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A strength degradation model of saturated soft clay and its application in caisson breakwater

Key words:

Saturated soft clay, Undrained strength, Degradation model, Damage dependency, Numerical simulation

Introduction

Breakwater

- typical offshore structure
- subjected to wave-induced cyclic loading

excessive

destruction

transferred to act on the soft clay grounds

Soft clay

- destruction of the soil fabric
- development of excess pore pressure

detrimental effect on the undrained strength of soft clay

A cyclic degradation model of soft clay

address the influence of the cyclic strength degradation of soft ground on the structural stability:

- practical yet robust
- with fewer parameters

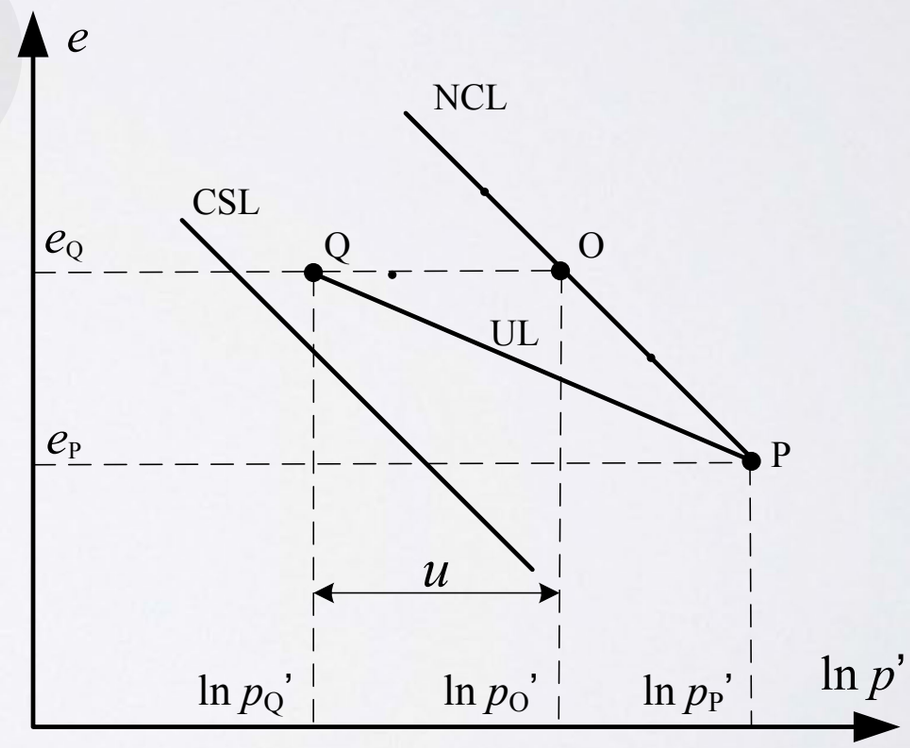
1. The degree of damage and remolding of soft clay is quantified by introducing a damage variable ω, which is related to the accumulative plastic deviatoric strain ε^{p} using the following expression

$$\omega = 1 - e^{-\beta \varepsilon^{p}}$$

A cyclic degradation model of soft clay

2. Through the correlation between the maximum pore pressure and the undrained strength of soft clay, a cyclic damage-dependent degradation model that employs the post-cyclic undrained strength degradation coefficient δ can be obtained, in terms of the cyclic stress ratio *CSR* and cycle number *N*, as follows

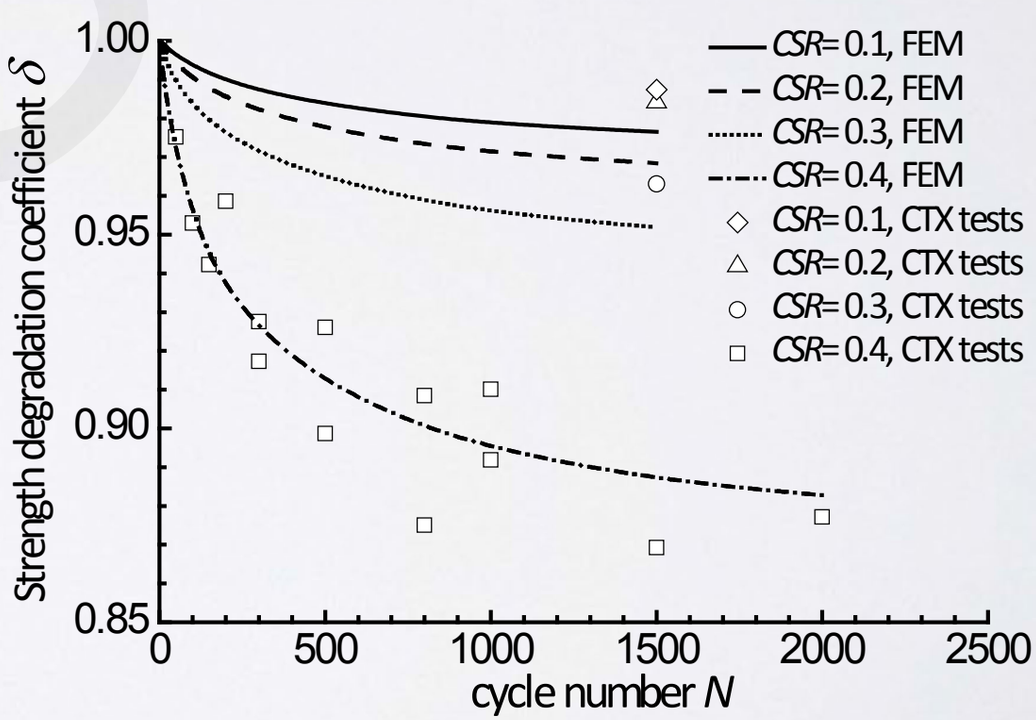
$$\delta = \frac{(c_u)_{cy}}{(c_u)_{nc}} = F(CSR, N)$$



NCL, UL and CSL in e-lnp' plane

A cyclic degradation model of soft clay

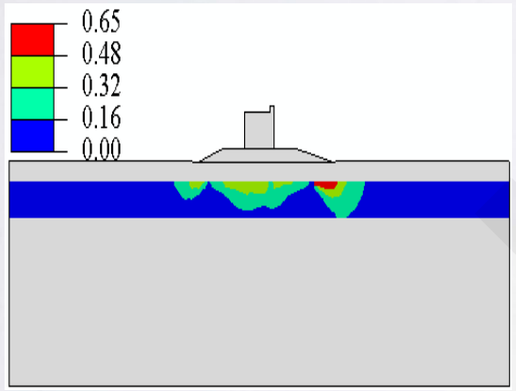
3. Based on Tresca yield criterion, the cyclic damage-dependent degradation model of undrained strength of soft clay is numerically implemented in the user subroutine of ABAQUS. The performance of this model is verified by the comparison between the numerical results (FEM) and experiment data (CTX test)



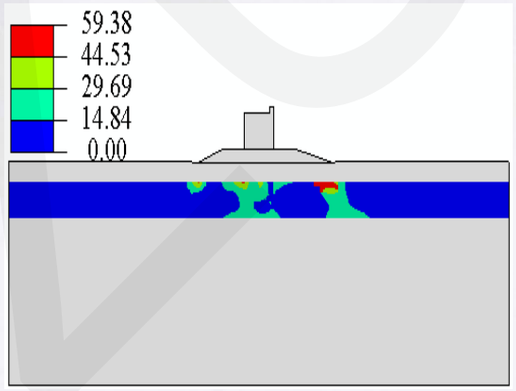
Numerical predictions of post-cyclic strength degradation coefficient δ

Application in a case study of caisson breakwater

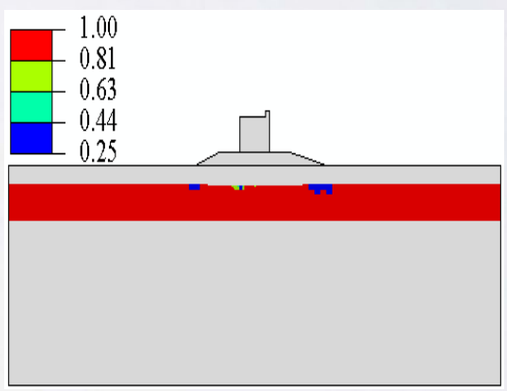
4. The cyclic damage-dependent degradation model is applied to the numerical simulation of a caisson breakwater resting on partially sand-filled soft clay seabeds. The cyclic stress distribution, the pore pressure development and the strength degradation of the soft foundation are presented



Distribution of cyclic stress ratio *CSR* after 500 cycles of wave-induced loading



Distribution of maximum pore pressure *u* after 500 cycles of wave-induced loading



Distribution of strength degradation coefficient δ after 500 cycles of wave-induced loading

Main conclusions

A damage parameter that quantifies the degree of damage and remolding of soft clay is related to the accumulative plastic deviatoric strain firstly. The correlation is then established between the maximum pore pressure and the undrained strength of soft clay to employ the post-cyclic undrained strength degradation coefficient in terms of the cyclic stress ratio and the number of cycles. Model parameters are calibrated by a series of static and cyclic triaxial tests of muddy-silty clay near Yantai port. Based on the Tresca yield criterion, the damage-dependent strength degradation model of undrained strength of soft clay is numerically implemented in the user subroutine of ABAQUS

- The undrained strength degradation coefficients of soft clay show a tendency that falls at the beginning and finally reach the stable status with the increase of *N*, and decrease with the increase of *CSR*
- Finite element predictions of the maximum excess pore pressures and the undrained strength degradation coefficients generally match well with the test data, which confirms the accuracy of damage-dependent strength degradation model
- Responses of soft layer are mainly distributed at the toes and directly in the middle of the rubble bed. Effect of the number of cycles is apparent in the maximum excess pore pressure as opposed to the cyclic stress and undrained strength degradation