Numerical Investigation of Shear Modulus in Cohesionless Soils under Cyclic Loading using ABAQUS

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Abstract

The dynamic behaviour of cohesionless soils governs the seismic performance of foundations and the long- term performance of unpaved sub-grades, but the relative contribution of confining pressure, gradation, particle size and depth to the shear-modulus reduction curve has typically been examined one factor at a time. This paper presents a combined systematic literature review and three-dimensional finite-element study that examines all four factors within a single numerical framework. A focused literature search across the ASCE, Scopus and ASTM databases was conducted using a PRISMA protocol; 41 studies were retained for synthesis after screening. Two ABAQUS models were then constructed using a Mohr-Coulomb constitutive law: a confining-pressure model in which a 1000 × 1000 × 980 mm soil cube is loaded through a rigid circular plate of radius 150 mm under monotonic loads of 250 N and 300 N, and a cyclic-loading model in which a translating wheel applies repeated load to a 375 × 300 × 500 mm sub-grade representative of an unpaved road. Four cohesionless soils were analysed: well-graded sand (SW), poorly-graded sand (SP), silty sand (SM) and low-plasticity silt (ML), with constitutive parameters taken from established laboratory studies. The simulated stress-strain curves, modulus-reduction (G/Gmax) curves, and load- displacement responses are compared with three independent benchmark datasets and reproduce the published trends within ±7 %. Among the four soils, well-graded sand consistently exhibits the highest stiffness, the slowest modulus degradation and the lowest cyclic settlement, while low-plasticity silt is the softest in every loading case. A supplementary analysis of a single horizontal geogrid layer in the unpaved- road model shows an increase in retained stiffness at $\gamma \approx 10^{-3}$ of 12 to 18 % relative to the unreinforced section. The results provide a calibrated, internally consistent numerical baseline for the preliminary dynamic design of cohesionless sub-grades and identify gradation and confining pressure as the principal design variables to control.

Keywords

Shear modulus degradation, damping ratio, cohesionless soils, confining pressure, finite-element analysis, ABAQUS, geogrid reinforcement.