TECHNISCHE UNIVERSITÄT DRESDEN

Fakultät Bauingenieurwesen
Institut für Geotechnik
Professur für Bodenmechanik und Grundbau

COMPARISON OF ADVANCED CONSTITUTIVE MODELS FOR SANDS

VERGLEICH VON FORTGESCHRITTENEN STOFFMODELLEN FÜR SANDE

NGUYEN HA KHA

Introduction

Over the past decades, many well established constitutive models have been developed for granular soil, e.g., sand, including hypoplastic model with intergranular strain and Sanisand model. The examination focuses on the model capability to predict monotonic behaviors (conventional oedometric and triaxial tests, i.e., under drained and undrained conditions). Their step-by-step calibrations are thoroughly demonstrated here as well.

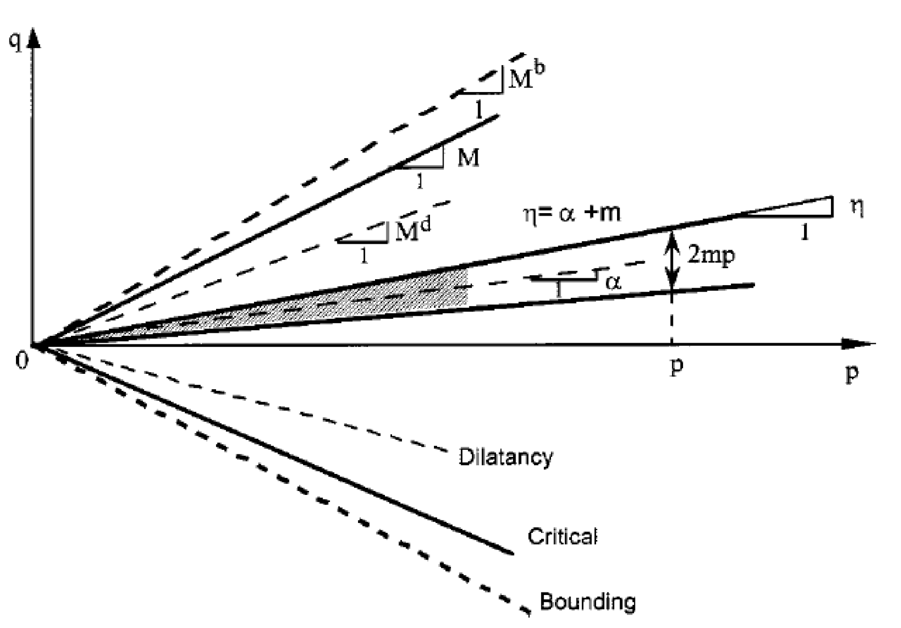

Fig.1: Schematic of the yield, critical, dilatancy and bounding lines

Hypoplastic Model with intergrnaular strain

The basic idea of Hypoplasticity stems from its formulation of soil behavior using a single non-linear tensorial function of the rate-type. Its general form of constitutive equation is

$$\mathbf{T} = \mathbf{F}(\mathbf{T}, e, \mathbf{D})$$

the tensor valued function $\mathbf{F}$ depends on two other state variables: the stress $\mathbf{T}$ and the current void ratio e. It has been demonstrated that basic hypoplastic model, under cyclic loading or deformation with small amplitudes, shows significant defects, such as excessive accumulation of deformation, called ratcheting. The concept of intergranular strain (\delta) has been introduced by to improve the small strain performance after changes of direction and stress.

Sanisand Model

The model is based on simple plasticity sand model accounting for fabric change effects during loading. It is stress-ratio controlled and critical state compatible. Developed from previous 1997 version by DAFALIAS and MANZARI, new features of the model are updated in the version of 2004, including fabric-dilatancy quantity, dependence of plastic strain rate direction on a modified Lode angle and system, and lastly the systematic connection between the simple triaxial and the general multiaxial formulation. The basic underlying assumption is that plastic shear and volume changes only occur with the change of stress ratio. Different surfaces represented by linear lines employed by the model are shown in Fig. 1.

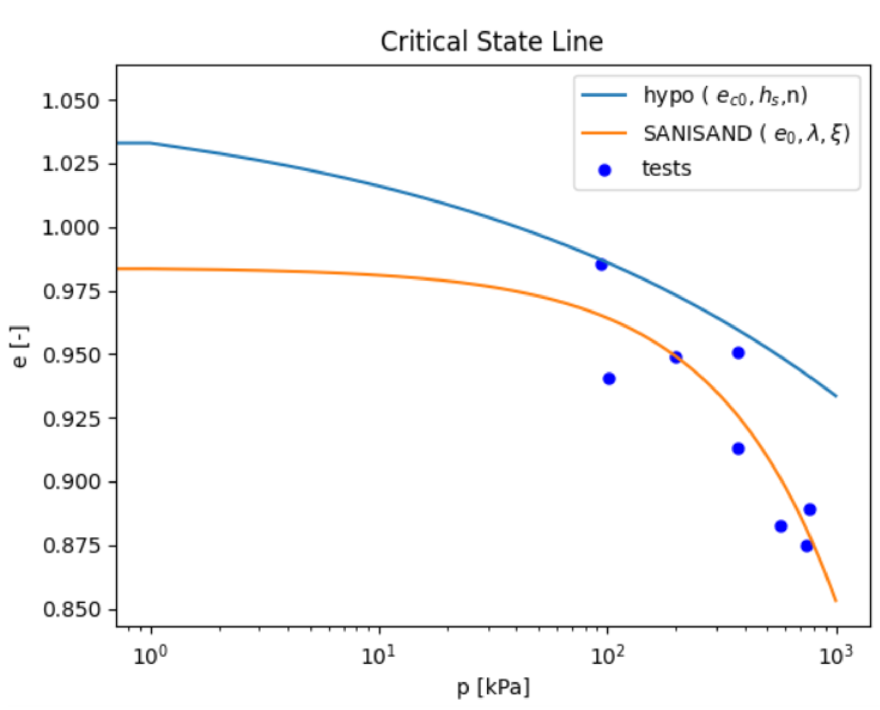

Fig. 2: Comparison of CSL between hypoplastic and Sanisand model

Calibration of the model parameters

Calibration can be, in this paper, be interpreted as the act of determining the model parameters that are not directly measured, by using empirical equation (analytical) or repetitive simulations to imitate experimental results (numerical or visual).

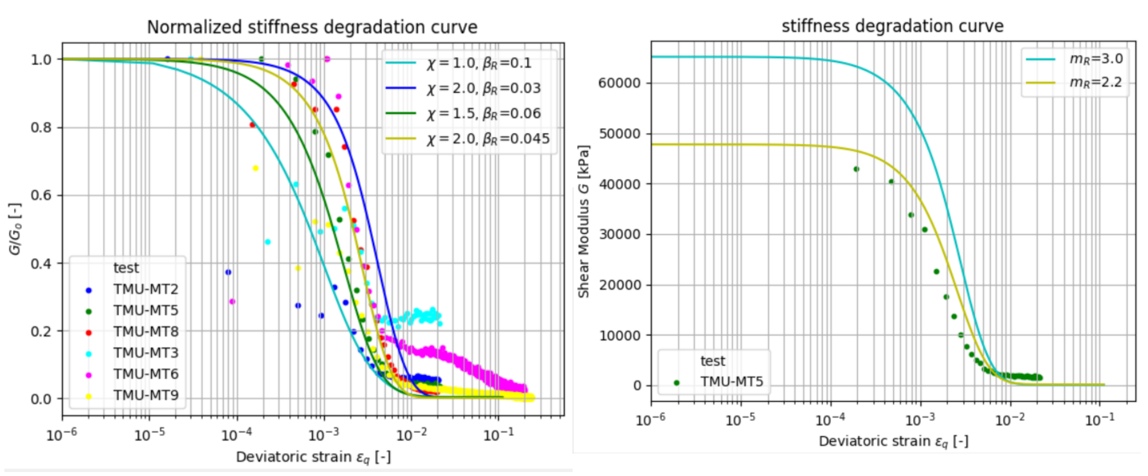

Fig. 3: Calibration of intergranular strain parameters.

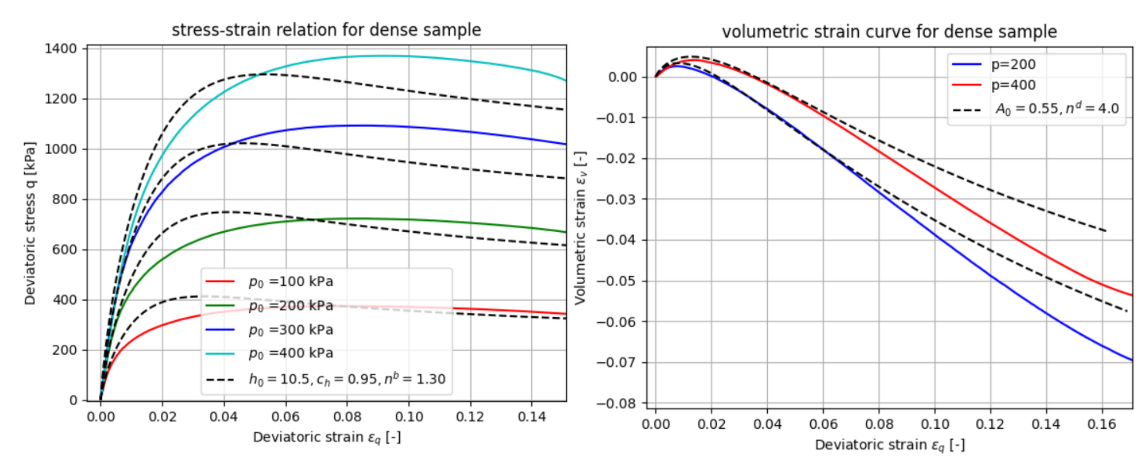

Fig. 4: Calibration of bounding and dilatancy surface Sanisand parameters

Element test simulations

The element test simulations are run by Incremental Driver developed by NIEMUNIS. All the tests are simulated with sand of varied densities, i.e., loose, medium dense or dense.

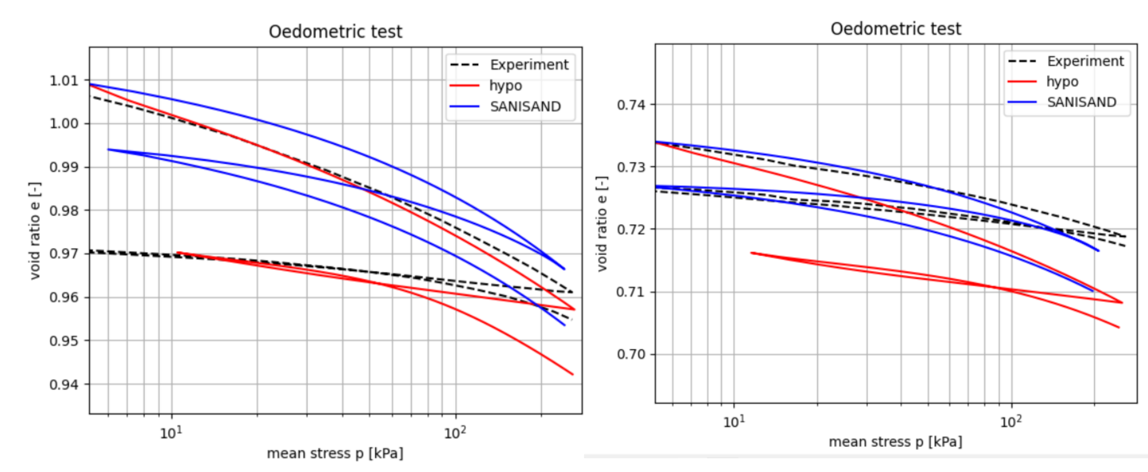

Fig. 5: Simulation of oedometric tests for loose samples

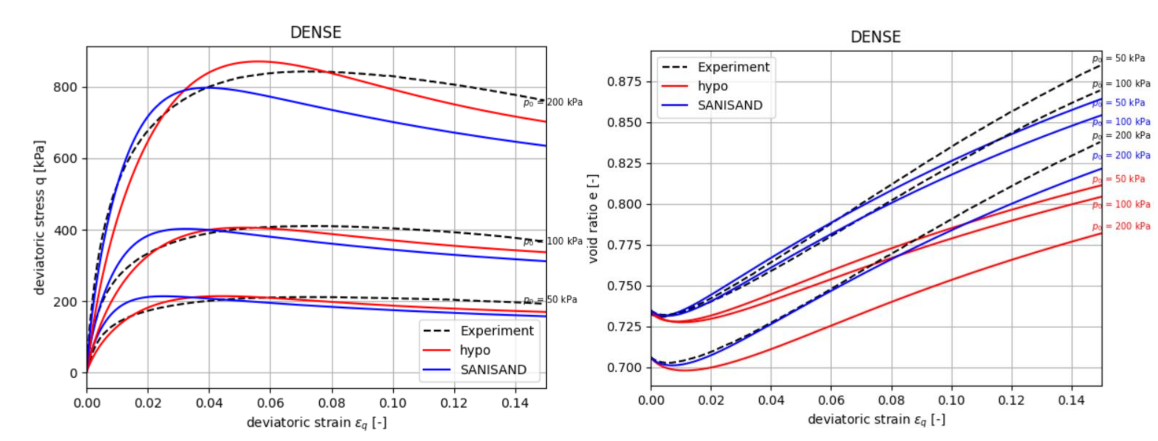

Fig. 6: Simulation of drained test for dense samples

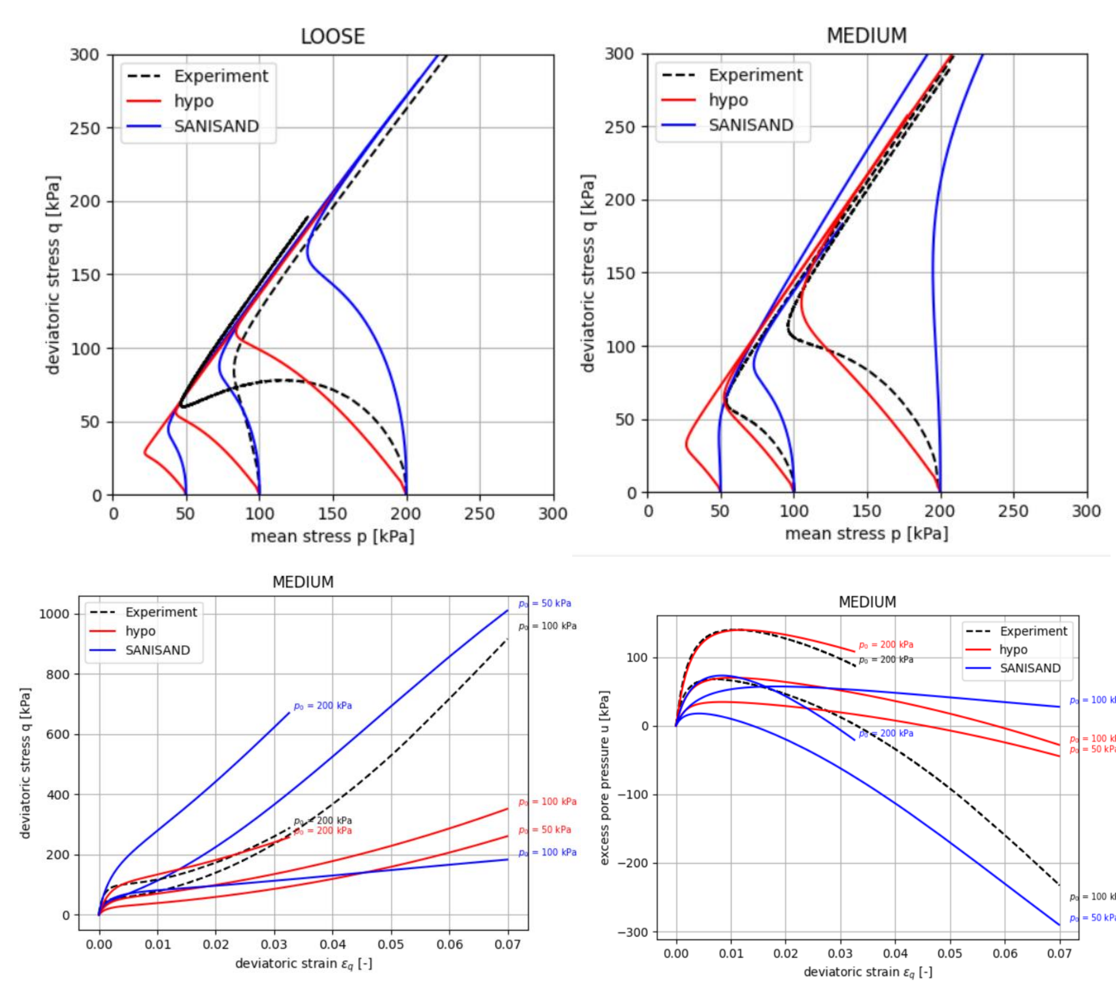

Fig. 7: Simulation of undrained test for medium dense samples

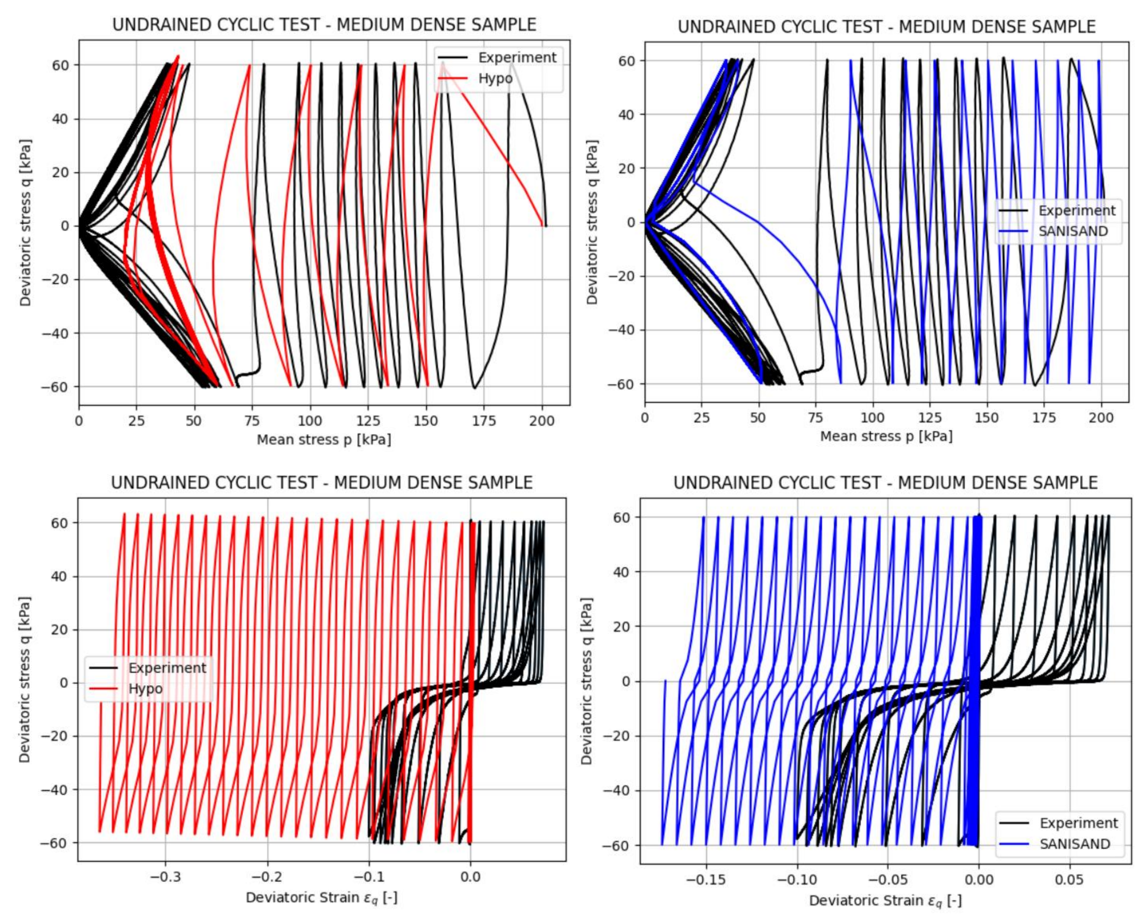

Fig. 8: Simulation of undrained cyclic test for hypoplastic model for medium dense sand

Summary

Two sophisticated constitutive models for sand have been studied in this paper, including their detailed calibration of parameters and comparison of their performance with experimental data.

- Both models have simple parameters that can be easily determined from conventional tests. Regarding parameters governing the performance under cyclic loading, the calibration process can be subjective and dependent on the engineering problems.
- For compression element (oedometric and isotropic) tests, hypoplastic model reproduces an agreeable volumetric response compared to the experimental data, in both primary, unloading and reloading phases. In comparison, Sanisand model shows a simi-lar behavior between primary and reloading curve in the oedometric element tests due to their underlying assumption that only change in stress ratio induces plastic deformation.
- Both models perform well with regards to drained triaxial compression element tests with varying density and initial stresses. However, Sanisand shows a poor capability of undrained element test simulations. It was suggested that bounding surface shall be controlled by other factors other than current mean stress p and void ratio e.
- Cyclic performances of both models are limited and varied corresponding to the density. Sanisand simulates a well fitted ‘butterfly’ shape during the cyclic mobility phase. On the other hand, hypoplastic model lacks the ability to reach zero mean stress. Both models show a strong tendency to accumulate strain under extension phases of the cycle.

Project
Project thesis

Professor
Univ.-Prof. Dr.-Ing. habil. Ivo Herle, TU Dresden

Supervisors
Dipl.-Ing. Selma Schmidt, TU Dresden
Dr.-Ing. Max Wiebicke, TU Dresden

Submission
02 2022