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Comparison of Soil Nailing-Anchor System with Soil Nailing Using (PIV) Method

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Abstract

Soil nailing-anchors method has many advantages rather than soil nailing in the reinforcement of ground slopes. In this paper behavioral comparison of soil nailing-anchor system with soil nailing using a small-scaled physical model was studied. Composite soil nailing-anchor including two row nails and one row anchors has been undertaken in order to stabilize the excavated wall. After each step of excavating the model and during loading the region adjacent the excavated wall, digital photographs were taken. Using image processing on sequences of digital images, behavior of reinforced soil was observed. The results show that maximum horizontal displacement of facing in the case of composite soil nailing occurs in lower part of wall; though in the soil nailing system it occurs in top of excavated wall.

Keywords: soil anchor-nailing, physical model, slip surface, PIV

1. INTRODUCTION

Constructing near the steep slopes poses some problems that should be considered in advance and proper method should be undertaken. There are diverse methods which can be applied for slope stabilizing depend on conditions. One of the most developed methods in recent decade is soil nailing which is economical and adaptable to different types of soil [1].

Another reasonable method is soil anchoring that is beneficial due to better control of displacement. Also in recent years composition of two methods was considered as a remarkable method for controlling of displacements[2].

Wang et al [3] by modeling the excavated wall using finite difference software FLAC have found that maximum horizontal displacement in foundation pit relates to lower heights. Hadad et al [4] using the ABAQUS software proved that placing the anchors in composite soil nailing increases the stability of slopes and the optimum place is middle of excavated height.

Different methods of analysis suggest the various shape of surface slip. For example, Davis in his method of analysis suggested that slip surface of soil nailed slopes are parabolic shape. Also, Germany method considered the equilibrium of forces by two-part wedge for a slip surface; however safety factor of different shapes doesn't vary too much [5].

In the recent study, small-scaled model was taken to observe behavior of supported excavated wall with composite soil nailing with pre-stressed anchors under steady loading and it is possible to control parameters which are effective using the small-scaled model. The Failure mechanism is determined by the PIV method helped to compare the changes in horizontal displacement of facing and slip surface in each test.

2. TEST APPARATUS AND SOIL DESCRIPTION

2.1. SOIL

The test soil was poorly graded, dry sand with various intergrain color. Properties of this sand are presented in Table 1.The soil medium was prepared by using a raining system to achieve a uniform and homogenous relative density.

Table 1: Mechanical properties of tested sand

Soil property	magnitude
C_u	1.7
C_c	0.98
φ	28
G_S	2.637
γ_{min}	14.7
γ_{max}	16.5
γ	15.5

2.2. NAILS, ANCHORS AND FACING

For modeling of facing, an aluminum sheet with following dimensions was used: 0.5× 300× 300 mm^3. It was punched, to place 2 rows nails and 1 row anchors by 3×3 arrangement. Furthermore, a steel box was prepared for loading of soil. It was 300 mm long, 60 mm wide and 30 mm deep. To maintain plain strain condition, width of box and facing were equal. Also the soil chamber was so rigid and its inner side was covered by plastic wrap to satisfy the plain strain condition.

Steel bars were used to model the soil nails and anchors. Their dimensions are shown in table 2. Bars were connected to the facing by bolt nuts. Thin layer of sand was glued on the surface of bars to model grouting in the soil nailing system. This method was repeated for anchors, although the bond length of anchors was 80 mm and its final diameter in this part was 8mm. Also elastic steel springs were prepared to represent pre-stressing in soil anchors.

Table 2: dimensions of soil nails and anchors

Soil nails	Length (mm)	300
	Diameter (mm)	3
Soil anchors	Length (mm)	300
	Diameter (mm)	3

2.3. PREPARATION AND LOADING SYSTEM

In order to investigate soil deformation pattern, a rigid-steel chamber with following dimensions was used: 0.3×1×0.6 m3. Front side of the soil chamber was transparent Plexiglass plate to observe the deformation in the soil sample. Figure1 shows the details of soil chamber and loading system.

In order to obtain homogeneous model, sand raining method was undertaken and the soil was poured from constant height of 20cm and it was condensed every 5cm. Then facing, nails and anchors were located in specific positions. A sensitive Load cell was applied to measure the vertical force during test. The right side of facing was excavated by vacuum in 9 steps. When anchors came out of soil in excavated side, they were pre-stressed by compressing the springs. The stiffness of spring was 0.106 KN/m and the pre-stressing load was 227 N. Excavation was continued to the depth of 0.3 m. the box adjacent excavated wall was loaded step by step by 200gr weights. Then its failure and deformation pattern was observed using the PIV method.

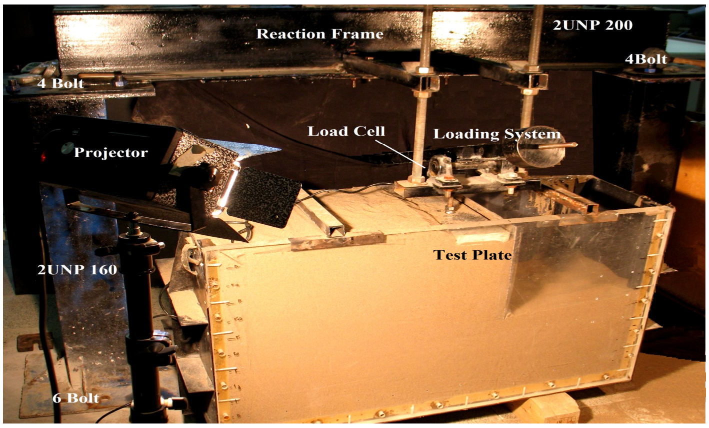

Figure 1: details of soil chamber and loading system

2.4. PHOTOGRAPHING AND PIV METHOD

As mentioned above, the front side of the box was made of transparent Plexiglass, 20 mm thick, in order to observe the soil deformation. After each step of excavating or loading, a digital image was captured using a Canon G6 digital camera with an image resolution of 3072×2304 pixels. All controls such as focus, gain and shutter speed were adjusted automatically. Two projectors were placed on the left and right sides of the camera at 45° angle at a level higher than the optical axis of the camera. The images were processed using the GeoPIV8 software, developed at Cambridge University. The PIV analysis was undertaken using patches of 64×64 pixels, with 32 pixels spacing center to center [6],[7].

3. RESULTS AND DISCUSSION

Series of tests were conducted to study the behavior of composite soil nailing with pre-stressed anchors under vertically loaded footing and compare it with soil nailing system.

3.1. DISPLACEMENT OF FACING

Horizontal displacement of facing was plotted by image processing tool in Matlab. Figure 2 shows the horizontal displacement of facing for three different places that pre-stressed anchors were located. It can be seen that maximum horizontal displacement of facing occurs in the bottom-middle of height and it is less in the top part of facing. Also the horizontal displacement of facing is less when anchors were placed in the middle row.
Considering the Figure 5, which is diagram of horizontal displacement of soil nailing, maximum horizontal displacement of facing is related to upper part of facing and it decreases by moving downward.

3.2. SLIP SURFACE

The maximum shear strain distributions for the composite soil nailing are shown in Figure 4. It can be seen that soil near the ground surface is the first region that begins to slip. Then soil near the bottom of facing slips and furthermore loading connects these regions to complete the slip surface. Also it is apparent that in Figure 1.b curvature of slip surface is less than two others. Also Figure 5 shows the maximum shear strain of soil nailing. Comparing this with Figure 4 reveals that slip surface of soil nailing is more than composite soil nailing with pre-stressed anchors. It can be concluded that by increasing the effectiveness of soil reinforcement, the curvature of slip surface decreases.

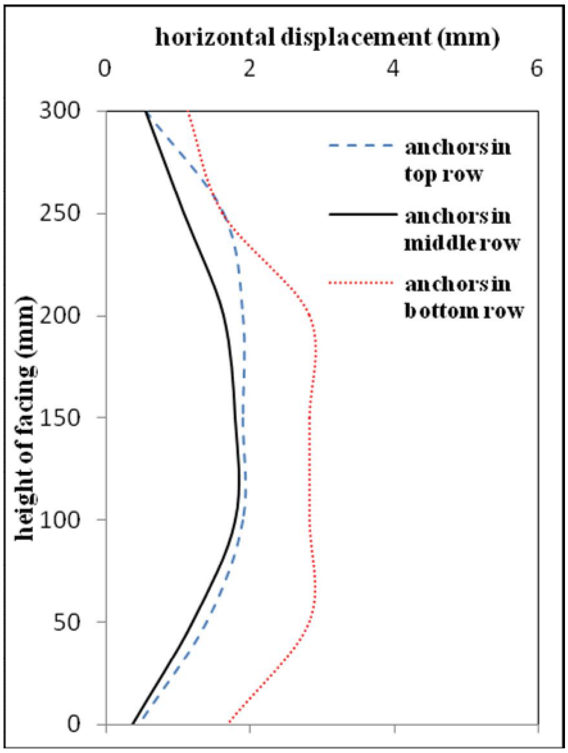

Figure 2:horizontal displacement of facing for composite soil nailing

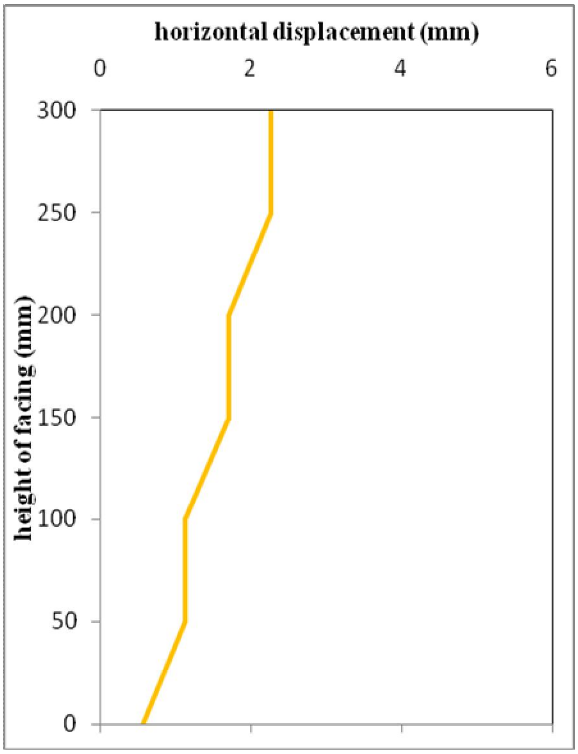

Figure 3: horizontal displacement of facing for soil nailing

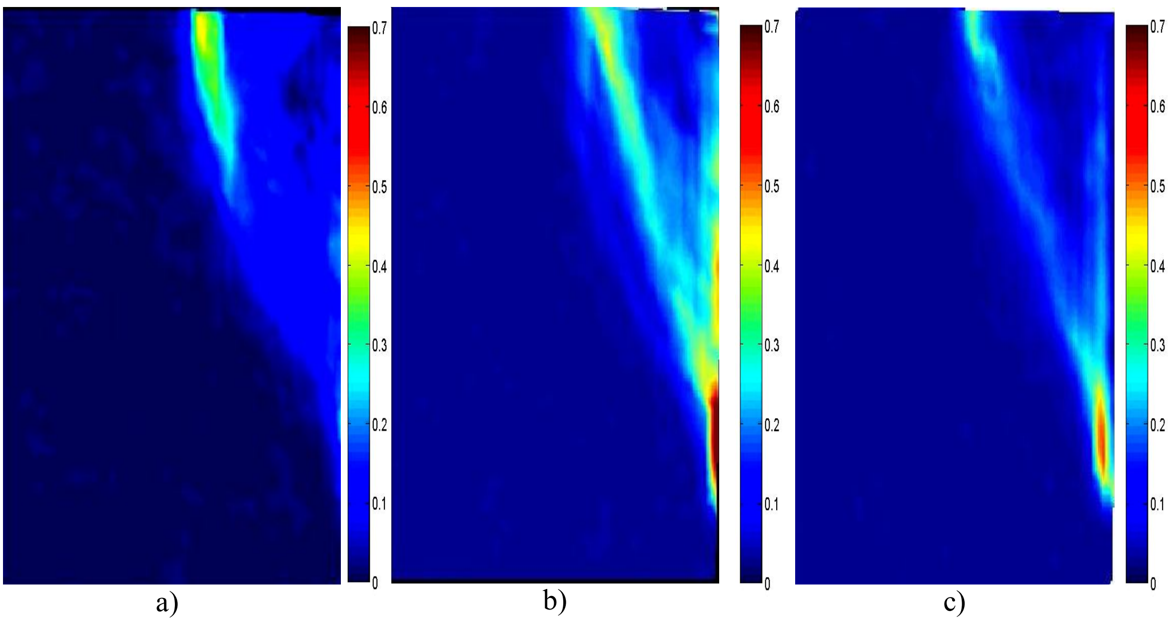

Figure 4: shear strain distribution for composite soil nailing for a)anchors in top row of facing b)anchors in middle row of facing c)anchors in bottom row of facing

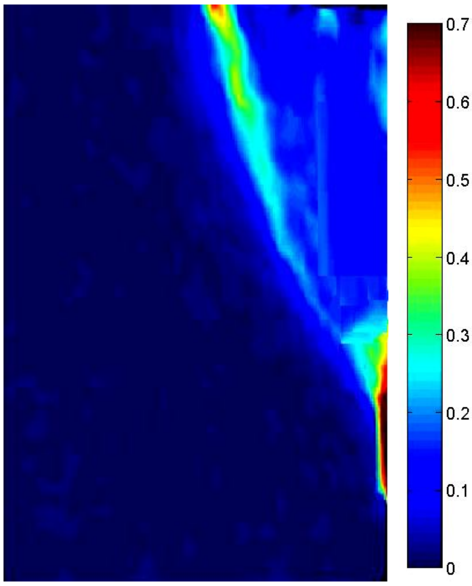

Figure 5: shear distribution for soil nailing

4. CONCLUSIONS

- The best place for locating the anchors in composite soil nailing is middle row of facing. In this region, horizontal displacement of facing is less than other places.
- Maximum horizontal displacement of facing of composite soil nailing-anchor occurs in bottom-middle of height. However, in soil nailing system, maximum horizontal displacement of facing occurs near the ground surface.
- Curvature of slip surface decreases by increasing the reinforcing effects.

5. REFERENCES

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