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Static Analysis of Soil-Nailed Structures Using Three-Dimensional Finite Difference Method (FDM)

Alimohammad Sheikhbahaei[1], S. Hamid Hashem-Al-Hosseini[2], Amir M. Halabian[3]

1. M. Sc student, Dept. of Civil Engineering, Isfahan University of Technology, Isfahan, Iran
2. Associate Professor, Dept. of Mining Engineering, Isfahan University of Technology, Isfahan, Iran
3.Assistant Professor, Dept. of Civil Engineering, Isfahan University of Technology, Isfahan, Iran

ali3726@cv.iut.ac.ir

Abstract

Soil nailing is an efficient new technique to stabilize soil structures. This method has been increasingly used to improve stability of slopes. Soil nailing constructions commonly involve three basic process: excavation, nail installation and face stabilization. The nails are inserted into ground by either drilling or grouting and are usually arranged in both horizontal and vertical directions.

In the present research a three dimensional finite difference model has been developed in order to perform a static analysis of soil-nailed structure. The soil behavior was predicted by an Elastic-Perfectly-Plastic model, associated to Mohr-Coulomb failure criterion. The numerical model simulates the soil medium, nail inclusions, shotcrete facing using different zone and structural elements. Different slope inclinations and nails lengths are considered to investigate the influence of these factors on the behavior of structure.

Keywords: Soil-Nailed wall, Finite difference method, Nails inclination, Nails length, Nails length pattern.

1. INTRODUCTION

Although there are several procedures to reinforce soil slopes and embankments, during recent decades, soil nailing as a new technology to reinforce soil structures has been significantly rising. This method is commonly used to stabilize soil in excavations and improve the stability of slopes. The method of construction usually involves three basic aspects; excavation, nailing installation and face stabilization. The reinforcements used to stabilize structures are bars with relatively small cross-sections and are inserted into the ground by either drilling and grouting or driving.

Despite of many similarities to common reinforced soil walls and gravity walls, soil nailed wall present many differences. One of the main discrepancies between reinforced earth walls and soil-nailed walls is related to the stress distribution during construction process. While common reinforcement methods for earth walls involve stress increases during construction sequences, soil nailing causes stress relief; Due to the features of the reinforcement in soil nailed walls, the development of the strengthening mechanism in the soil nailed wall may be very different to that operating in the common soil-strip reinforced earth walls or geosynthetic reinforced walls [1]. The strengthening and failure mechanisms may be related to various factors such as the properties of nails, the nail arrangement in wall surface during construction, construction methods, etc, So the overall failure mode may be altered from a one-block failure mechanism in rotation to translative two-block failure mechanism when the positions of service loading are moved [2]. In spite of general failure mechanism of soil structure, soil nailed walls present more potential failure modes which may include breakage of the nails, bending overstress with plastic hinges in nails, nail-soil pullout failure, nail tensile failure, bar-grout pullout failure, facing flexure failure, etc. However there are many kind of approaches to design soil nailed walls but there are mostly based on limit equilibrium methods available for the analysis and design of reinforced earth walls. Even though these methods can present information concerning both overall and internal stability of the soil nailed wall, they fail to give any information about deformations of structure; For instance ground movements in deep excavations have been observed in the field and they may bear some consequences to safety of other building near the area [3]. Hence traditional method of design cannot predict general behavior of structure and also its deflections; then it's much more crucial to monitor behavior of structure and observe its deflections. The numerical methods therefore have been employed to obtain better predictions about behavior of soil nailed wall including deformations.