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Internal Stability Analyses of Geosynthetic Reinforced Retaining Walls

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Abstract

Monitoring of realized structures shows significant difference between assumed and measured values of the wall displacements and axial forces in geosynthetic reinforcements. This difference is caused by the conservative approach of conventional analytical methods and by the high values of the safety factors of geosynthetic reinforcements that undervalue their strength parameters. Therefore, deformation properties of the reinforcements and their interaction with soil environment become more important because strength parameters are not fully reached. Analysis of quantities, such as wall face displacements, axial forces and strains in the reinforcements using analytical methods and numerical modelling, is presented in this paper.

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Keywords: FEM; geosynthetics; internal stability; retaining wall; soil-reinforcement interaction;

1. Introduction

Use of geosynthetic materials for reinforcing purposes allows us to replace the massive concrete retaining walls with reinforced earth structures that have advantages in realisation of the structure on soft soils. Reinforced earth structures also withstand the differential settlement very well.

Design of these structures includes verification of global and internal stability. Global stability check is based on the gravity walls theory, with reinforced volume of the soil considered as a rigid block. Several methods of internal stability verification, which were calibrated by the monitoring of real structures, were developed. Beside the static equilibrium, these methods consider the influence of the reinforcement stiffness on overall structure stiffness, axial forces and strains of the reinforcement.

Despite the improvements of these methods, outputs of the monitoring mention the differences between assumed and measured strains and axial forces. Divergences are caused by the limitations of the analytical design methods, which verify only static equilibrium without considering deformations.

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Nomenclature

AASHTO	The American Association of State Highway and Transportation Officials
FHWA	Federal Highway Administration
H_e	effective height of the retaining structure (m)
J	axial tensile stiffness of the geosynthetic reinforcement (kN/m)
T_i	axial force in the i-th layer of the reinforcement (kN)
δ	inclination of the resultant of earth pressure (°)

Numerical methods are suitable for complex verification of the structure stability in terms of both limit states and for the design of the key elements of the structure.

Closer look at the recent design approaches indicates that despite the accomplishment of the first limit state, second limit state is usually not an object of verification and has a small space in the standards. Second limit state is critical for the reinforcement design because of limited strain of the geosynthetic reinforcing elements. Axial force, acting at considering strain, does not reach the strength of the strip.

Presented series of verification of the analytical methods using numerical modelling represents the contribution to the safer and more economical design of retaining earth structures reinforced with the geosynthetics.

2. Methods of internal stability verification

Internal stability check of the structure involves the verification of all potential failure mechanisms including stability of the structure elements, sliding of the upper layer on the inspected surface or internal stability of potential wedges of reinforced block of soil. For the purpose of these analyses, several methods were developed. Many of them were verified by the in-situ monitoring or physical modelling in large scale and they are included in national design standards [4].

2.1. Tie-back wedge method

Tie-back wedge method was developed for structures reinforced with the geosynthetic or welded meshes [2, 4]. The face of the wall is considered flexible, thus horizontal stresses do not have any influence on the vertical stresses in the reinforced soil block. Flexible facing allows the active earth pressure to rise, when resultant of the earth pressure acts only horizontally, $\delta = \delta_a = 0°$. Vertical load, including self-weight of the fill, surcharge load and overturning moments, acts on the structure as a horizontal force. Vertical stress is calculated according to the Meyerhof's theory of stress distribution due to the eccentric load. Vertical spacing of the reinforcing elements is then considered in the calculation of the axial forces. Additional verification of the potential wedges behind the facing is required. Forces acting on each potential wedge are investigated.

2.2. Coherent gravity method

Coherent gravity method was originally developed for determining the forces in the steel reinforcing strips [2, 5]. Coefficient of earth pressure for both limit states is set for earth pressure in rest at the top of the structure and linearly decreases to the value of the active earth pressure 6 m below. Distribution of the earth pressure coefficient was based on the monitoring outputs. These structures were reinforced with the inextensible reinforcement (e.g. steel stripes), when strains do not reach the values allowing the active earth pressure to develop.

2.3. Structure stiffness method

Structure stiffness method is the result of FHWA research. It is based on the series of physical models in several scales and the monitoring of real structures. Method is similar to the tie-back wedge method but coefficient of earth pressure is determined as a function of depth below the top of the structure and global stiffness of the structure.