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# Calibration of Hypoplastic Models for Soils

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**Abstract:** The paper is concerned with hypoplastic models for both coarse and fine grained soils. It concentrates on the description of models parameters and presents procedures for their evaluation based on laboratory tests.

## Introduction

The theory of hypoplasticity offers a sound approach to the modeling of soil behavior which considerably differs from classical plasticity theories represented for example by the Mohr-Coulomb or Cam-Clay material models. Unlike these models it allows for the description of nonlinear response of soils from the onset of loading as well as upon unloading. It captures most of the principal features of the soil behavior including the dependence of the soil stiffness on void ratio and stress level. Although the essential material parameters can be calibrated on the bases of standard laboratory tests, the hyploplastic models are still far from being generally accepted. The objective of this paper is thus to provide a suitable tool for the estimation of model parameters exploiting laboratory measurements and numerical simulations to bridge the gap between the theoretical formulation of hyploplastic models and their application in engineering practice.

## Hypoplastic model for coarse grained soils

This model was put forward already in 1996 [1] and at the present time is generally accepted as a hypoplastic model for sand. It introduces eight parameters $\varphi_c$, $h_s$, $n$, $e_{d0}$, $e_{c0}$, $e_{i0}$, $\alpha$ and $\beta$, which can be divided into groups according to the laboratory tests and methods necessary for their determination.

We begin with the critical angle of friction $\varphi_c$. This angle is possible to evaluate as an angle of repose $\varphi_{rep}$ for a soil with the grain size larger than 0.1mm. For soils containing grains smaller than 0.1mm the friction angle $\varphi_c$ can be determined from standard triaxial shear test. Two other parameters $h_s$ and $n$ control the slope and curvature of the limiting void ratio curve represented by Eq. (1), which describes the evolution of void ratio $e_i$ under isotropic compression as

$$e_i = e_{i0} \exp[(-3p/hs)\exp(n)]. \quad (1)$$

Notice that parameter $h_s$ can be directly extracted from the Eq. 1 upon time differentiation. Parameters controlling the position of limiting void ratio curves in the $e$ x ln$(p)$ plane are $e_{d0}$, $e_{c0}$, $e_{i0}$ (see Fig. 1). The limiting void ratio $e_{c0}$ might be evaluated by the means of undrained triaxial shear test or oedometric test. In case of triaxial test, the parameters $h_s$ and $n$ have to be evaluated in advance. When adopting eodometric test, the parameter $e_{c0}$ can be associated with the initial void ratio providing the soil sample is in its loosest state. The limiting void ratio $e_{i0}$ is the theoretical value of the loosest possible state having analogy with a distribution of spheres in a gravity-free space. For that reason the value of $e_{i0} = 1.2e_{c0}$ was proposed as a representative one. The void ratio of maximal density $e_{d0}$ can be acquired by cyclic shearing with a small amplitude at constant pressure and additionally evaluated from oedometric test using parameters $h_s$ and $n$ and Eq. 1. The last two parameters $\alpha$ and $\beta$ control the evolution of stiffness and pyknotropy factors [1,2]. These parameters can be found numerically by simulating the triaxial shear test.

## Hypoplastic model for fine grained soils

The hypoplastic model for clay [2] consists of five parameters $\varphi_c$, $\nu$, $\lambda^*$, $\kappa^*$ and $N$, which are much similar to those defining the Cam-Clay model. First two parameters can be evaluated from the results of triaxial test while other three follow from oedometric or isotropic compression test.

The the critical state friction angle $\varphi_c$ can be estimated from the results of triaxial shear test displayed in the form mean stress-deviatoric stress diagram. The parameter ν controls the ratio of bulk modulus $K$ to the shear stiffness $G$. A suitable way of how to determine the parameter ν is to perform a parametric study of the triaxial shear test. In order to minimize errors resulting from sample defects, it is advisable to determinate parameters $\varphi_c$ and $\nu$ from the set of at least three triaxial tests.

Establishing parameters $\lambda^*$, $\kappa^*$ and $N$ requires performing the isotropic compression test or alternatively the oedometric test (see Fig. 2). Parameters $\lambda^*$ and $\kappa^*$ represent slopes of the *NCL* (Normal Consolidation Line) and isotropic unloading line, respectively, and are read out from the ln($e$ + 1) x ln($p$) plane. Conveniently, the test might be executed on the reconstituted soil samples and *NCL* is then reached under a lower loading pressure. Parameter $N$, similarly to parameters $e_{d0}$, $e_{c0}$ and $e_{i0}$ in the coarse grained soil moded, specifies the position of *NCL* in ln($e$ + 1) x ln($p$) plane and represents the value of void ratio corresponding to the mean stress $p$ = 1. When deriving the parameter $N$ from the oedometric test, its value has to be adjusted in consideration of the correct position of *NCL*. [2]

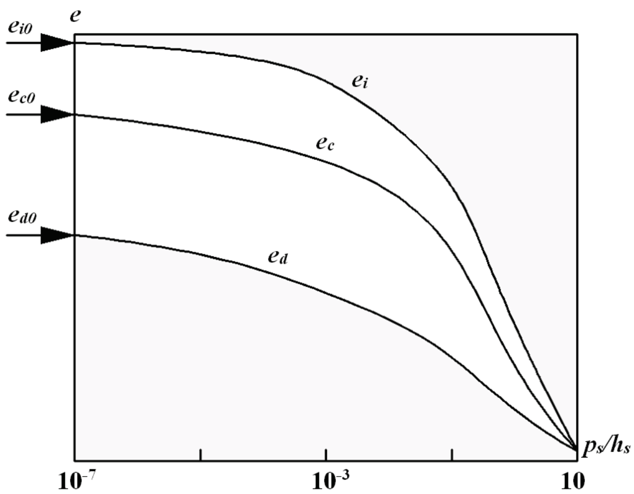


Fig. 1: Evolution of limiting void ratios

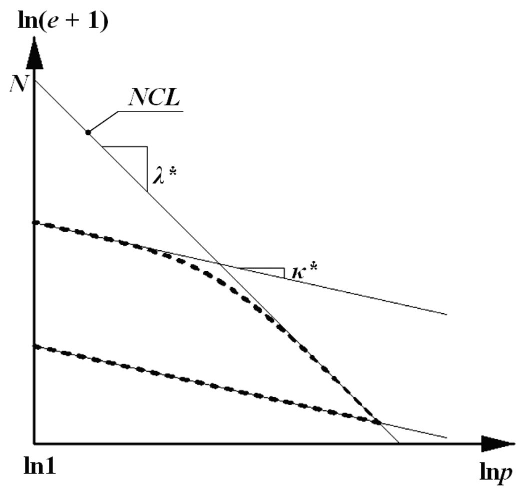


Fig. 2: Progression of an isotropic compression test

## Summary

A brief overview of material parameters of two hypoplastic material models was given together with their possible evaluation from a suitable combination of basic laboratory tests and simulations. It is our current effort to developed an automotive numerical tool to make the calibration process as simple as possible and thus to brink these models to the point of practical applications.

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