An Study on the Effects of Nail Arrangement on the Stability and Performance of Soil Nailed Walls

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Extended Abstract

(Paper pages 201-224)

Introduction

Soil nails are traditionally designed with uniform length and equal spacing to stabilize slopes which do not meet safety requirements. However, nails with uniform layout in a slope may not be the optimal design if the construction cost is taken into account. The optimal layouts lead to a minimum usage of nails and satisfies the allowable factor of safety and wall deformation.

In this study a decreasing trend of nails length along the wall height was considered to investigate the stability and the performance of the wall in different nail patterns. Then nail density was introduced as an important factor on the overall stability and deformation of the wall. It can be beneficial in the preliminary estimation of the required nail length at the beginning of a project.

Findings of this study are helpful for effective design of soil–nailed slopes.

Materials and Methods

The finite element analyses were conducted to investigate the effects of nails pattern on the overall stability and deformation of soil–nailed walls. Slope/W software was used to obtain the Factor of safety and Plaxis 2D was used to calculate the deformation of the soil nail walls. Soil hardening model was used to simulate the behavior of soil. In this study, various walls with different specifications were modeled and analyzed. As an example, a 10 m deep soil nail wall with C=10 kN/m^2, ?=25 deg, E_{oed}=20000 kN/m^2 is discussed here to monitor the trends (C represents cohesion, ? is the angle of friction and E_{oed} is the modulus of elasticity of the soil).

As it is shown in Figure 1, by considering the decreasing trend of nail length along the wall height, an ordered arrangement (pattern) is introduced by presenting “L” as the base nail length and “□” as the inclination of stabilized zone border then, the effect of nail arrangement on the safety factor and deformation of nailed wall is investigated. The nails were installed with an angle of 15 degrees relative to the horizon. According to FHWA a minimum value of 1.35 is considered for the factor of safety. Circular failure surfaces are assumed and the tensile and pullout resistance of the nails crossing the failure surfaces are considered as the governing stabilizing forces.

Results and discussion

In this study, soil nails pattern effects on the performance and the stability of the soil nail wall are investigated. In Figure 2 variation of safety factors caused by different soil nails arrangements is illustrated. Generally three separated trends are observed in each curve. It demonstrates that at lower values of □ with small bond length, the factor of safety is constant. As □ increases the bond length behind the slip surface becomes longer and the safety factor is increases gradually. Eventually it reaches a point that the nails are long enough that increasing the nails length is not influential in the stability of the wall. Hence, nails at different elevations of a slope have different contribution to the overall stability of soil–nailed slopes.

Wall deformations need to be controlled by the allowable deformation level in designing the soil nailed wall especially when buildings or other underground facilities exist near the excavation. One of the most important parameters on soil nailed wall deformations is the arrangement of nail lengths.

Figure 3 shows the effect of nail arrangements on the wall horizontal deflection. In general, as □□and L increase, horizontal deflection of the wall decreases. The rate of this reduction is higher in lower base length. As it is

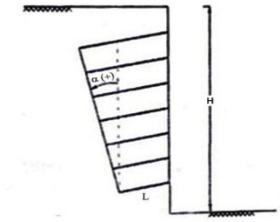

Figure 1. The assumed distribution of nails along wall height

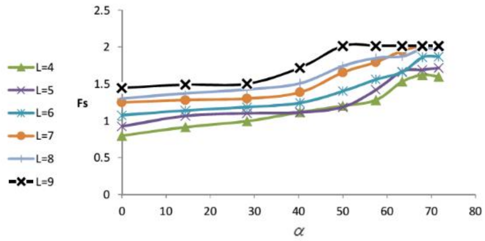

Figure 2. Variation of safety factors in various layouts of the nails

illustrated in Figure 3, by increasing the length of the nails, the deflection is decreased till no significant reduction is observed.

As it is shown the arrangement and the layout of the nails are influential on the stability and deformation of the soil nailed walls. However, it is important to identify an optimal layout in a way that with optimum nail length, allowable stability is reached and the wall deformation stay in an allowable range.

Nail density is defined as the ratio of the required nail length per the unit area of the wall surface and defined as below:

$$D_n = \frac{\sum_{i=1}^{n} L_i}{A} \quad (1)$$

where L_i is nail length of each row and A is the stabilization area. Hence, estimating the nail density can be beneficial for the engineers to have a preliminary estimation of the costs of the project at beginning of the project.

Figure 4 indicates that the nail density governs the wall deformation. As it is seen, for different layouts with the same nail density, the resulted deflections are so close. Hence, it can be concluded that nail density is a key factor in determination of the wall deflection. It is also illustrated that, as the nail density increases, the reduction rate of the deflection is decreased. Effective nail density is defined as a threshold point that increasing the nail density is no longer effective on deformations.

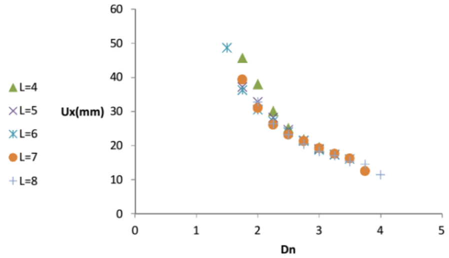

Figure 3. Variation of horizontal deflection in various layouts of the nails

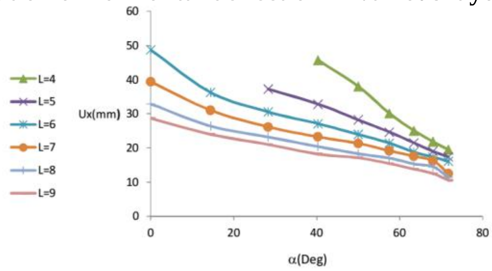

Figure 4. Effect of nail density on the wall deformation

As it is demonstrated in Figure 5, different layouts with a similar nail density have close values of safety factors. In walls with higher nail density increasing the nail length is fruitless and at lower nail density nails are not effective. ~~So~~ Optimum design~~ation~~ should be somewhere at the middle part with an allowable factor of safety. In the middle part the variation of factors of safety is more tangible.

Horizontal deflection profile

During the construction process the wall tends to move outward. Figure 6 illustrates the effect of soil nails arrangements on the deformation of a 10 m deep wall for a constant base length. As it is shown, by increasing □□ the horizontal deflection at the top of the wall decreases in a way that at higher □ values, the wall deformation mode changes from overturning mode to bulging mode .

Conclusion

In this paper the effects of soil nail arrangement on the stability and performance of the wall was investigated. An ordered arrangement of the nails was introduced and the effect of various nail lengths at different elevations of the wall was discussed. Major findings concluded from this research are summarized as follows:

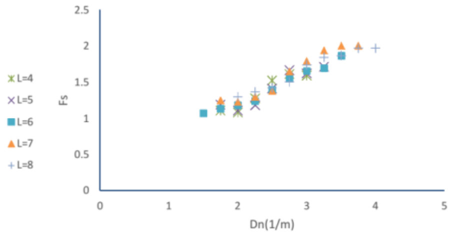

Figure 5. Effect of nail density on the factor of safety

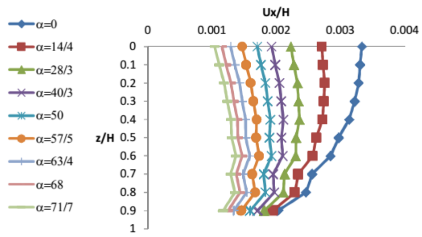

Figure 6. Effect of the nails layout on the Horizontal deflection profile

Nail density was defined as a key parameter and the findings demonstrate that nail density plays an important role in controlling the stability and the performance of the soil nail walls, in a way that patterns with the same nail densities but different arrangements, result in the almost similar factors of safety and deformations. Therefore based on the allowable factor of safety and deformation, nail density can be concluded and the nail arrangement which meets the standards, is selected.

Threshold nail density is defined as a value of nail density which no significant reduction of deflection happens afterward.

Uniform distribution of the nails and lower values of □ generates the maximum deflection at the top of the wall. As □ increases, the bond length in the upper parts of the wall controls the deformation. In that case, the deflection value is bounded and the maximum deflection occurs at the middle depth of the wall. Therefore the mode of deformation changes from overturning mode to bulging mode. As a result, in the projects which their adjacent structures are of high importance, it is recommended to use more nail.

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