A CPT-based Effective Stress Analysis Procedure for Liquefaction Assessment

ID: 18

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Overview

Key steps of a procedure for 1D effective stress analysis of free-field soil columns are presented [1]. The proposed procedure can be fully automated in a programming environment, and it is directly equivalent (in the definition of liquefaction resistance and required input data) to the CPT-based simplified procedures for liquefaction assessment. These features allow advanced effective-stress analysis to be routinely applied in practice, in parallel with simplified procedures.
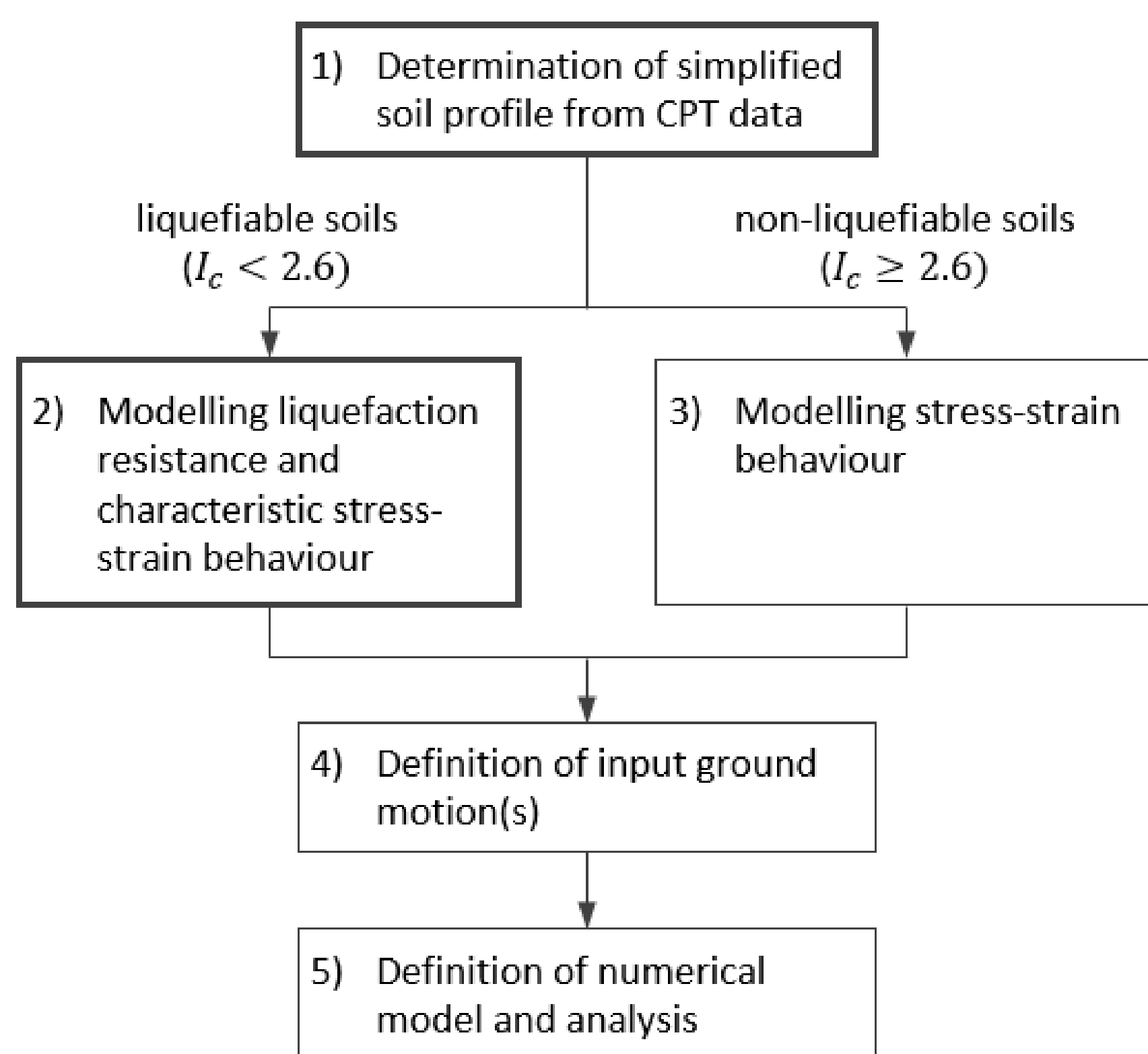

1) Determination of simplified soil profile from CPT data

liquefiable soils ($I_c < 2.6$) — non-liquefiable soils ($I_c \geq 2.6$)

2) Modelling liquefaction resistance and characteristic stress-strain behaviour

3) Modelling stress-strain behaviour

4) Definition of input ground motion(s)

5) Definition of numerical model and analysis

Figure 1. Key steps in the proposed CPT-based effective stress analysis procedure.

1. Determination of simplified soil profile
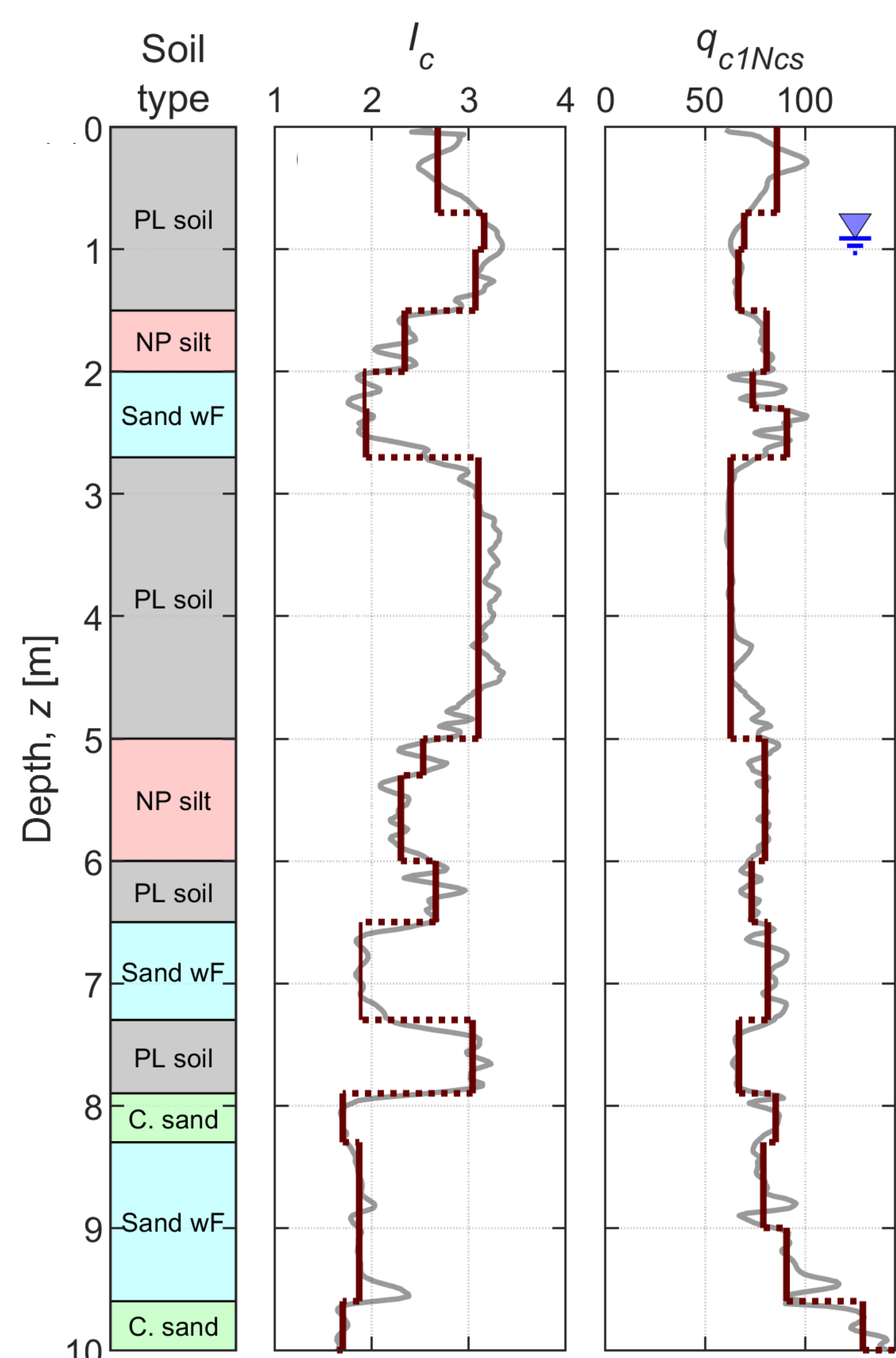

Figure 2. Determination of a simplified (discretized) soil profile from the nearly continuous CPT data.
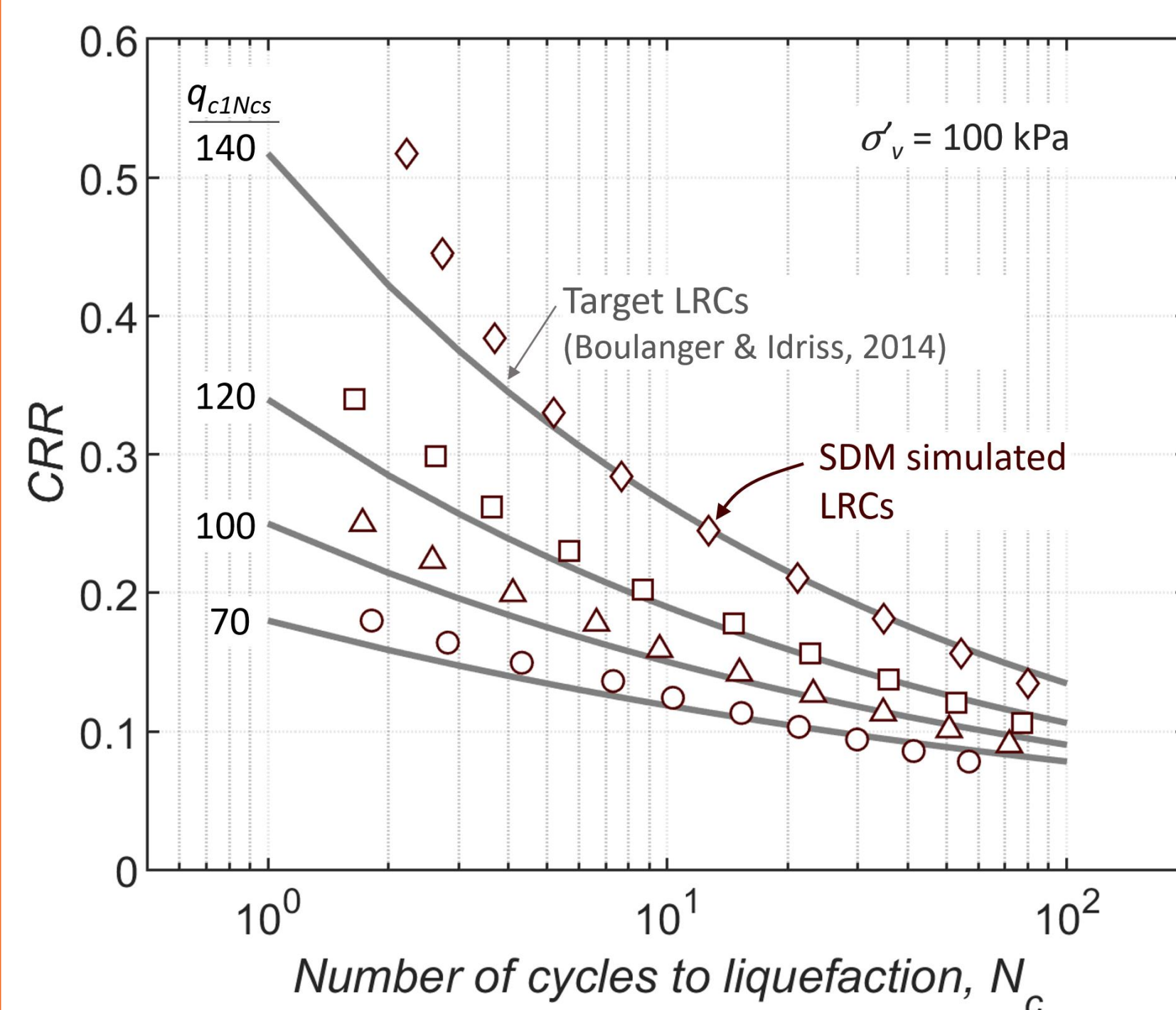
2. Modelling of liquefiable soils

Figure 3. Modelling of liquefiable soils focuses on the simulation of their (cyclic) liquefaction resistance. Target liquefaction resistance curves (solid lines), obtained based on simplified liquefaction triggering procedures, are used to calibrate a constitutive model (SDM) capable of reproducing the target resistance over all densities (q_{c1Ncs}) and confining stresses of interest, with a single set of values for model parameters.

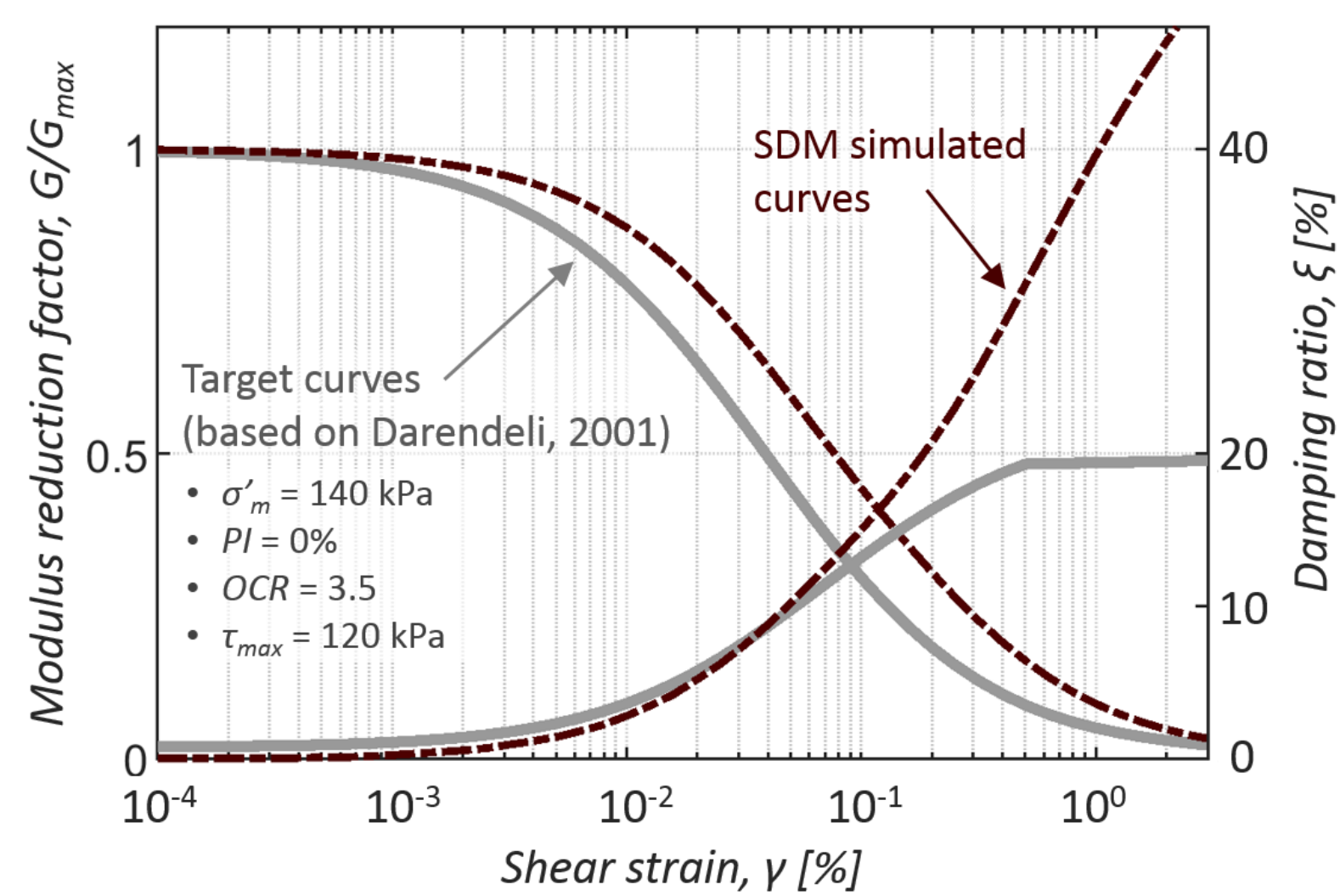## 3. Modelling of non-liquefiable soils

Figure 4. Modelling of non-liquefiable soils targets their cyclic stress-strain response, defined in terms of generic modulus reduction and damping ratio curves. The calibration of the constitutive model aims at providing a reasonably accurate and concurrent modelling of the target curves over the expected range of shear strains.

4. Definition of input motions

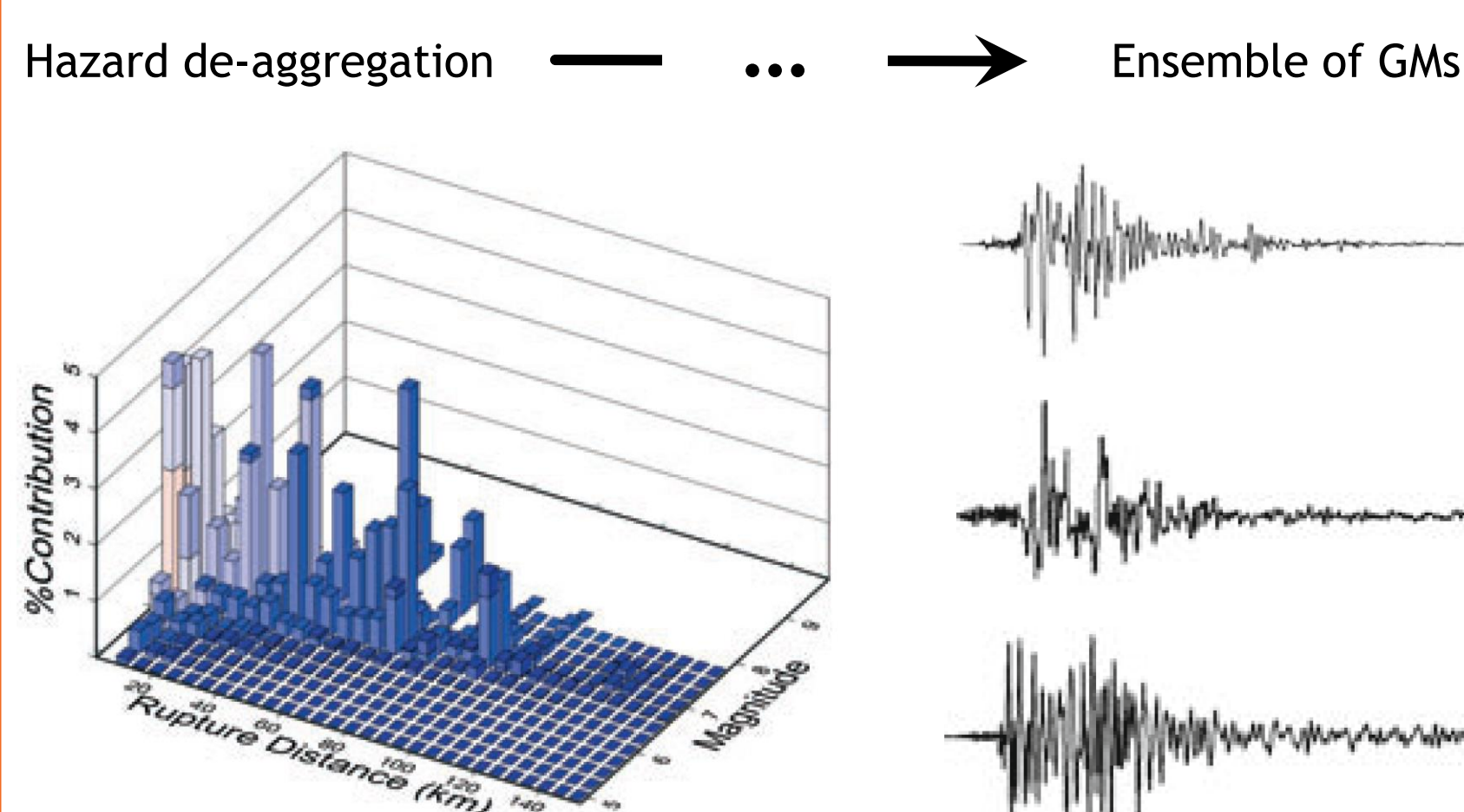Hazard de-aggregation → ... → Ensemble of GMs

Figure 5. An ensemble of input ground motions is selected for a specified level of hazard based on established ground motion selection procedures (e.g. [2]).

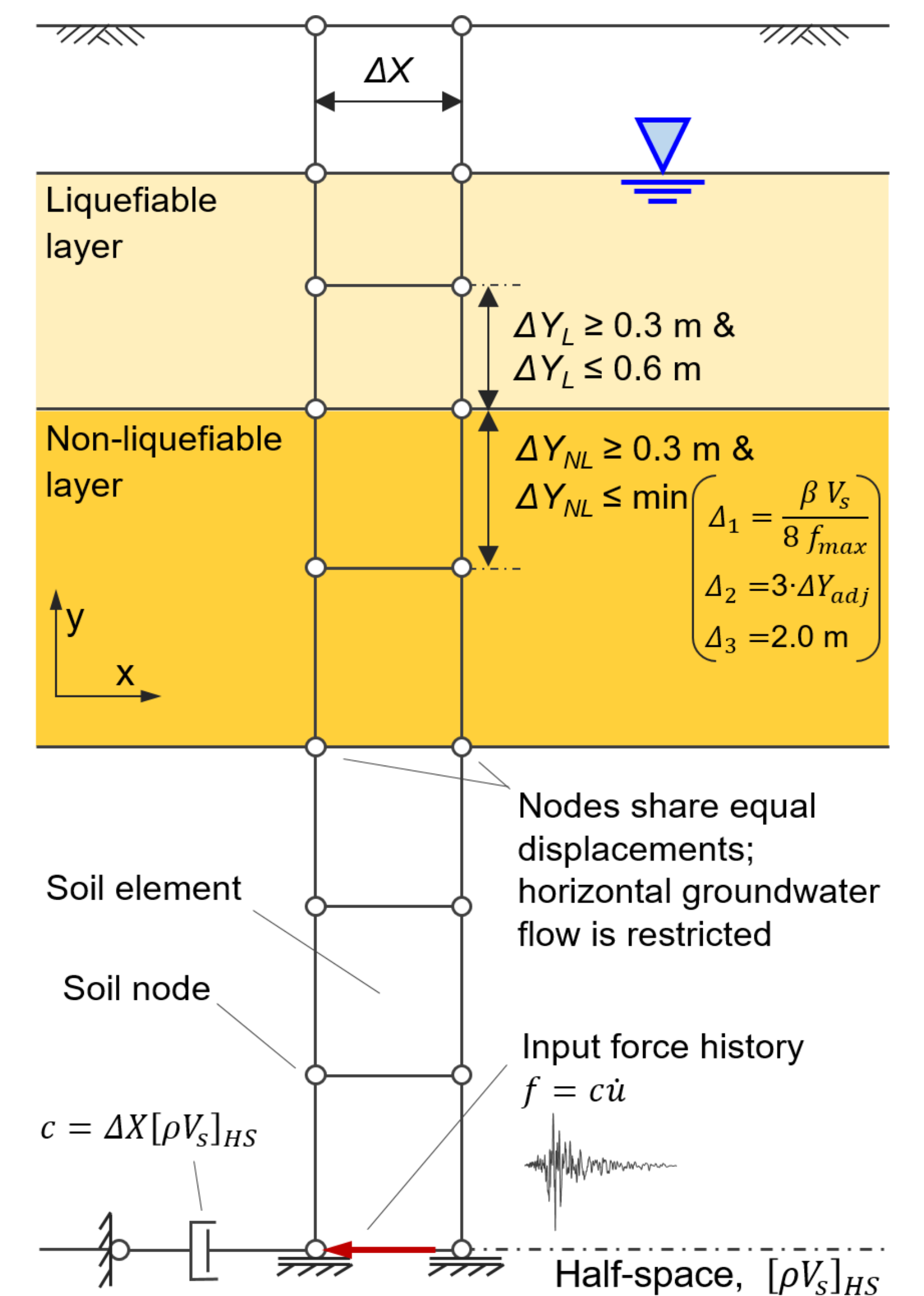## 5. Numerical model & analysis parameters

Figure 6. The final step entails the definition of element size, boundary conditions, initial stress state of the soil, and analysis parameters (e.g. computation time increment, integration scheme, numerical damping).
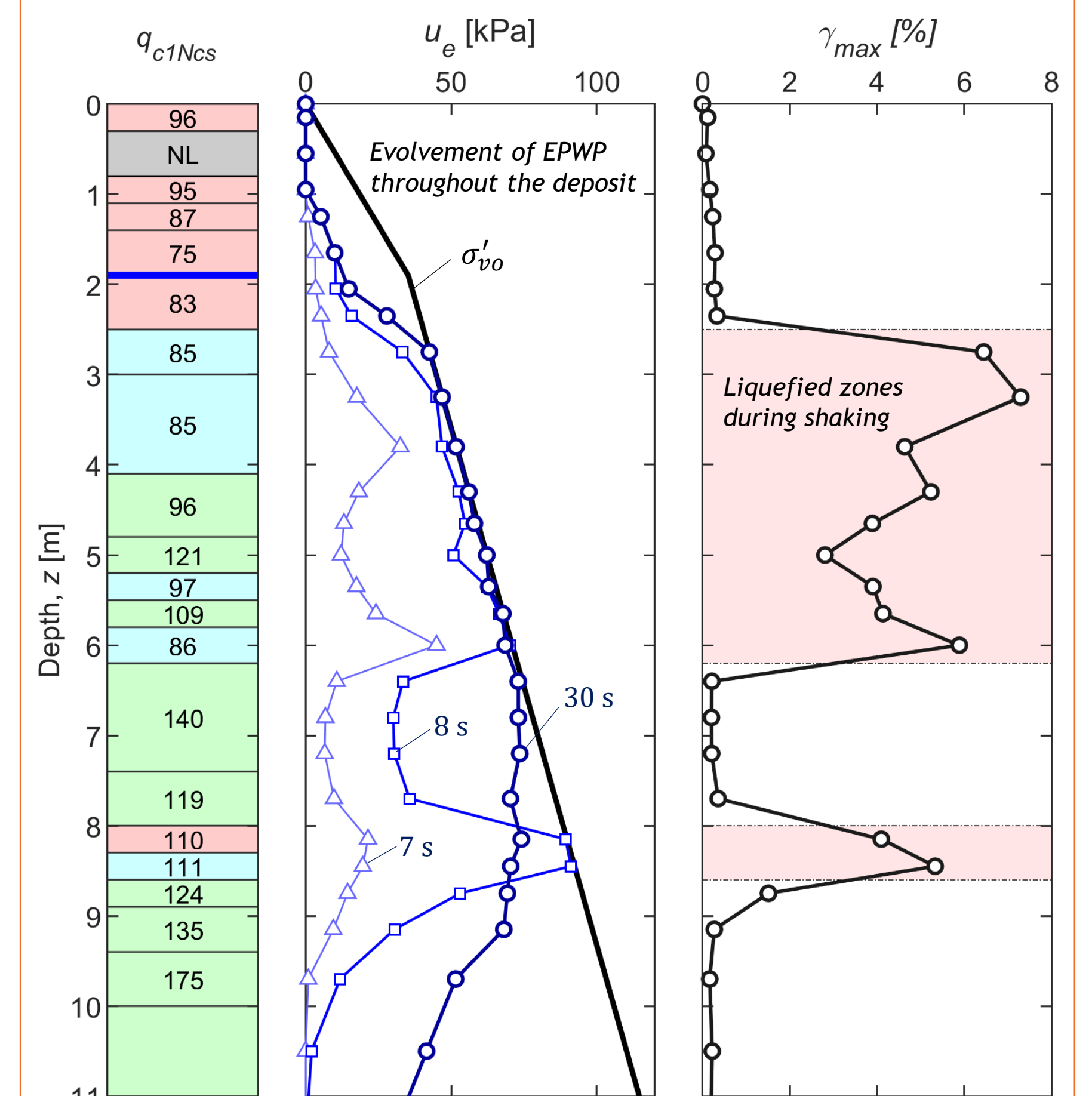
Application

Figure 7. The proposed effective stress analysis procedure can capture key aspects of the response of liquefiable soils and deposits, including pore water pressure development, triggering of soil liquefaction, and resulting deformations during the dynamic shaking and post-shaking dissipation of excess pore water pressures. Importantly, *system response* mechanisms involving cross-interaction amongst different soil layers in the dynamic response and through pore water pressure redistribution and water flow are rigorously simulated in the analysis.

Contact

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References

1. Ntritsos, N., and Cubrinovski, M. (2020). A CPT-based effective stress analysis procedure for liquefaction assessment. *Soil Dynamics & Earthq. Eng.,* 131.
2. Bradley, B. A. (2012). A ground motion selection algorithm based on the generalized conditional intensity measure approach. *Soil Dynamics & Earthq. Eng.,* 40, 48-61.