Calculation of pile group reduction factors and foundation springs for a cable-stayed bridge

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Summary

The mathematical capture of the load-displacement behaviour of piles located in a pile group is very complex and it depends on many influencing factors like pile type and diameter, size of the pile group, center-to-centre distance, pile length and subsoil conditions.

For bored piles the load-displacement behaviour and the bearing capacity is influenced by group effects. Pile group settlements are larger than single pile settlements (at least for small deformations), whereby the axial bearing capacity of the pile group is reduced compared to the bearing capacity of all single piles.

During the early foundation design for a cable-stayed bridge, group reduction factors have been determined acc. to the German recommendations (Recommendations on Piling, EA-Pfaehle). In the particular case - caused by small center-to-centre distance and large pile length - massive reduction factors have been derived from the EA-Pfaehle which have directly affected the bearing capacity and would have lead to larger pile quantities.

By means of TOCHNOG project specific group reduction factor have been calculated using advanced hypoplastic constitutive equations for sand and clay acc. to von Wolffersdorff and Mašín. Hypoplastic parameters and properties of the pile-soil interface have been calibrated by laboratory test results and data obtained from a static pile load test. Specific group reduction factors for the cable-stayed bridge are much more favourable compared to the conventional ones obtained from EA-Pfaehle. Calculated values are in very good agreement to values given in the „Design Memorandum, Bearing resistance of shaft groups, Bridge and Structures Office, Washington State, Department of Transportation, 2010“.

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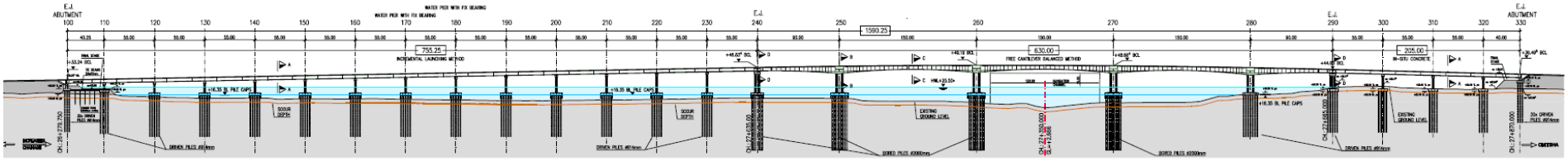
Project „Cable-Stayed Bridge“

Description

- Infrastructure project comprising a main bridge and approaching roads.
- Main bridge: L = 1,590 m, 22 axes, three axes founded on bored piles, remaining axes are founded on closed ended driven steel piles.
- Bored piles will be constructed from a jack-up barge using temporary steel casing.
- Construction of bridge by incremental launching, balanced cantilver construction and classical shoring system.

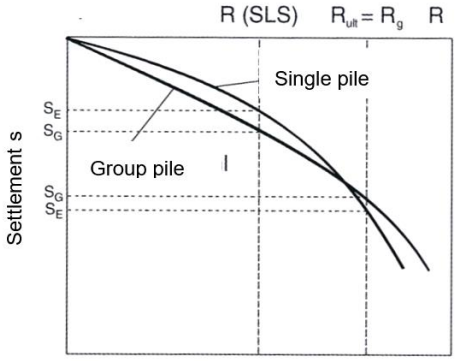


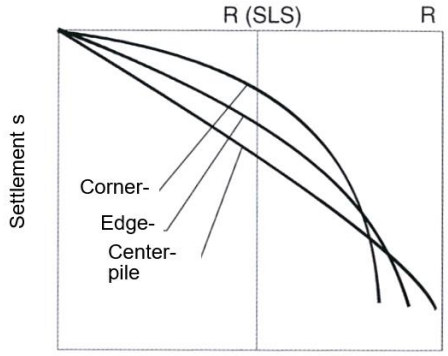
Longitudinal section of the main bridge

Project „Cable-Stayed Bridge“

Task

- Calculation of specific group reduction factors of foundation axis founded on bored piles. Method presented in German EA-Piles is based on simplified numerical calculations and leads to very high group reduction factors. Current pile diameter and embedded length are outside the validity limits of the method proposed in EA-Piles.
- Validation of numerical models by back-calculation of a pile test (Osterberg-method).
- Realistic simulation of mechanical soil behaviour by means of hypoplastic constitutive laws.



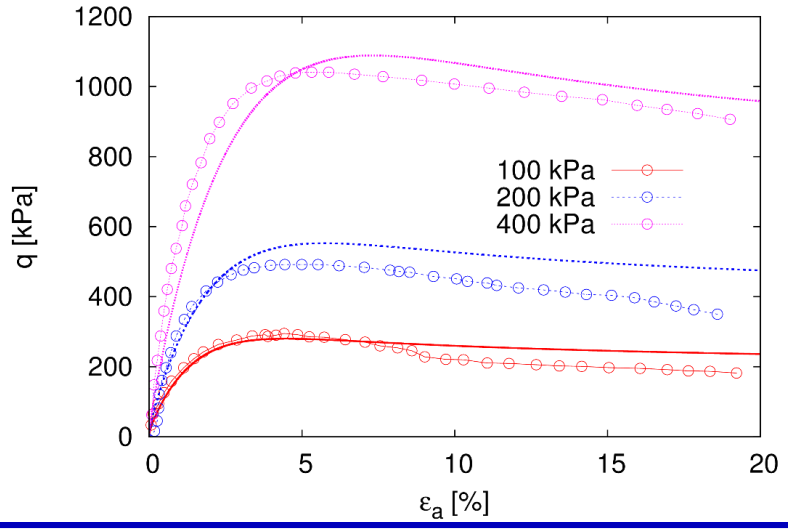


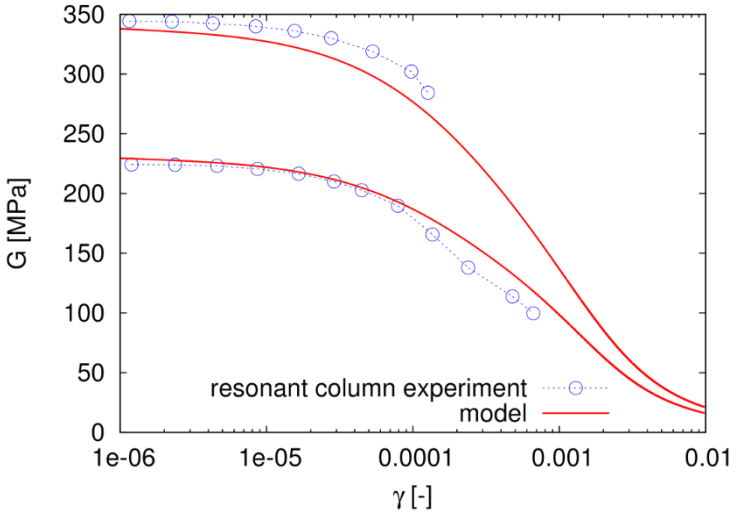
Typical load-displacement behaviour of single piles and group piles (Grundbautaschenbuch, Teil 3, 7. Auflage)

Project „Cable-Stayed Bridge“

Subsoil conditions and calibration of parameters

- River sediments with complex soil layer structure. Close to river bed loose sand. Beneath alternating sequences of medium dense and dense sand with intermediate layers of clay.
- Calibration of individual parameters using laborartory test results and local experience.

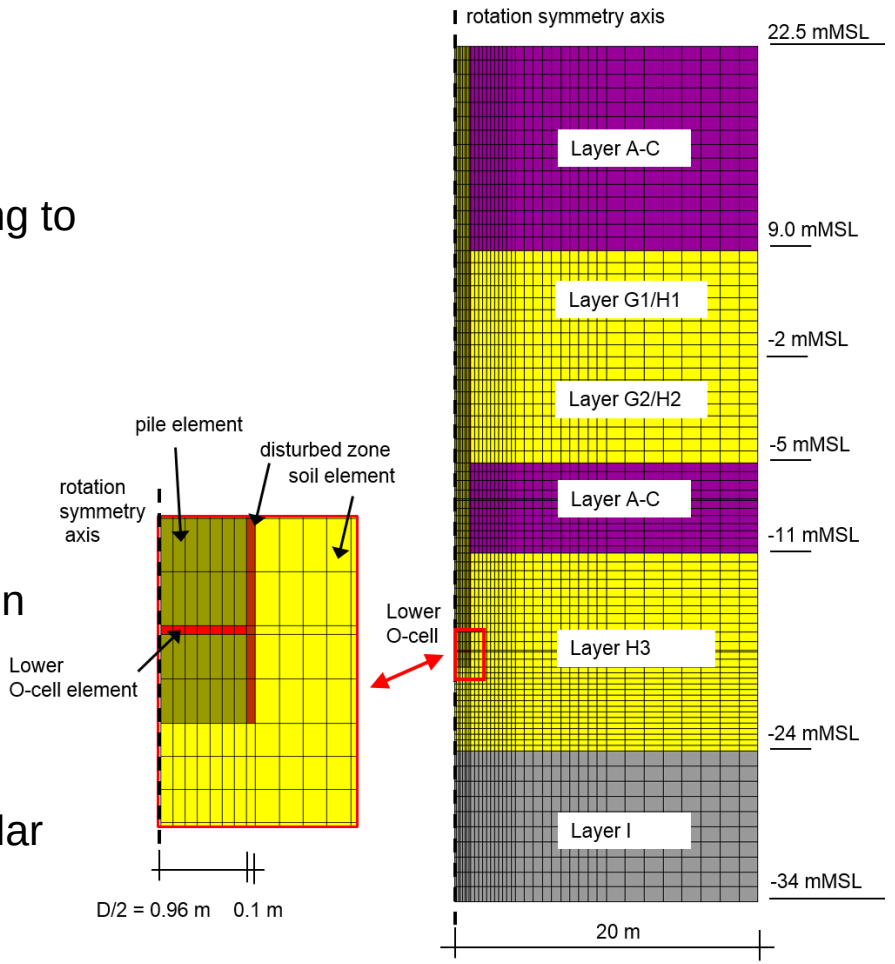




Project „Cable-Stayed Bridge“

Numerical simulation of pile test

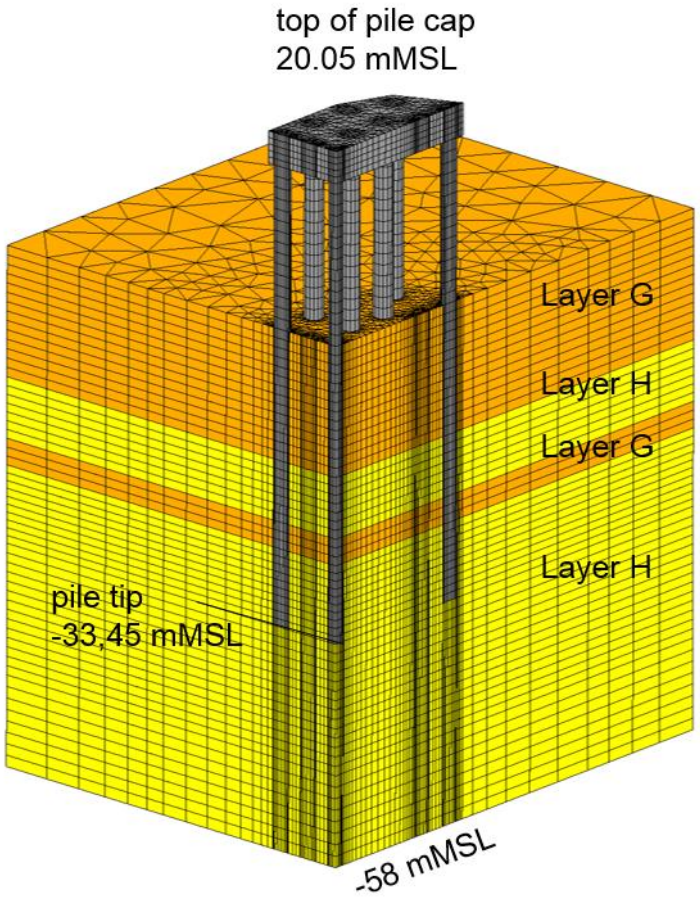
- Axis-symmetric FEM model.
- Gradual loading of the Osterberg-cells according to the actual testing procedure.
- Disturbed zone around the pile and additionally interface elements between pile and soil.
- Calibration of pile-soil interaction properties by means of the pile test measurement at the strain gauges and the load cells.
- Clay-hypoplasticity (Mašín) and basic hypoplasticity (von Wolffersorff) incl. intergranular strain concept.



Project „Cable-Stayed Bridge“

Numerical simulation of bridge axes founded on bored piles

- 3D-FEM model (one quarter of the structure).
- Clay-hypoplasticity (Mašín) and basic hypoplasticity (von Wolffersorff) incl. intergranular strain concept.
- Loading up to failure of single pile model and pile group model.
- Comparison of load-displacement behaviour and derivation of group reduction factors for center, edge and corner piles.



Project „Cable-Stayed Bridge“

Horizontal and torsional loading

- 3D-FEM model including 25 bored piles.
- Clay-hypoplasticity (Mašín) and basic hypoplasticity (von Wolffersorff) incl. intergranular strain concept
- Loading up to the charactersitic loading provided by the bridge designer.
- Derivation of horizontal and torsional springs to be used in the structural calculation of the superstructure of the main bridge.