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Pullout load tests of the anchor plates in compacted sand used for typical backfill embankment in Thailand

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ABSTRACT: In Thailand, soil-reinforced walls have been constructed increasingly every year upon the needs of road widening and highway reconstruction. It is necessary to characterize the relationship of pullout load and displacement for backfill materials used. Therefore, the full-scale reinforced wall tests with anchors plates were performed. Three anchor plates were installed at the depth of 0.1, 0.5, 0.9, 1.3, and 1.7 meters from the top of compacted sands. Pullout load tests of tie rod with and without anchor plates in compacted sand at various depths were carried on. Regarding to test results, the force coefficient correlates with the embedment ratio. It is shown that the force coefficient increases exponentially when the embedment ratio increases. The theoretical method proposed by Merifield and Sloan (2006) could be used for a good estimation of the pullout load of anchor plates in compacted sand.

1 INTRODUCTION

Department of Highways (DOH), Thailand, is the main agency to construct and maintain highways in Thailand. Recently, Department of highways operates over sixty thousand kilometers long of highways and over fifteen thousand highway bridges throughout the country. In hilly terrain especially in the northern part of Thailand, numbers of landslides occur along the highways. DOH spends hundred million baht of annual road maintenance budget to maintain highway backfill slopes with mechanical stabilized earth and soil-nail wall systems.

With limiting budget on constructing highway bridges, DOH adopts backfill embankment as a bridge approach. Moreover, Department of highways applies concrete facing with metal strips as a reinforcement in the area of limited right of way. Therefore, numbers of constructions of reinforced walls increases every year.

In the design and analysis of soil reinforced wall, guidelines and manuals are available in literature (e.g., FHWA/RD-82-047, 1982); however, the understanding of the relationship of pullout load and displacement for backfill material specifically in Thailand is very scare. In 1995, highway engineers at the Center of Highway Research and Development constructed the full-scale reinforced wall with steel anchor plates on compacted crushed rock to investigate the two considerations: a) the pullout load and displacement relationship and b) the performance of the reinforced wall. Bearing capacity and stability failures of the reinforced wall are not concerned on this study since the walls are constructed on the compacted crushed rock. Three anchor plate dimensions are installed at the depth of 0.1, 0.5, 0.9, 1.3, and 1.7 meters from the top in compacted sand. Pullout load tests of tie rod with and without anchor plates in compacted sand were carried out. Test results are studied and compared with available case histories and standard practices.

2 CONSTRUCTION OF TRIAL REINFORCED WALL

2.1 *Backfill material*

Backfill material used in this construction is cohesionless and classified as SP-SM following the unified soil classification system (USCS). In addition, gradation of this material is shown in Figure 1. Maximum dry

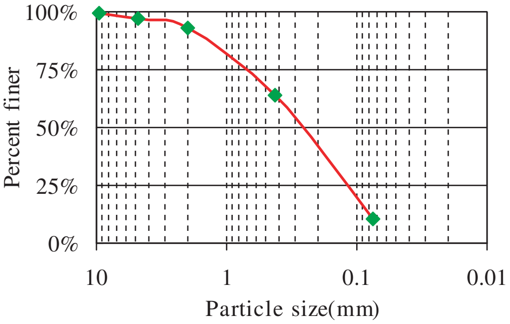

Figure 1. Gradation plot of the backfill used in the study (After Leerakomson and Charoenpon, 1996).

Table 1. Square plate dimensions (After Leerakomson and Charoenpon, 1996).

No.	Width (m)	Thickness (m)
1	0.10	0.010
2	0.15	0.010
3	0.2	0.015

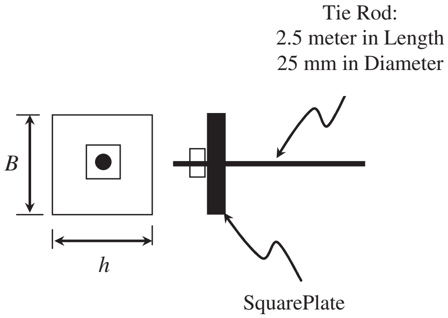

Figure 2. Square plate and tie rod cross-section used in the study (After Leerakomson and Charoenpon, 1996).

density and optimum moisture content of the standard proctor are 1750 kg/m^3 and 14.4 percent, respectively. California Bearing Ratio (CBR) at 95 percent compaction of the standard proctor is 17 percent. Internal friction angle from direct shear tests is 36 degree.

2.2 *Reinforced concrete block, tie rod and steel anchor plate*

Facing of the constructed wall is made from reinforced concrete block; a reinforced rebar is a deformed rebar with a diameter of 12 millimeters and the yield strength is 3,000 ksc (SD30). Concrete ultimate compressive strength is 135 kg/cm^3. The dimension of the reinforced concrete block is 0.2, 0.4 and 0.15 meter in width, length, and thickness, respectively.

Tie rod is a deformed bar with a diameter of 25 millimeters and the yield strength of 3,000 ksc (SD30). Yield strength from tensile tests in laboratory indicates average yield and ultimate strengths are 3,900 and 5,700 ksc, respectively. The square anchor plate is made from SR24 steel type.

The dimension of the square plates is shown in Table 1. Tie rod and anchor plate connection is shown in Figure 2.

2.3 *Reinforced wall construction*

The reinforced wall is constructed on a 40 centimeters compacted crushed rock. The construction of the reinforced wall is by compacting sand with a vibratory compactor in a layer of 20 centimeters at the water content approximately around the optimum moisture content till the total wall height of 1.8 meters. Field density tests, listed in Table 2, are performed at depth in which tie backs and anchors are installed. Average moist density of the backfill sand is 2016 kg/m^3. In addition, reinforced concrete block and tie rod connection is similar to that of the anchor plate and tie rod connection (see Figure 2).

Table 2. Field density tests of the compacted sand backfill (After Leerakomson and Charoenpon, 1996).

Number	Depth (m)	Average moist density (kg/m^3)
1	0.41	1,950
2	0.81	2,028
3	1.04	2,037
4	1.39	2,020
5	1.81	2,016

Table 3. Characteristics of the anchor plates and tie backs (After Leerakomson and Charoenpon, 1996).

Type	Depth (h_e:m)	Diameter of tie rod (mm)	Anchor plate dimension (m)
1	0.1, 0.5, 0.9, 1.3	25	–
2	0.1, 0.5, 0.9, 1.3	25	0.10 × 0.10 × 0.01
3	0.9, 1.3	25	0.15 × 0.15 × 0.10
4	0.5, 1.3, and 1.7	25	0.20 × 0.20 × 0.15

2.4 *Pullout load tests*

Pullout load tests are performed on both tie rods only and tie rods with anchor plates. All pullout load tests are performed after finishing constructing the reinforced wall. An application of pullout load is by a hydraulic jack, used in prestressed concrete construction. Dial gauges are installed at a fix steel column to measure horizontal displacements during pullout load tests.

3 LOAD TEST RESULTS AND EVALUATIONS

3.1 *Pullout load test results*

All key parameters used in this study are listed in Figure 3. Since the yield load of tie rod in this study is approximately four times the maximum pullout load in this study, an elongation of the tie rod during the pullout load test is not taken into account.

Pullout load and displacement relationship at the depth of 0.9 meter are shown in Figure 4. The rest of the pullout load test results are provided in Leerakomson and Charoenpon (1996). From the series of testing

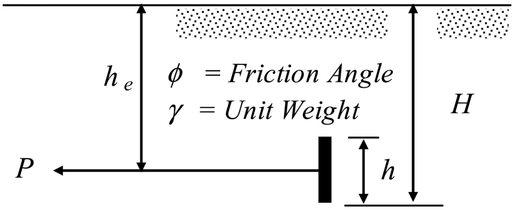

Figure 3. Parameters used in this study.

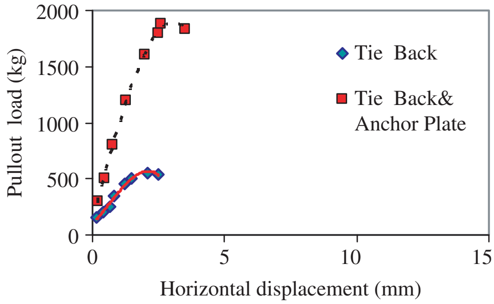

Figure 4. Pullout load test of tie back and anchor plate at the depth of 0.9 meter (After Leerakomson and Charoenpon, 1996).

results, it is found that tie back with anchor plate enhances their pullout capacities about three to fours times that of the tie back rod only.

In addition, from the full scale load tests, the relationship between pullout load and embedment ratio (H/h) can then be characterized as shown in Figure 5.

3.2 *Pullout load test evaluations*

All Pullout load test data are analyzed and compared with case histories. Neely et al. (1973) and Akinmusuru (1978) introduced the normalized pullout load, called force coefficient ($F_{\gamma q}$), as shown in Equation 1.

$$F_{\gamma q} = \frac{P}{Bh^2\gamma} \qquad (1)$$

Where P = the ultimate pullout load; B = the width of the plate; h = height of the plate and γ = the unit weight of the backfill material. Pullout loads and embedment ratio are scatter (Figure 5), however, force coefficient and embedment ratio are much less scatter (Figures 6 and 7). For embedment ratio not less than three, field data from this study, Figure 6, are matched with data presented by Neely et al. (1973) with the embedment ratio equal to 1. Whereas the embedment ratio is over four, field data from this study are outside the range proposed by Neely et al. (1973), see Figure 6. However, they lower than the range proposed by Akinmusuru (1978). In addition, the force coefficient and embedment ratio as shown Figure 7 indicates that this relationship is highly correlated.

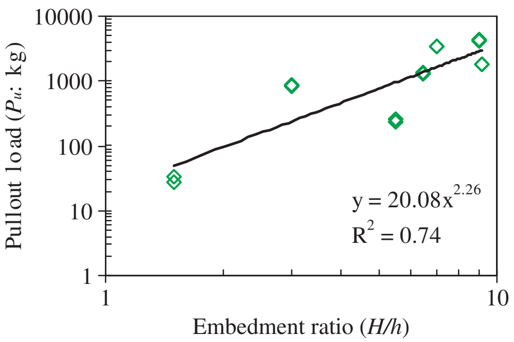

Figure 5. Maximum pullout loads, subtracting load resistances from tie rod, and the embedment ratio (H/h) relationship.

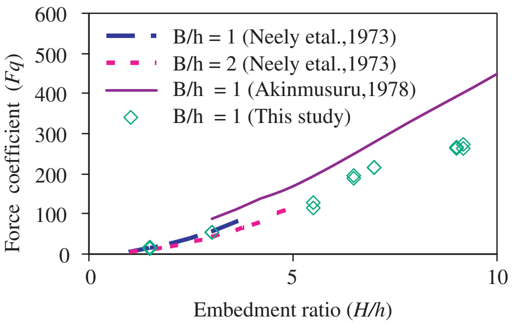

Figure 6. Variation of the force coefficient with embedment ratio.

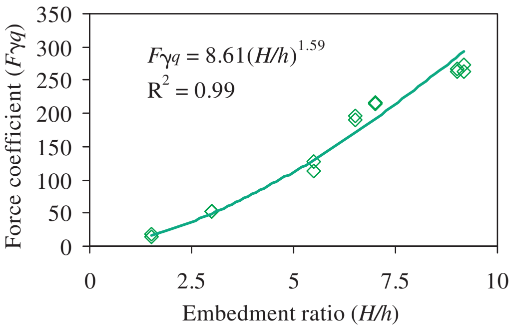

Figure 7. Correlation of the force coefficient with embedment ratio.

Glaly (1997) collected several case histories and proposed the pullout capacity as shown in Figure 8. Since the backfill sand is compacted beyond the density in the direct shear test, the internal friction angle of the backfill sand should be over thirty six degree. Following NAVFAC (1982), the friction angle of the

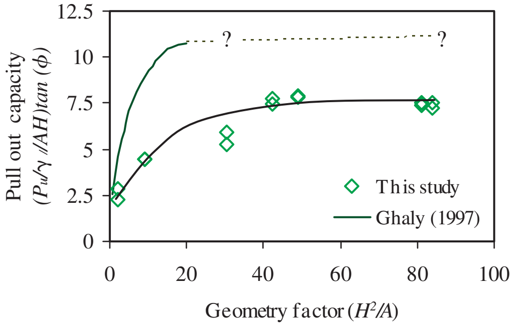

Figure 8. Relationship between the pullout capacity and geometry factor (After Ghaly, 1997).

backfill material used in this study is around forty degrees. However, pullout capacity of this study is lower than that proposed by Glaly (1997).

3.3 *Theoretical solutions for pullout load estimation*

Merifield and Sloan (2006) proposed a theoretical method to predict the maximum pullout load resistance of the anchor plate by the application of limit analysis of the upper and lower bound theorem, see Merifield and Sloan (2006) for more information. The ultimate pullout load capacity is presented following Equation 2, in which, $N\gamma$ is the anchor break-out factor. The anchor breakout factor by Merifield and Sloan (2006) with pull out load test data is presented in Figure 9.

$$P_u = \gamma H N_\gamma \tag{2}$$

In addition, pullout load test data in this study are plotted in Figure 9 to verify the effectiveness of Merifield and Sloan method. Regarding to pullout load test data in Figure 9, the method by Merifield and Sloan tends to provide a good estimation of the pullout resistance of the anchor plate for backfill sand in this study.

4 CONCLUSIONS

The full-scale reinforced wall tests with anchors plates were successfully performed. Pullout load tests of tie rod with and without anchor plates in compacted sand at the depth of 0.1, 0.5, 0.9, 1.3, and 1.7 meters from the surface were carried on. Regarding to test results, the force coefficient correlates with the embedment ratio. In addition, the theoretical method by Merifield and Sloan (2006) provides a good estimation of the pullout load of the compacted sand.

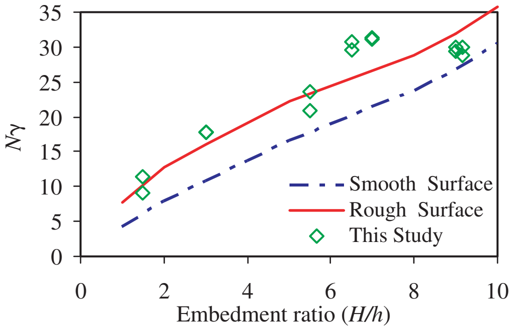

Figure 9. Theoretical solutions by Merifield and Sloan for backfill material with friction angle of 40 degree (After Merifield and Sloan, 2006).

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