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Numerical Analysis of Reinforced Soil Walls with Finite Element Method

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Abstract

The technique of reinforced soil has been widely used in construction of retaining walls and levee foundations. Nowadays geosynthetic reinforced soil walls are one of the important options in the design of retaining walls due to their superiority than other reinforcements. Traditionally, the design of geosynthetic reinforced soil walls is performed using the simplified classical analysis or empirical methods. Unfortunately, the applications of these methods render various degrees of approximations in determination of major designing factors. In this research, the behavior of geosynthetic reinforced soil walls is studied by the numerical method (FEM) with PLAXIS 2-D software. The numerical model simulates the panel with beam elements, the reinforced layers with geogrid elements and the soil-structure contact area with interface elements. Furthermore, the Mohr-Coulomb plastic model is used for the soil. The wall construction is modeled with staged construction. Then, numerical models are calibrated by using instrumented model results or experimental model and the ability of PLAXIS software in prediction of wall displacement, facing deformation and tension of reinforcement layers is assessed. Finally, one of the models is selected and the parametric study is performed. The effect of factors such as: property of soil, type of mesh and stiffness, length, distance and number of reinforcements on reinforced soil wall behavior will be investigated. The effect of changes in length of reinforcements on the model output results compared to the model are calibrated. In that case, the length of reinforcements than the calibrated models have changed, the maximum displacement of the wall is a big change than calibrated model. According to the results of numerical analysis, increasing the length of reinforcements, the effect of small on the maximum deformation of the facing has a total height of the wall. When the length of reinforcements have reduced or increased, the tension in reinforcements than the calibrated model respectively increased or decreased.

Keywords: Reinforced Soil Wall, Geosynthetic, Finite Element Analysis, PLAXIS Software.

Introduction:

The technique of reinforced soil has been widely used in construction of retaining walls and levee foundations. A wide range of reinforcement elements of different materials are produced and developed for use in such structures. Most important elements of reinforcements are metal strips, steel bars and various geosynthetics. Soils are materials that have good resistance against pressure and cutting, but are weak in tension. Numerous efforts are performed to overcome the weakness of the soil stretching process. Polymer or synthetic fabrics such as geosynthetics are compatible with the soil in deformability. Moreover, they are resistant to corrosion and acid attacks. Nowadays geosynthetic reinforced soil walls are one of the important options in the design of retaining walls due to their superiority than other reinforcements.

Many investigators have studied the reinforced soil walls, i.e., Hausman and Lee (1978), Pinto and Cousens (1996), Jewell (1985), Lawson et al. (2004), Juran and Christopher (1989), Palmeira and Lanz (1994), Wong et al (1994), Rowe and Ho (1997), Pinto and Cousens (1999), Filippo et al. (2000), Simonini et al. (2003), Hatami and Bathurst (2004), Ma and Wu (2004), Desai and Hoseing (2005), Bathurst et al. (1992), and Kapurapu and Bathurst (1995), Madhav and Poorooshasb (1988), Poorooshasb (1989, 1991), Ghosh and Madhav (1994), Shukla and Chandra (1994, 1995), Yin (1997a, b, 2000), Maheshwari et al. (2004), Nogami and Yong (2003), Deb et al. (2005), Love et al. (1987), Poran et al. (1989), Abioghli (2011).

Materials and Methods:

In this paper, the behavior of geosynthetic reinforced soil walls is studied by the numerical method (FEM) with PLAXIS 2-D software. In a study conducted by Abioghli (2010), five of geosynthetic reinforced soil walls were modeled with the use of Plaxis software. Then, numerical models are calibrated by using instrumented model results or experimental model and the ability of PLAXIS software in prediction of wall displacement, facing deformation and tension of reinforcement layers is assessed. Here, one of the models is selected and the effect of changes in length of reinforcements on the model output results of compared to the model are calibrated.

Figure 1 shows the geometry of the reinforced soil wall. Properties of various materials used in the model reinforced soil wall is presented in study conducted by Abioghli (2010). The numerical model simulates the panel with beam elements, the reinforced layers with geogrid elements and the soil-structure contact area with interface elements. Furthermore, the Mohr-Coulomb plastic model is used for the soil. The wall construction is modeled with staged construction.

Note that design and analysis of experiments tools, such as full factorial design of experiments and composite desirability function approaches, proposed and used by Mobin et al. (2016) can be used in this research to have more effective numerical analysis of the reinforced soil walls.

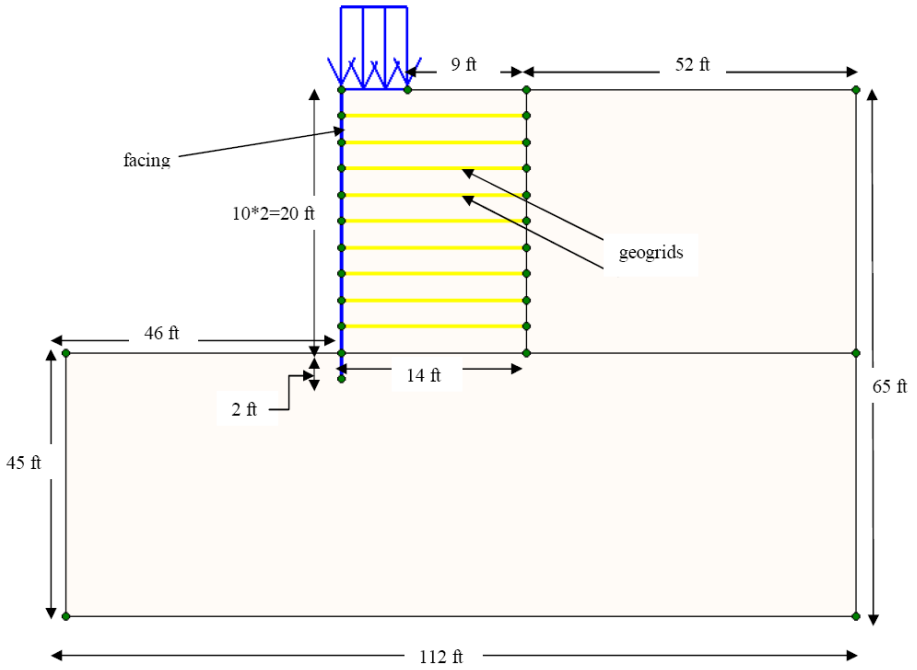


Fig. 1: Geometry of the model reinforced soil wall

Results and Discussion:

Here, one of the models is selected and the effect of changes in length of reinforcements on the model output results of compared to the model are calibrated. The length of reinforcement (L) than the calibrated model to the amount of 30,50 percent reduction and to the amount of 30,50 percent have increased. Table 1 shows the effect of changes in length of reinforcements on maximum displacement of the wall and on maximum deformation of the facing. Figure 2 shows the effect of changes in length of reinforcements on deformation of the facing. Figure 3 shows the effect of changes in length of reinforcements on tension in reinforcement in the upper reinforcement layer.

Table 1: Effect of changes in length of reinforcements on maximum displacement of the wall and on maximum deformation of the facing

Maximum deformation of the facing (mm)	Maximum displacement of the wall (mm)	Change in length of reinforcements
64.8	278	0.5 L
12.6	244	0.7 L
13.8	70.3	L (calibrated model)
11.8	40.6	1.3 L
13.6	23.4	1.5 L

As is clear from Table 1, when the length of reinforcements 50 and 30 percent have reduced the size, maximum displacement of the wall is increased by about 3 to 4 times to the calibrated model. It can be seen from Table 1, when the length of reinforcements 30 percent have increased the size, maximum displacement of the wall is reduced by about 40 percent to the calibrated model. Also, when the length of reinforcements 50 percent have increased the size, maximum displacement of the wall is reduced by about 65 percent to the calibrated model.

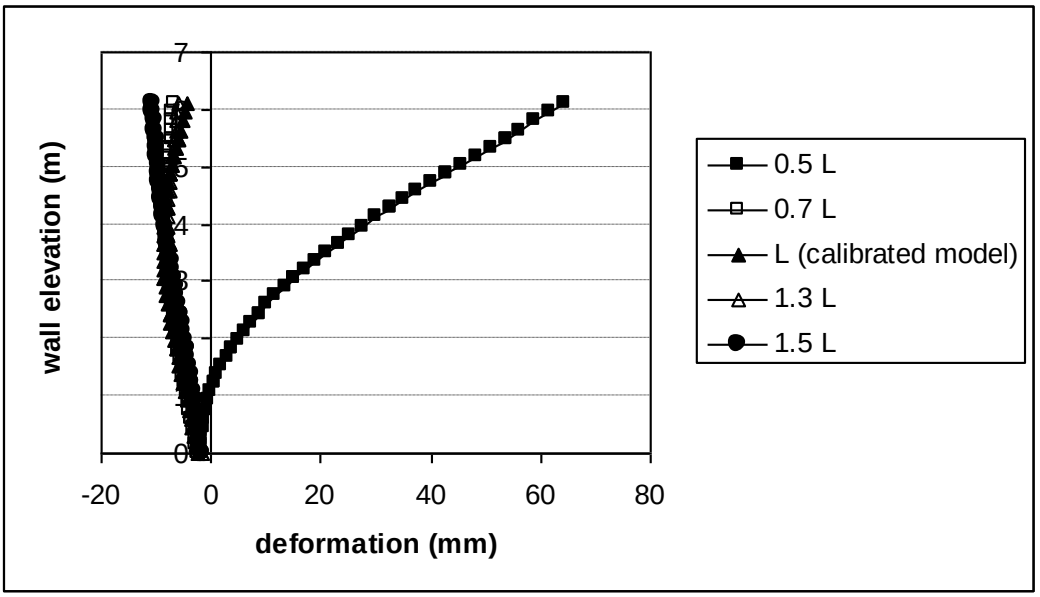


Fig. 2: Effect of changes in length of reinforcements on deformation of the facing

As is clear from Table 1, when the length of reinforcements 50 percent have reduced the size, maximum deformation of the facing is increased by about 4.5 times to the calibrated model. But, when the length of reinforcements 50 and 30 percent have increased the size and also 30 percent have reduced the size, maximum deformation of the facing is slightly reduced to the calibrated model.

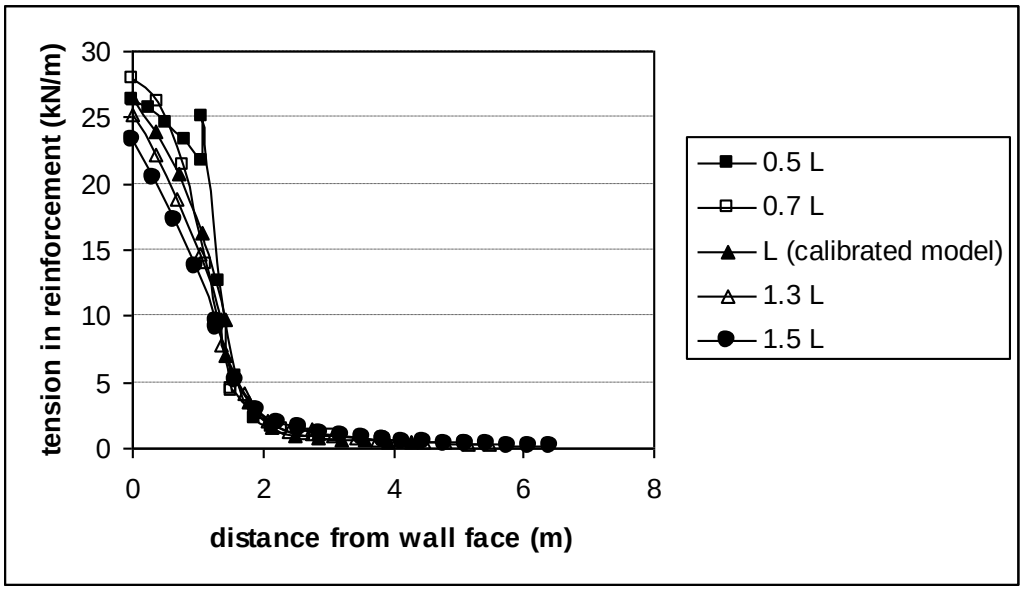


Fig. 3: Effect of changes in length of reinforcements on tension in reinforcement in the upper reinforcement layer

Figure 2 shows, the when the length of reinforcements 50 percent have reduced the size, deformation of the facing much has changed to the calibrated model. But, when the length of reinforcements 50 and 30 percent have increased the size and also 30 percent have reduced the size, deformation of the facing little has changed to the calibrated model.

As is clear from Figure 3, when the length of reinforcements have reduced or increased, the tension in reinforcement than the calibrated model respectively increased or decreased. However, the tension in reinforcement at the beginning of reinforcements is much higher than the end. Also the tension in reinforcement at the end of reinforcements is very small and close to zero.

As a future research, and in order to have better understanding about the parameters involved in the model, a mathematical model can be developed and solved using evolutionary algorithm such as non-dominated sorting genetic algorithm (Li et al., 2016) and multiple objectives particle swarm optimization (Tavana et al., 2016).

Conclusion:

According to the results of numerical analysis, increasing the length of reinforcements, the effect of small on the maximum deformation of the facing has a total height of the wall. In that case, the length of reinforcements than the calibrated models have changed, the maximum displacement of the wall is a big change than calibrated model. When the length of reinforcements have reduced or increased, the tension in reinforcements than the calibrated model respectively increased or decreased.

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