Pull Out Characteristics of Soil Nails in Pahang

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Abstract

A total of 45 locations of slope failures occurred along Jalan Baru Gap to Fraser Hill, Pahang. Of the 45 locations of slope failures, only 31 locations were repaired using soil nails. At each location, only one pull out test was carried out. This study involved the results of the pull out tests at all the 31 locations and the results were obtained from Public Works Department, K.L. The maximum pull out load during the test was 90 kN and the displacement at 90 kN load must be less than 10mm for the test to be considered satisfy the specifications. The main purpose of this study is to determine the characteristics of the pull out test on soil nail and the interaction between the soil nail and the soil.

1.0 Introduction

In the recent years, there are many cases of slope failures along the roads that were constructed in hilly areas. The tragedy of landslide and slope failures along North-South Highway near Bukit Lanjang, Selangor, road near Ulu Yam, Selangor, along KL-Karak Highway, Pahang and road along North-South Highway near Gua Tempurung, Gopeng, Perak are examples of slope failures.

The soil nailing techniques have been used since the 1970s and this technique was first used in France with the first wall was built in Versailles in 1972. The soil nailing technique has been used successfully in the past 2 decades, mainly in France and German in cut slope-retaining system and slope stabilisation. Soil nail is a slender unstressed reinforcement that is placed in-situ soil. Figure 1 shows how soil nail improved the stability of an unstable slope. Figure 2 shows the construction of the soil nails from bottom of slope upwards after trimming and removing of loose soils on the slope surface. Figures 1 and 2 are obtained from Powell and Watkins (1990). Figure 3 shows the typical soil nail while Figure 4 shows the cross section of the soil nail. The pull out test of soil nail is very important test to confirm the design of the soil nails. Slope facing is also an important element in the construction of soil nailed reinforced slope where it prevents surface erosion and localized failure. The common types of surface protections are guniting and hydroseeding reinforced with PVC coated wire mesh.

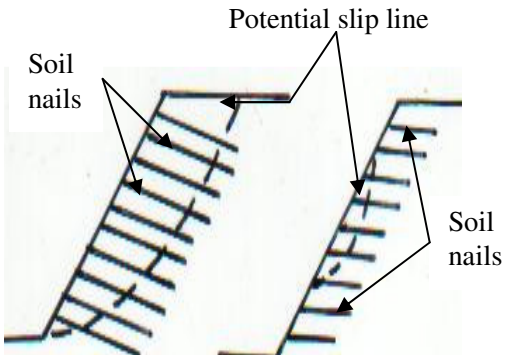

Fig. 1 : Soil nails improved the stability of slopes

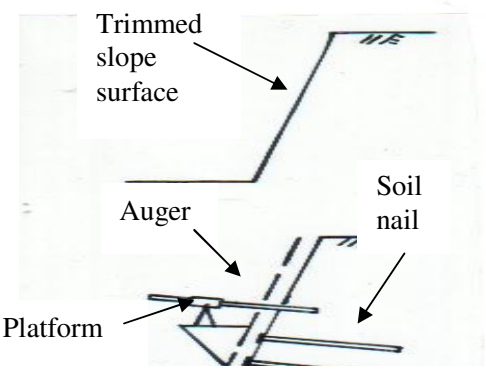

Fig. 2 : Installing soil nails from bottom of slope upwards

2.0 Problem Statement

This research is to determine the relationship of strain energy exerted on the soil nail during testing and the coefficient of friction between the nail and surrounding soil. It is also to determine the relationship between pull out load test and soil nail displacement.

3.0 Objectives

The objectives in this research include the following:

ii) To analyse the pull out load of tested soil nail and its displacement

ii) To determine the pull out characteristics of the soil nail i.e. the relationship between pull out displacement, strain energy of the tested soil nail and the coefficient of friction between the soil and soil nail.

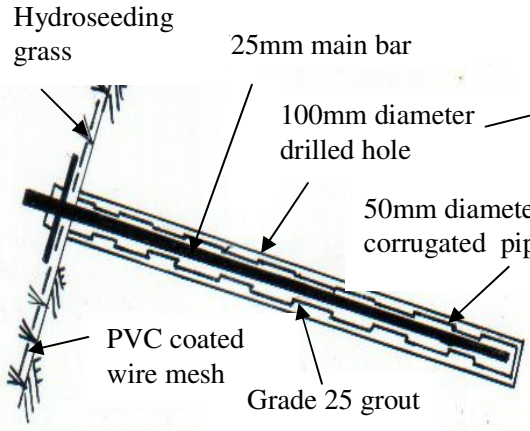

Fig. 3 : Soil nail reinforced slope

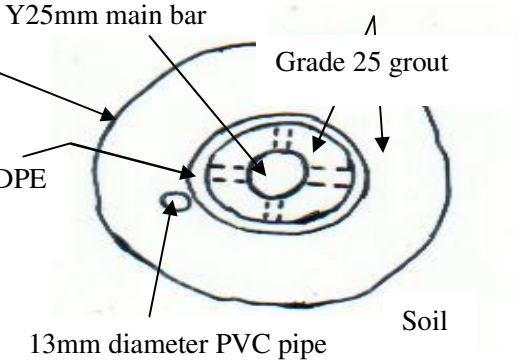

Fig. 4 : Detail cross section of soil nail

4.0 Research Methodology

Background Of The Slope Stabilization Works

The newly constructed road of length 9 km was facing problems due to slope failures at 45 locations and was dangerous to the public. Figure 5 shows the typical slope failure along Jalan Baru Gap to Fraser Hill, Pahang. Soil nail with hydroseeding reinforced with PVC coated wire mesh as the surface protection were used as slope repair works. The new road was passing through a hilly area with slope angle of greater than 45 degrees. The type of rock found was granite. The location plan of Fraser Hill is shown in Figure 6 while Figure 7 shows all the locations where soil nails were tested.

Fig. 5 : The typical slope failure along Jalan Baru Gap to Fraser Hill

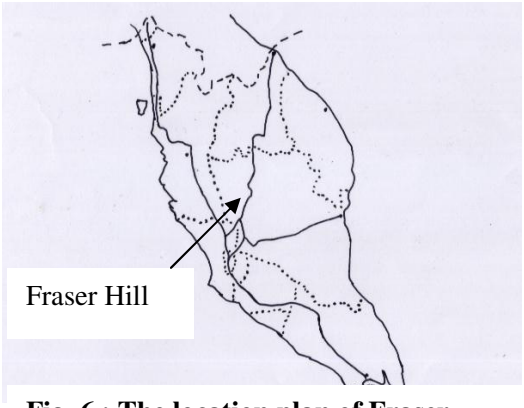

Fig. 6 : The location plan of Fraser Hill

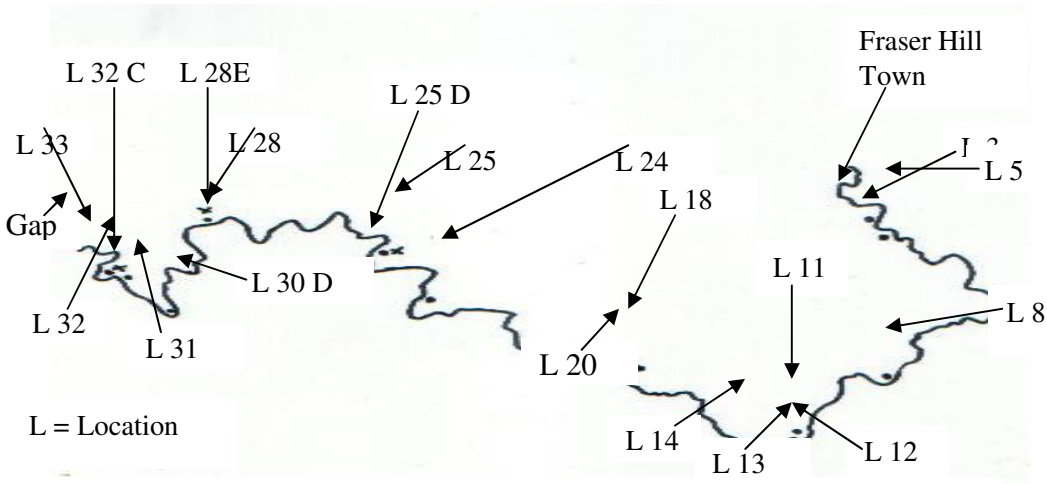

Fig. 7 : Plan showing all the locations where soil nails were tested along the road from Gap to Fraser Hill town.

The summary of methodology adopted in this research includes :

1) Obtain all the locations where soil nails reinforced slope were used from JKR illustrated.
2) Obtain all the repair drawings proposal from JKR.
3) Obtain all the pull out test results on soil nail as well as their graphs from JKR.
4) From pull out results, check the soil nails satisfy all the test requirements.
5) Calculate the strain energy up to 90 kN pull out load from test graphs.
6) From the repair proposal drawings, determine the overburden height of the tested soil nails and calculate the coefficient of friction.
7) Plot all the necessary graphs.
8) Analyse and compare all the calculations results and make conclusion.

The flow chart of the research methodology is shown in Figure 8.

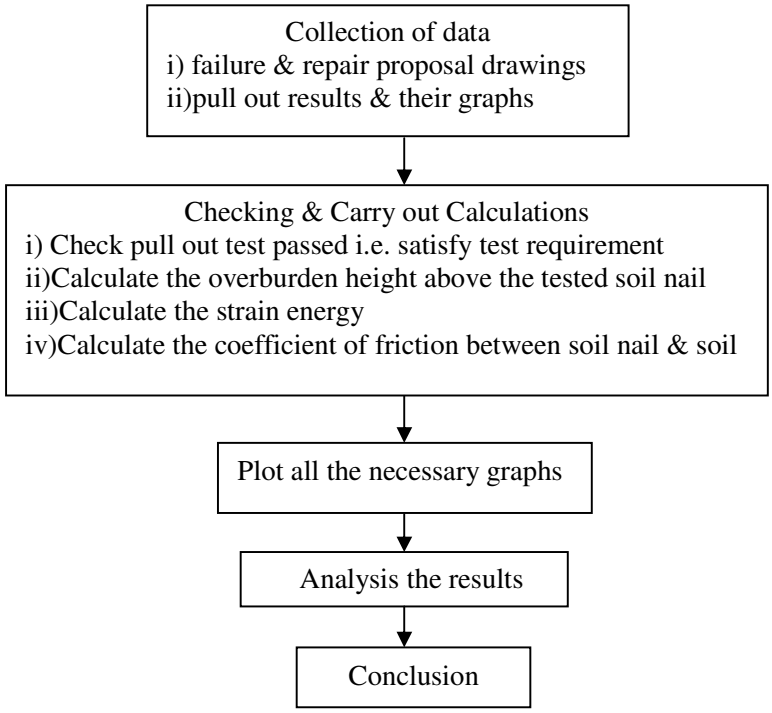

Fig. 8 : The flow chart of the research methodology

5.0 Results & Discussions

Pull Out Load Versus Displacement

The typical arrangement of the pull out test is shown in Figure 9 while the typical pull out test graph is shown in Figure 10. The pull out test is considered passed when the displacement under 90 kN is less than 10mm i.e. less than 10% of the

soil nail diameter of size 100mm. Table 1 shows the tested soil nail locations, displacement under 90 kN pull out load, strain energy and coefficient of friction. From Table 1, all the pull out tests satisfy the test requirements with minimum displacement of 0.60mm at location 13 while the maximum displacement under 90 kN of 7.2mm at Location 24.

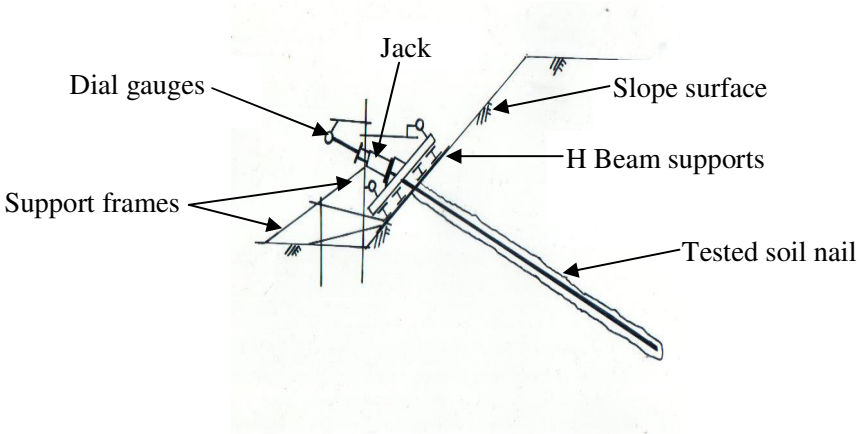

Fig 9 : Typical arrangement of the pull out test on soil nail

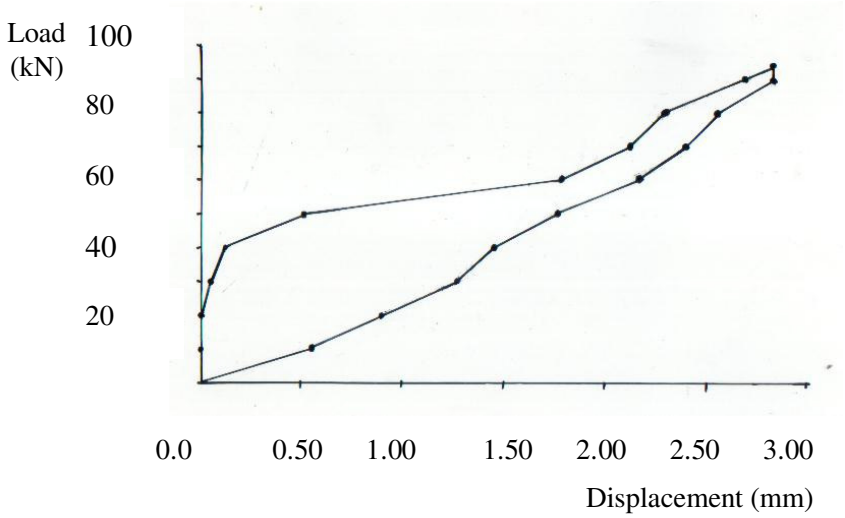

Fig. 10 : Typical graph of pull out test result at Location 14

Table 1 : Pull out test results, pull out strain energy and apparent coefficient of friction of soil nails along Jalan Baru Gap to Fraser Hill, Pahang (After Terratech 1999 and Mohd Ali 2004)

No	Location No	Displaceme-nt under design load of 90 kN (mm)	Pass/Fail (passed test if displacement under 90kN < 10mm)	Avg. overbu-rden height (m)	Pull out strain energy (kNm)	Apparent coefficient of friction (u*)
1	3	2.28	Passed	15	0.11785	0.18
2	5	2.15	Passed	15	0.14137	0.18
3	8	2.32	Passed	5	0.15815	0.53
4	11	2.99	Passed	-	0.19466	-
5	11	2.99	Passed	15	0.21836	0.18
6	12	2.79	Passed	5	0.16513	0.53
7	13	0.60	Passed	12	0.04258	0.22
8	14	2.83	Passed	8	0.17475	0.33
9	18	2.32	Passed	12	0.15850	0.22
10	20	1.99	Passed	16	0.10445	0.17
11	24	7.20	Passed	12	0.65781	0.22
12	25	4.82	Passed	-	0.34544	-
13	25	5.26	Passed	16	0.66038	0.17
14	25	3.30	Passed	9	0.20641	0.29
15	25D	5.84	Passed	-	0.33206	-
16	25D	3.96	Passed	-	0.24309	-
17	25D	3.60	Passed	16	0.21909	-
18	25D	5.63	Passed	9	0.30699	-
19	28	2.18	Passed	-	0.14388	-
20	28	2.98	Passed	17	0.18868	0.16
21	28E	6.33	Passed	-	0.29457	-
22	28E	6.88	Passed	19	0.38869	0.14
23	28E	5.06	Passed	14	0.23569	0.19
24	28E	5.44	Passed	8	0.24804	0.33
25	32C	3.87	Passed	-	0.36775	-
26	30D	5.98	Passed	-	0.28391	-
27	30D	5.24	Passed	-	0.27229	-
28	30D	5.87	Passed	8	0.15716	0.33
29	31	2.85	Passed	6	0.26841	0.44
30	32	3.98	Passed	-	0.16359	-
31	33	3.80	Passed	-	0.24176	-

Soil nail Ø = 100mm, Length of soil nail = 6m, Working load = 75 kN
Design load = 90 kN, Average unit weight of soil = 18 kN/m^2

Strain Energy

Based on Case and Chilver (1971), the strain energy of pull out test is represented by the shaded area under the load versus displacement graph as shown in Figure 11. Based on this concept, the area under the graph was calculated by dividing it into rectangles and triangles as shown in Figure 12. Table 1 shows the strain energy along all the locations of the tested soil nails.

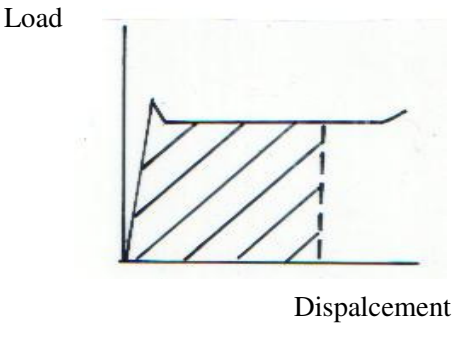

Figure 11 : Strain energy is the shaded area under load versus displacement graph (After Case et al. 1971)

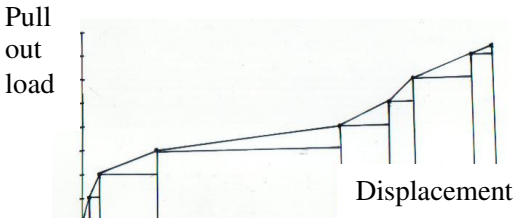

Figure 12 : Areas under the load against displacement graph were calculated by dividing into rectangles and triangles

The value of strain energy varies between 0.04258 kNm and 0.66038 kNm at location 13 and location 25 respectively.

Overburden height (H) above a tested soil nail is shown in Figure 13. Coefficient of friction is obtained from the formulae below based on Soulas, Aris, Schlosser, and Plumelle (1991).

$T_{90} = л \times D \times L \times \tau_{90}$ ---------- (1)

$\tau_{90} = \gamma \times H \times \mu$ ---------- (2)

substitute (2) into (1)

$$\mu = \frac{T_{90}}{\pi x D x L x \gamma x H} \quad \text{---------- (3)}$$

Where T_{90} = pull out load 90 kN D = soil nail diameter (100mm)

L = length of soil nail (6m) γ = unit weight of soil (18 kN/m^3)

τ_{90} = shear stress under 90 kN pull out load

μ = coefficient of friction

H = overburden height above the soil nail – refer to Figure 13

Figure 13 shows the overburden height above the tested soil nail.

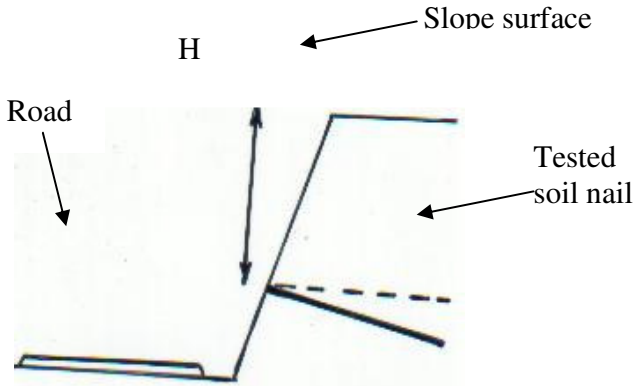

Fig. 13 : Overburden height (H) above a tested soil nail

The value of coefficient of friction varies between 0.14 and 0.53 at height of overburden 19m and 5m respectively. The higher is the height of the overburden the smaller is the value of coefficient of friction.

6.0 Conclusions

The characteristics of pull out tests on soil nail are the displacement at 90 kN, the strain energy and coefficient of friction. All the tested soil nails satisfy the test requirements with minimum displacement of 0.60mm at location 13 while the maximum displacement of 7.2mm at Location 24. The minimum strain energy was found to be 0.04258 kNm while the maximum strain energy was found to be 0.66038 kNm at location 13 and location 25 respectively. Coefficient of friction reduces as the overburden height increases. The minimum coefficient of friction was found to be 0.14 while the maximum coefficient of friction was found to be 0.53 at the height of overburden of 19m and 5m respectively.

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