of (Zbraslav) sand and (Malaysian) clay?

4. The initial stiffness of the SANICLAY-B model for the monotonic triaxial tests (p. 72, Figure 4.4, Paper 3) is very high, in comparison with the experiments. The same is true for the oedometer test (p. 71, Figure 4.3). Why? How this effect can be improved?

5. Regarding the cyclic behaviour of sands, the relationship between the cyclic stress ratio and number of cycles to a particular accumulation magnitude (p. 102, Fig. 5.6, Paper 4) is poorly captured by all tested models, especially for loose sand. Is the suggested improvement (Paper 5, additional state variable for intergranular strains) applicable also to other constitutive models?

6. The explanation of the self-healing property of a tripod suction bucket foundation (Paper 7) is based on experiments and calculations in dry conditions. With respect to the offshore structures, a generation of substantial pore water pressures can be expected during cyclic loading. What would be the consequences of the PWP for the observed mechanism?

Evaluation of the thesis

The thesis is composed of reviewed and submitted journal publications. This is reflected in a high quality of the written text and the included diagrams. The content is fully within the context of the current research topics in the field of soil mechanics. It brings valuable contributions to the experimental database and constitutive modelling of the cyclic soil behaviour.

I recommend to accept the thesis for the final defence.

Dresden, October 21, 2021   Univ.-Prof. Dr.-Ing. habil. Ivo Herle