Chapter 33
Significance of Calibration Procedure Consistency

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Abstract Significance of calibration procedure consistency for geotechnical earthquake engineering is emphasized. The material parameters should be calibrated consistently for specimen preparation during the tests. Particularly, the laboratory-based parameters should not be mixed up with those for in-situ conditions.

Reliable prediction for nonlinear dynamic problems using an advanced constitutive model remains challenging either for real-site response analyses or centrifuge tests. Uncertainties come from many factors, such as calibration procedure consistency, which is stressed here for the numerical prediction. The material parameters should be calibrated consistently for specimen preparation during the tests. Particularly, the laboratory-based parameters should not be mixed up with those for in situ conditions.

There are many different behaviors for sands in the field and in the laboratory, essentially because the sand samples prepared in the laboratory usually have been disturbed or the fabric has been damaged or reconstituted, even though some material parameters, e.g., critical state parameters, are believed to be independent of sample preparation approaches. Yoshmi et al. (1989) showed that the cyclic resistance ratio (CRR) of frozen (assumed undisturbed) samples from the in situ deposit is about 200% of that of the samples from the new deposit sand fill, despite very small differences of sample densities. The material parameters calibrated from the disturbed laboratory samples should be adjusted for in situ deposit simulations.

The slope of cyclic stress ratio (CSR) versus number of cycles (N) is also observed steeper for undisturbed samples compared to that for disturbed samples (Yoshmi et al. 1989). The results of CSR versus N can be approximately fitted with a power law, CSR $= aN^{-b}$. The b-value for the naturally deposited sands in the field could be much higher than those obtained from the laboratory tests, depending on the sample preparation methods. Applying an underestimated b-value based on the laboratory tests for field case studies may lead to an increased calculated liquefaction

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hazard for magnitudes less than 7.5, but reduce calculated hazards for magnitudes greater than 7.5, if the CSR has been adjusted to the correct value at magnitude 7.5.

Even for the material parameters that define the model elasticity in constitutive models, calibrated parameters are quite different for in situ and laboratory samples. Cheng (2018) illustrated that the slope of elastic shear modulus (G_e) versus sand relative density (D_r) calibrated from field data is much steeper than that calibrated from empirical relations based on laboratory data, while the intercept of G_e versus D_r is much smaller for in situ sands compared to that for laboratory-based sands. This probably partially explains the higher b-values for in situ sands.

One key calibration procedure for some constitutive models is to match an accepted empirical curve of CRR versus a field measure, e.g., normalized blow-counts, or $(N_1)_{60}$, which is one of the most welcomed features by practice engineers, assuming that CRR for a magnitude 7.5 earthquake and effective overburden stress of 1 atm is approximately equal to the CRR during a DSS (direct simple shear) test with 15 uniform loading. However, this match implies that the calibrated material parameters should be used for field sands and not for laboratory sands because the empirical CRR versus $(N_1)_{60}$ curve is based on the field observations. These parameters are probably going to predict a steeper curve of CSR versus N, or other discrepancies, if used for laboratory-based sands. Note that the liquefaction triggering in the empirical curve of CRR versus $(N_1)_{60}$ is based on case histories with any of the ground observations, e.g., boils, failures, large settlement or lateral deformations, so the liquefaction triggering criteria based on this curve for a constitutive model should be consistently based on a certain excess pore pressure ratio or shear strain value, whichever is earlier satisfied, but not just one of them. Some constitutive models are using a single liquefaction criterion, e.g., 3% shear strain, for simplicity, which is more or less acceptable, but the users should be aware of the possible intrinsic discrepancy.

Another note is that because the target empirical relation was based on in situ data covering a wide range of sands, it represents only general sand behavior in a statistic sense, but may have considerable bias if evaluating some specific sands. For example, for a relative density of 80% Fraser River sand, to match the target CRR determined by the NCEER empirical curve of CRR versus $(N_1)_{60}$, the laboratory test showed liquefaction in approximately 11.5 cycles rather than 15 cycles (Beaty and Byrne 2011).

The CSR versus N curve is also quite sensitive to the test types, e.g., triaxial compression tests, DSS tests, or torsion shear tests, and sample preparation methods. The calibrated parameters should be used only for predictions with similar conditions, or careful adjustments should be incorporated.

In conclusion, to obtain satisfactory prediction between the numerical modeling and the centrifuge tests, the material parameter calibration procedure should be consistent such that it is based on laboratory samples considering disturbances, not directly or indirectly based on the in situ materials. In the other direction, some parameters that are calibrated from the laboratory tests should be used cautiously for case studies if not correctly adjusted.

References

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