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Iterative Design Approach for Soldier Pile Walls Based on Nonlinear Horizontal Subgrade Modulus

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Extended Abstract

The mobilization of earth resistance for soldier pile walls is generally characterized by a nonlinear relationship between horizontal displacements and activated earth pressures. The relationship between stresses and displacements is generally defined as the subgrade reaction modulus [1] and is useful for the appropriate design of embedded part of retaining structures.

This behaviour was investigated by many researchers e.g. in the meaning of earth pressure theory [2], plane retaining structures [3] and pile design [4]. For soldier pile walls a few more effects such as 3D effects [5] are interacting with the mobilization of earth resistance and the subgrade reaction in front of embedded part of the piles.

For a detailed investigation of the subgrade reaction a 3D numerical model was created and validated on obtained field test measurements [6]. The soil model was formulated for typical sand with an elastoplastic constitutive law that was calibrated on the results of laboratory tests. Parametric studies were executed to determine the nonlinear relationship between mobilization of earth pressure stresses and pile movement.

The results of numerical parametric studies pointed out the strongly nonlinear subgrade reaction defined by the mobilized earth pressure stresses divided by horizontal pile displacements. The maximum earth resistance at failure which can be calculated by earth pressure theory [7] with a shell-shaped failure mechanism was not completely mobilized. The mobilizing degree of 3D earth pressure stresses varied strongly with depth and is mainly affected by the kind of pile movement [8].

Based on these results a new approximation formula for the horizontal subgrade reaction modulus of sand with medium density was developed [9]. The formula relates to the most significant parameters such as horizontal displacements, pile diameter and embedding depth coordinate. It describes a nonlinear decreasing of subgrade reaction with increasing displacements.

Because of dependency on displacements the implementation of this subgrade reaction modulus for design of soldier pile walls needs an iterative solution. The mechanical design algorithm can be formulated as a beam, loaded by active earth pressure and possibly external forces with nonlinear bedding of pile below excavation level. Even for backturning part of the pile in case of lateral restrained conditions this nonlinear subgrade reaction can be considered.

For the first iteration step an estimated initial value of subgrade reaction modulus was recommended to simplify the iteration process for practical application.

This new approach with nonlinear subgrade reaction enables an improved design and a reliable prediction of displacements for common soldier pile walls in sand.

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