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Foreword

Welcome to ESTEEM Volume 2. In this issue, we address a gamut of topics from the engineering disciplines to language education. We hope that ESTEEM, by publishing articles from a diverse range of disciplines, will encourage debate and exchange among researchers from assorted academic backgrounds.

I would like to thank our advisor, Prof. Madya Mohd Zaki Abdullah for his distinctive imprint on this edition. His leadership of the journal in its 2nd year of growing impact and reputation has been outstanding. His vision, commitment to excellence, and attention to detail are widely recognized by the Penang academic community as determining factors in the journal's success so far. We will do our best to continue and expand on this tradition of excellence.

Since its launch in 2003, ESTEEM is indeed fortunate to have a dynamic Editorial Team. These people have provided the journal with an outstanding service of reviewing submissions for publications. The journal follows the established policy of a blind review process consisting of at least two peer reviewers per submission. We depend upon their knowledge and judgement in advancing the scope and utility of this journal. Without their support and enthusiasm none of this would have been possible. Also, my thanks to all the contributors, both the successful and not so successful.

Our vision of the ***ESTEEM*** journal is that it should be the journal that belongs to you, the academic and research community. This includes all engineers and academicians working to unravel the mysteries of research, teaching and learning, in all its facets. We wish the journal to be responsive to your needs and your interests. Please feel free to contact any of us in the editorial board to give us your ideas and suggestions for the development of the journal. We look forward to working with you all in expanding this emerging venue for communicating high quality research on the many aspects of academia.

Finally, I would like to take this opportunity to invite all authors and readers to contact me at **esteem@ppinang.uitm.edu.my** to share their comments and advice on how to further enhance the journal's value to the wider research community in knowledge and how to move ESTEEM to the next level of excellence.

The Chief Editor
May, 2005

Study on Nylon Strip-soil Interaction

Iqraz Nabi Khan
Swami Saran

ABSTRACT

An attempt has been made to explore the possibility of use of nylon strips (niwar) for reinforcing soil by conducting a study on frictional characteristics of nylon strips and soil using pull-out and sliding shear tests. Effect of over burden pressure and density of soil on coefficient of friction between soil and nylon strip has been studied. The friction coefficient decreases with increase in overburden pressure and decrease in density.

Keyword: *Soil reinforcement interaction, pullout test, sliding shear test.*

Introduction

Conventional retaining walls are some times not suitable where there is a soil with poor bearing capacity or suitable construction materials are not available or site is not easily accessible or it is to be erected within a short period. In such type of situations, reinforced earth wall seems to be a pragmatic solution. Structures made by using locally available materials are economical and can be erected faster. Nylon strip is one of such type of materials which is available everywhere and can be transported easily by light vehicles and can be easily cut into required sizes. So an attempt has been made to find its possibility to be used as a reinforcing material in reinforced earth structures by conducting a study on frictional characteristics of nylon strip and soil using pull-out and sliding shear tests. Effect of density and overburden pressure on the coefficient of friction between soil and nylon strip has been studied.

Reinforced Earth is a composite material, which is formed by the association of soil and tension resistant reinforcing elements. The reinforcement suppresses the normal tensile strains in the soil mass through friction interaction. Hence the analysis and design of reinforced earth wall and retaining wall with reinforced backfill (backfill supported by a conventional wall is reinforced with unattached reinforcement laid horizontally to reduce horizontal thrust on wall) require the knowledge of the value of the coefficient of interfacial friction between soil and reinforcement. This coefficient is usually obtained either by sliding shear test or pull out test. Both tests give different results. In sliding shear test (Figure 1a), the local coefficient of friction (μ) between the reinforcement sample and the soil is measured, while in pull-out test (Figure 1b), the reinforcement is extracted from a real structure or from an embankment. Friction coefficient obtained from pull-out tests is referred as apparent friction coefficient (f^*). Sliding shear test is easier to monitor but does not give any information on real interaction between soil and buried strip, which is more complex than a simple friction. In pull-out tests only displacement is recorded. Because of dilatancy effects, which develop in the vicinity of the reinforcement, the local stress at the surface of the strip is not known. From the mechanics point of view the sliding test is akin to kinetic or rolling friction condition, while static friction condition prevails in pull-out tests. However, the interaction mechanisms are not so simple. In sliding shear tests, the soil movement is minimum at the interface, since the movement of soil is restrained by reinforcement, and increases with distance away from it. Whereas in the case of a pull out test, the soil movement at the interface will be maximum, since the soil resists the movement of reinforcement, and reduces away from it.

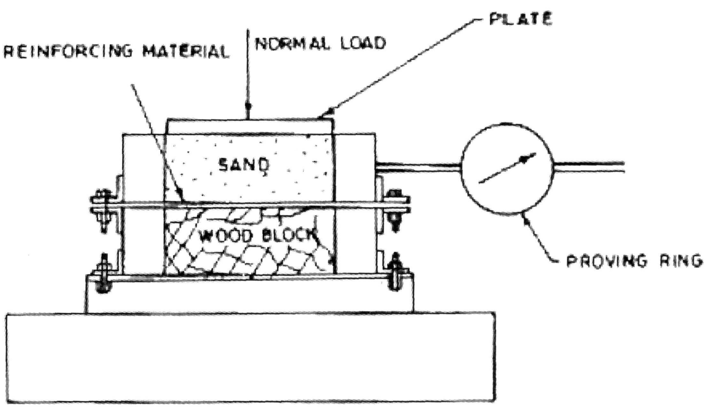

Figure 1a: Modified Sliding Shear Test

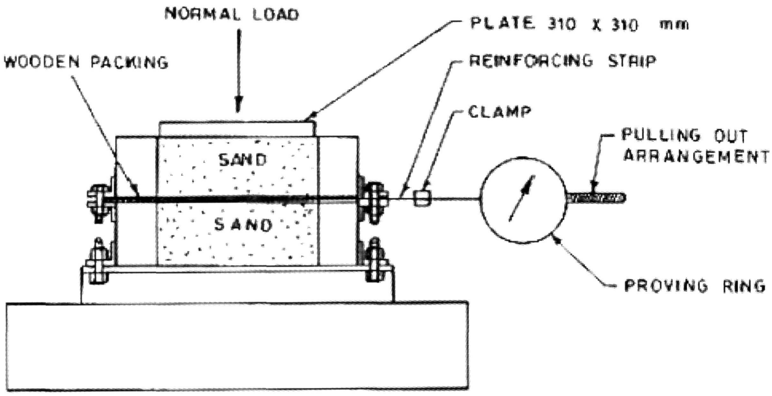

Figure 1b: Pull-out Test Setup

Earlier investigators, (Bacot et al, 1978), (Schlosser, 1978), (Mckittrick, 1978), (Talwar, 1981), (Garg, 1988), (Khan, 1991) etc. reported that the reinforcement-soil interaction depends basically on density of soil, overburden pressure, length and width of reinforcement, state of surface of reinforcement and pull-out speed (strain rate).

Development Test Programme

Type of test to be used for a particular problem should be decided by keeping in view the relative movements of soil and reinforcement. It can be suggested that apparent friction coefficient (f*) should be used in case of reinforced earth retaining walls, since at the time of pull-out (friction) failure the reinforcement is pulled out from the stationary soil mass i.e. resisting zone. Similar is the case of footing placed on loose to medium sand reinforced with flexible reinforcement where punching shear will occur which will cause pulling-out of reinforcement. Values obtained from sliding shear tests can be used for designing a footing resting on dense sand reinforced with stiff reinforcement, where soil slides over the reinforcement. However, in case of the wall with reinforced backfill, both type of relative movement can take place. In the upper region the reinforcement is pulled out of the soil mass whereas in lower region soil moves over the reinforcement.

Soil and Reinforcement

The soil used in this study was dry sand. The soil was classified as SP with effective size (D_{10}) of 0.185 mm, coefficient of uniformity (C_u) of 1.30. Backfill soil was deposited at a density of 15.5, 16.0 and 16.5 kN/m^3, relative density of 55%, 60% and 81% and angle of internal friction, obtained from direct shear test, was 33°, 37°and 41° respectively.

The reinforcement used was nylon strip. Width of nylon strip was 32 mm, thickness 1.41 mm and rupture strength 50 N/mm width.

Sliding Shear Tests

Sliding shear tests (Figure 1a) were performed to determine the angle of sliding friction between sand and the nylon strip. Tests were carried out in shear box of size 60 mm × 60 mm placing sand at densities of 15.5, 16.0 and 16.5 kN/m^3. Normal pressure range adopted for 60 mm × 60 mm box was 16 to 104 kN/m^2. The strain rate was kept as 0.5 mm/min for each normal pressure.

Pull-out Tests

Friction coefficient between reinforcement and sand was determined by conducting pull-out tests in modified shear box (Figure 1b) of size 315 mm × 315 mm at a density of 16.0 kN/m^3. Effect of overburden pressure on friction coefficient was studied by conducting pull-out tests by keeping density of soil (16.0 kN/m^3), strain rate (1.853 mm/min), width of nylon strip 32 mm and length 300mm as constant and varying pressure intensities from 20 to 200kN/m^2.

Pull-out tests were also conducted in a tank of size 1.5 m × 1.5 m × 1.5 m high (Figure 2) by adopting strain rate as 1.853 mm/min, density 16.0 kN/m^3, width of strip 32 mm, length 1.0 m and overburden height was varied from 0.2 m to 0.9 m.

Test Procedure

Sliding Shear Tests

Sliding shear tests were performed in shear box of size 60 mm × 60 mm. Nylon strip was pasted on wooden block of size 60 mm × 60 mm × 20 mm which was fixed in lower half of 60 mm × 60 mm shear box such that the reinforcement lies along the failure plane (Figure 1a). Wooden

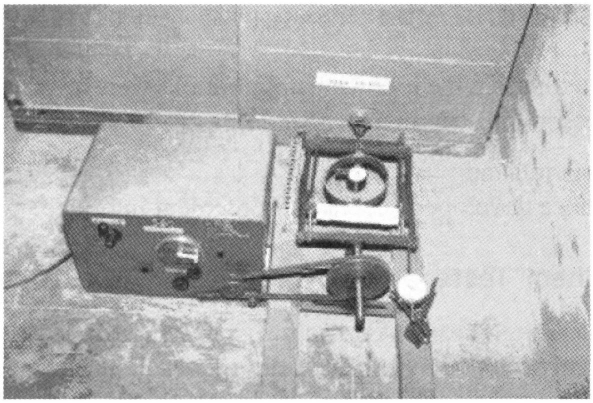

Figure 2: Pull-out Test Set-up (Tank 1.5 m × 1.5 m × 1.5 m)

block having reinforcement fixed at its top occupied the lower half of shear box with the reinforcing material along the failure plane. The top half of box was filled with dry sand at desired density. Desired normal pressure was applied through loading pad. For each normal pressure, the shearing of reinforcement with soil was done by applying horizontal load till failure. For each normal pressure, records were taken for shear strain and the corresponding shear stress at regular intervals.

Pull-out Tests

Schematic diagram of the modified shear box is shown in Figure 1b. 8mm thick packing was provided between lower and upper half of the box. An opening was kept in one side of the box to facilitate the pulling of strip. Size of opening varied according to the width of strip to be pulled out. Desired normal pressure was applied through top iron plate by a hydraulic jack and proving ring.

Rainfall technique was adopted for depositing the sand in tank of size 1.5 m × 1.5 m × 1.5 m to the desired height of overburden. Strips were pulled-out by an electrically operated pulling out device. For each test, records were taken for displacement and the corresponding resistance offered by strip.

Test Results and Analysis

As mentioned earlier, the following observations were recorded for every normal pressure on strip in a test.

i. Deformation and
ii. Resistance developed at soil-reinforcement interface.

Sliding Shear Tests

In case of sliding shear tests, friction coefficient was determined by plotting shear stress versus shear strain curves and shear stress versus normal stress curves as shown in Figure 3. Friction angle was obtained from the peak shear stress corresponding to the applied normal stress. Test results have been summarised in tabular form and given in Table 1.

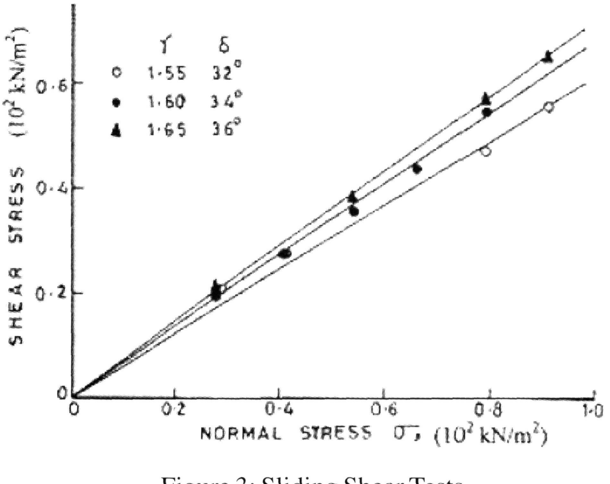

Figure 3: Sliding Shear Tests

Table 1 shows that the angle of friction increases as the density of sand increases. Angle of interfacial friction between sand and nylon strip was always less than the angle of internal friction of soil.

Pull-out Tests

Plots between pull-out resistance and displacement of strips were plotted for every normal pressure intensity. Peak of pull-out resistance for the

Table 1: Sliding Shear Test Results

Size of shear box	Density (kN/m^3)			Remarks
	15.5	16.0	16.5	
	Friction angle (degrees)			
60 × 60	23.0°	25.0°	25.5°	

normal stress was chosen from displacement versus pull-out resistance curve to calculate friction coefficient (f*) using the following equation:

$f^* = T/(2\sigma.L.w)$

where,

T = maximum pull-out resistance (N),
σ = normal pressure intensity at strip level N/m^2,
L = length of strip (m), and
w = width of strip (m).

Figure 4 shows variation of friction coefficient (f*) with overburden pressure on nylon strip for the tests conducted in modified shear box and Figure 5 shows the same relationship for the tests conducted in tank of size 1.5 m × 1.5 m × 1.5 m. Friction coefficient was found to be decreasing with increase in normal pressure.

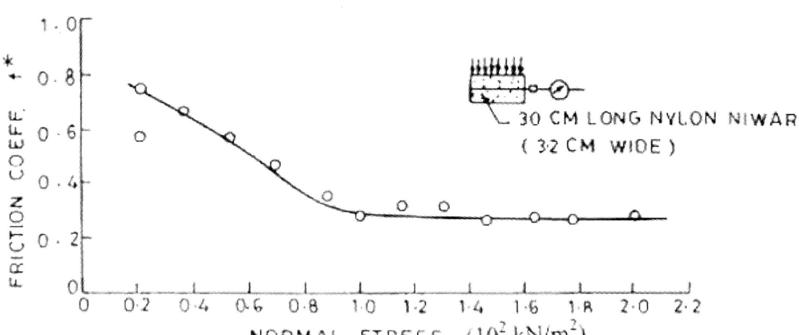

Figure 4: Friction Coefficient f* Versus Overburden Stress (Modified Shear Box)

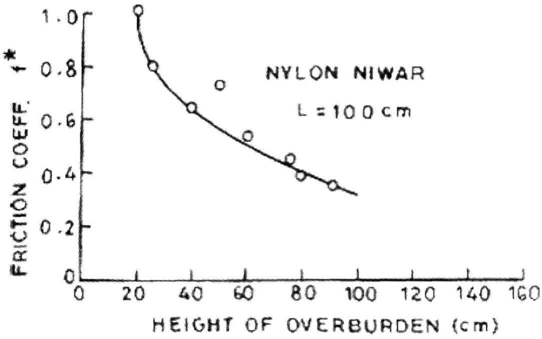

Figure 5: Friction Coefficient f* Versus Overburden Stress (Tank 1.5 m × 1.5 m ×1.5 m)

Conclusions

In this investigation the study has been conducted to determine the interfacial resistance between nylon strip and soil by sliding shear tests and pull-out tests.

Salient conclusions obtained from this study are given below:

Sliding Shear Tests

Angle of interfacial friction (δ) between sand and nylon strip was less than the angle of internal friction of soil. Angle of interfacial friction (δ) increased with increase in density of soil.

Pull-out Tests

Value of apparent coefficient of friction (f*) decreases with increase in overburden pressure. It becomes constant when overburden pressure is more than about 20 kN/m^2.

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IQRAZ NABI KHAN, Associate Professor, WAREM, Faculty of Civil Engineering, Universiti Teknologi MARA Cawangan Pulau Pinang, 13500 Permatang Pauh, Malaysia.

SWAMI SARAN, Professor, Department of Civil Engineering, Indian Institute of Technology, Roorkee-247667, India.