Numerical study on the behaviour of structures in the near-field of sheet-pile driving work

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H. Meißner
University of Kaiserslautern
Institute for Soil Mechanics and Foundation Engineering
Germany

A. Becker
University of Kaiserslautern
Institute for Soil Mechanics and Foundation Engineering
Germany

ABSTRACT

The driving of sheet-pile walls into subsurface by driving work and/or vibration is, due to its economy, a frequently used method for temporary building pit supporting systems. Because of numerous improvements on the driving mechanism, the manufacturers have almost eliminated many limiting characteristics, e.g. the well known vibration-peaks caused by starting and stopping of driving due to variable number of revolutions. But there still exists the risk that especially in the near-field of structures, too large oscillation and particularly unequal settlements could arise. This paper investigates in a pilot study the above mentioned problems using numerical studies.

For the numerical computations, the finite element method (FEM) is used to calculate the wave propagation in subsurface. By using this method both physical and geometrical non-linearity can be taken into account. The calculations were done in time domain. The formulation of FEM requires among other things determination and keeping of static or kinematic boundary conditions of the calculated structure. Problems in the field of geotechnical engineering are as a rule not defined on closed areas. They are rather defined on infinite or semi-infinite areas. As a special form of elements, we used in our calculations infinite elements. The displacement shape functions for two infinite element types are defined on infinite or semi-infinite intervals. These elements were placed on the outer boundary of the FE-mesh and simulate in this way the behaviour of half-space.

The numerical studies were carried out using the example of (sheet-) pile driving processes. Among other things, the epicentral distance between vibration-source and structure, the “actual” working depth of piling in subsurface and the way energy transfers from pile to soil are discussed. The observed points lay on subsoil surface (free field response), on loaded and embedded foundations (soil-structure interaction) as well as in half-space at different depths (buried pipes) below the plane ground. The process of pile driving is simulated by the dynamic response reactions in subsoil in differentiating between shaft and base resistance. The influence of different distributions of shaft resistance along the sheet pile is investigated. Also the ratio of shaft to base resistance is discussed. At first the total loading is absorbed by shaft resistance. Further steps bring a reduction of this part with simultaneous increase in base resistance. Finally the total load is transferred only through base resistance. This simulates the practical stage that loosening-up-drillings were done before piling work. Another two parameters to be investigated are the influence of driving frequency and the influence of loaded foundations.

By these first parameter studies the effect of piling depth $t$, the depth of the observation point $t_0$ (foundation on surface or buried pipe-line), ratio of base-resistance $R_B$ to shaft-resistance $R_S$ during piling, exciting frequency $\Omega$ and foundation loading $p_0$ are demonstrated. Based on the numerical results presented, it can be stated that especially for points below surface the depth of piling source significantly affect the displacement-behaviour of a structure. This is in some contrast to well known attenuation laws where we find the epicentral distance between source and observation point only. Furthermore the results show that pre-drilling can reduce displacements of buried structures considerably.

The investigations will be continued. One main topic is considering the elasto-plastic material behaviour of soil. Particularly in the near and under foundations changes in damping behaviour and consequently in vibration behaviour is expected.

Additional field measurements are necessary to come to all-out formulations. Results of first measurements are in good agreement with the numerically obtained values.