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Strain-controlled pull-out tests on bamboo culm embedded in quarry dust

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ABSRTACT: A laboratory pull out test apparatus using a strain-controlled concept has been developed to study frictional characteristics of reinforcements embedded in soils. The advantages of carrying out pull out tests using this apparatus are the maximum pull out stress can be defined and effect(s) of strain softening, if any, can be observed. The concept is achieved via pulling out the reinforcement at a constant strain rate with the entire testing set-up including the data collecting is fully automated.

Several series of tests have been carried out with the objectives of introducing cheaper and locally available materials. Test materials like Malaysian bamboo species, namely Bambusa blumenea (Buluh Duri) and Giganthocloa scorterchinii (Buluh Semantan) with quarry dust as backfill materials have been used in the study. The suitability of these materials for reinforced earth system in term of frictional criterion is discussed.

1 INTRODUCTION

Reinforced Earth (R.E) is a soil improvement technique which has been popularised by Henri Vidal 1966. To achieve full benefits of this technique, there must be a transfer of stresses from surrounding soil to the reinforcement. This is accomplished by frictional resistance, bearing resistance or combination of both (Binquet 1979). Subramaniam 1991, Palmeira 1989, Schlosser 1978 and many others have successfully developed apparatus to carry out pull out test in understanding the interaction between reinforcement and backfill material. However a more meaningful results may be obtained through conducting the pull out test using constant strain-controlled pull out mechanism.

Bamboo is considered an attractive alternative for reinforcement in R.E system because it has relatively high ultimate tensile strength and it can be found abundantly in Malaysia (about 329,000 hectare, Razak 1992). In addition to mechanical properties such as tensile strength, physical property like culm thickness is also important as it dictates the absorption and retention ability of the bamboo in any chemical preservatives treatment (Latif 1990). Quarry dust was used in this research because it is relatively cheap that is RM6.00/tonne.

2 MATERIALS AND TESTING PROGRAMME

G. scortechenii and B. blumenea (locally known as Buluh Semantan and Buluh Duri respectively) are selected with an average age of 3 years. It is important to know when the bamboo are harvested as season has an effect on the mechanical properties of bamboo (Latif 1989).

The grain size distribution for the quarry dust used is shown in Fig. 1. Large direct shear box (300mm x 300mm) tests were also carried out on the quarry dust. The results are shown in Fig. 2, where the apparent cohesion and angle of internal resistance are 50kPa and 41° respectively.

Four important aspects were investigated, namely; species effect, portion effect within a single culm, pull out direction effect and frictional characteristic between bamboo and quarry dust.

There are more than 50 bamboo species can be found in Malaysia. Since it is a biological natural material, physical and mechanical properties differences are the main concerns in selection of the suitable species to be used. In conjunction, a comparative study between B. blumeana and G. scorthecinii species was carried out to determine any significant effect on the pull out stress. Physical and mechanical characteristics of these two species used in the tests are shown in Table 1.

There are also differences of physical and mechanical characteristics within a single bamboo culm (Latif 1989). Therefore series of test were carried out to establish any significant effect of different portions of bamboo on pull out stresses. In these tests, each bamboo culm of 12 metres was divided into 3 equal portions namely bottom, middle and top. They were air-dried for 2 months under similar conditions. Soenardi 1988, observed an increase of tensile strength of about 1.3 percent per 1.0 percent decrease in moisture content.

Visual observation revealed that the nodes have relatively sharp edges arranged in such a way that they are facing upward (growth direction). Therefore it is expected that this distinct feature may influence pull out stress. Only bottom and middle portion were used in order to study the influence of pull-out direction. In the test, bamboos were laid in the growth direction and anti-growth direction. To be consistent, the number of nodes were kept constant for each bamboo specimen.

Series of tests were also carried out to establish the frictional interaction characteristic between bamboo and quarry dust. Normal stress of 30kPa, 60kPa and 90kPa were applied to obtained plots of shear stress versus normal stress.

The aspects of portion and pull out direction effects were conducted only on G. scorthecinii species.

3 DEVELOPMENT OF PULL OUT APPARATUS

Schematically, the pull out test apparatus set-up is shown in Fig 3, and consists of three major elements ie, pull out box, pull out mechanism and gripping mechanism, with a data logger connected to measuring instruments. The box is made of 10mm thick steel plate and rolled steel beams with welded and bolted connections. The inside dimensions of the pull out box are, 2000mm length, 400mm width and 400mm height. Uniform surcharge distribution is applied by pressing two hydraulic heads onto two 1000mm length x 400mm width x 33mm thick steel plates at the top of the box.

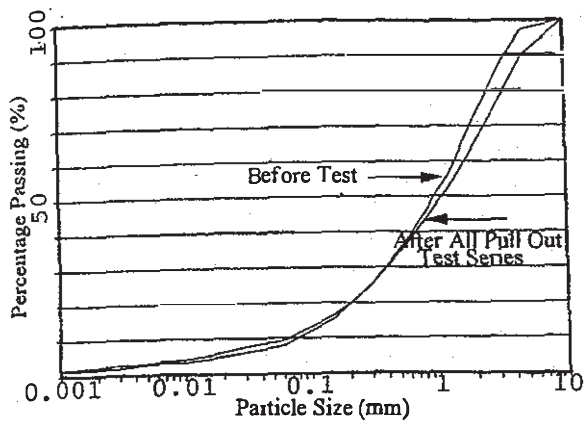

Fig.1 Grain Size Distribution (Ampang Quarry Dust)

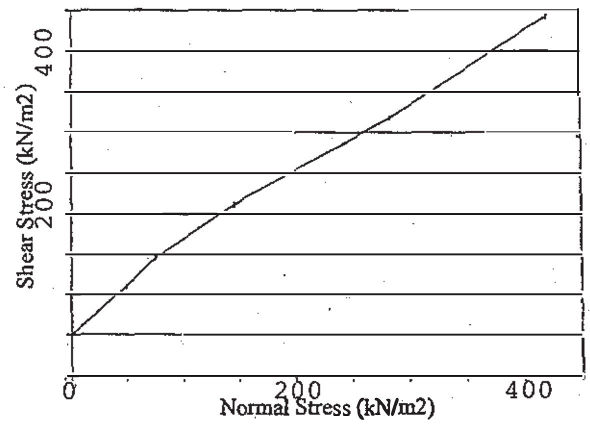

Fig.2 Shear Stress vs Normal Stress (Large Direct Shear Box - 300mm x 300mm)

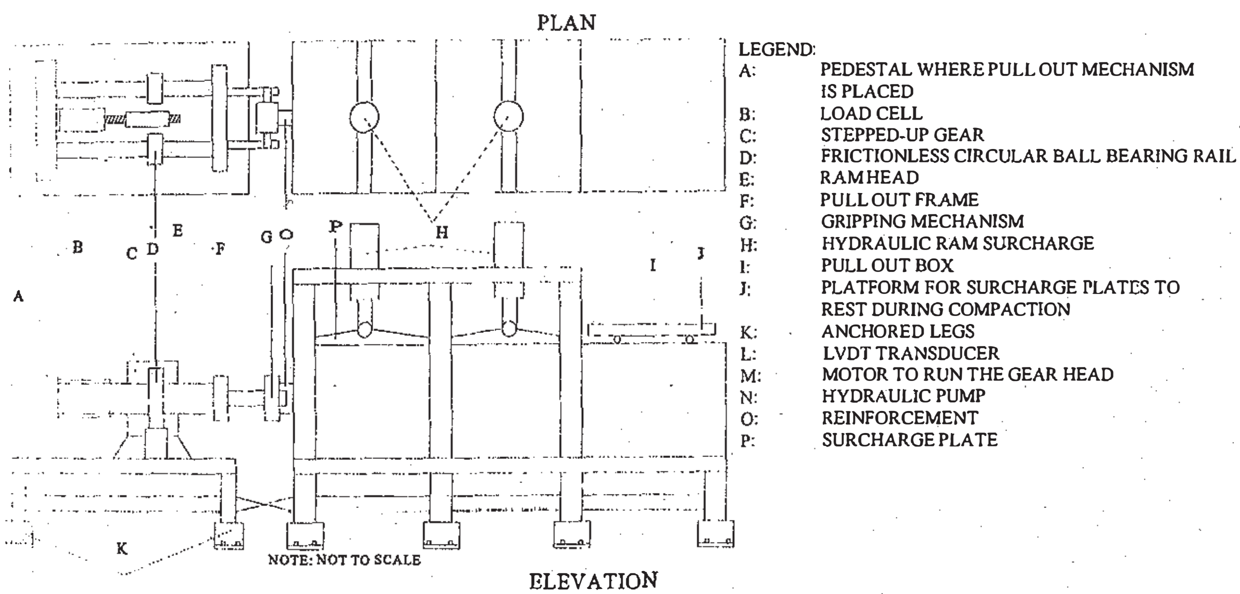

Fig 3 - Schematic of Pull Out Test Apparatus

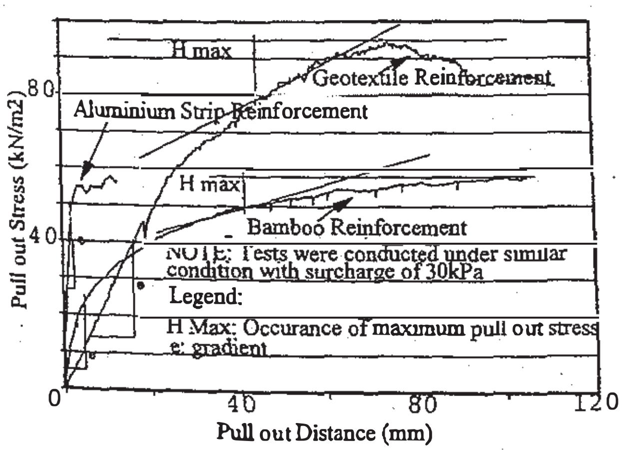

Fig.4 Pull out Stress vs Pullout Distance - Various Reinforcement Types

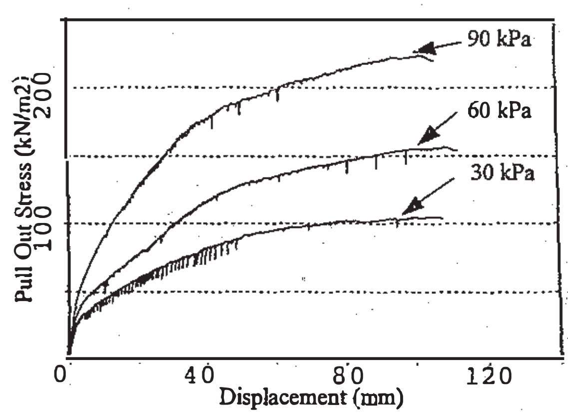

Fig.5 Pull out Stress vs Displacement of B. blumeana at Different Confining Pressure

Reinforcements are pulled out at a constant strain rate of 1mm/min. A tapered wedge and barrel gripping system is adopted, where wedges get tightened into the barrel as reinforcement is being pulled. Load cell of eight tonnes capacity and 100mm TML LVDT are used to measure pull out force and horizontal displacement and they are fully automated. Six (6) layers of backfill material, three layers before placing reinforcement and the other three layers after placing reinforcement were compacted with a modified vibratory hammer to produce a density of 19.8 kN/m3.

4 RESULTS AND OBSERVATION

The pull-out stress versus displacements plots for different types of reinforcement are shown in Fig. 4. The figure indicates that bamboo is stiffer than geotextile but less stiffer than metallic reinforcement. This may be due to the fact that bamboo is slightly deformable in term of shape when subjected to high confining pressure. Geotextile is expected to have much flatter initial gradient because it is highly extensible. It gives the highest maximum pull-out stress because that particular type of geotextile used has a much rougher surface. The small vertical drops in stress along the stress-displacement plot for bamboo were due to slippages in the gripping mechanism. This however did not affect the overall results as the gripping resumed immediately after each slippage.

The typical pull-out stress versus displacement plots at different confining pressures for B. blumeana and G. scorthecinii species are shown in Fig.5 and Fig. 6. From these plots, maximum pull out stresses against confining pressure for these two species are produced (see Fig. 7).

Fig. 7 indicates the apparent adhesion between both types of bamboo (B.blumeana and G. scorthecinii) and quarry dust are approximately 40kPa and 46kPa respectively. However B. blumeana produced a much higher angle of friction (i.e $58^{0)}$ compared to angle of friction produced by G. scorthecinii which is only 43^{0}. It seems that the apparent adhesions are slightly lower than the soil cohesion (from direct shear box test), but the angle of friction in B. blumeana is significantly higher that of G. scorthecinii. However the angle of friction in G. scorthecinii is about the same order of magnitude as the angle of internal friction obtained from the direct shear box test. The pull out resistance from bamboo is generated by friction between the bamboo surface and the soil as well as by the soil bearing at the nodes of the bamboo specimen. From Table 1., the difference between the average node diameter and the average internode diameter is in the order of 35% in B. blumeana and 25% in G. scorthecinii. This may explain the higher angle of friction in B. Blumeana. It can be said that the presence of nodes on bamboo enhanced the pull out resistance and the contribution is a function of the difference between node and internode diameter.

Tests conducted to investigate the portion effect indicate that the middle and bottom portion give greater maximum pull out stress compared to the top portion as shown in Fig. 8. This is because the middle and bottom portions contain more number of nodes for the same length of bamboo specimen. The top portion internodes lengths are about 20% longer than the middle and bottom portions. The pull out stress for the middle

Table 1 - Physical and Mechanical Properties of B. Blumeana and G.Scorthecinii Species Used

SPECIES	SAMPLE NO.	PORTION	AVG. INTERNODES LENGTH (CM)	AVG. INTRNODES DIAMETER (CM)	AVG. NODES DIAMETER (CM)	AVG. CULM WALL THICKNESS (CM)	ULTIMATE STRENGTH	
							COMP	TENS
G. scotechini	S 1	MIDDLE	61	7.3	9.1	0.63	56.1 N/MM2	392.4 N/MM2
		BOTTOM	58	7.7	9.6	0.92		
	S 2	MIDDLE	58	7.9	9.8	0.58		
		BOTTOM	48	8.1	9.9	0.87		
	S 3	MIDDLE	58	8.5	10.4	0.65		
		BOTTOM	54	8.3	10.3	0.96		
B. blumeana	D 1	MIDDLE	48	5.1	6.8	1.03	59.2 N/MM2	412.5 N/MM2
		BOTTOM	41	4.7	6.4	1.46		
	D 2	MIDDLE	48	4.8	7.1	1.05		
		BOTTOM	45	4.9	6.6	1.36		
	D 3	MIDDLE	47	5.1	6.9	1.10		
		BOTTOM	46	4.8	6.5	1.5		

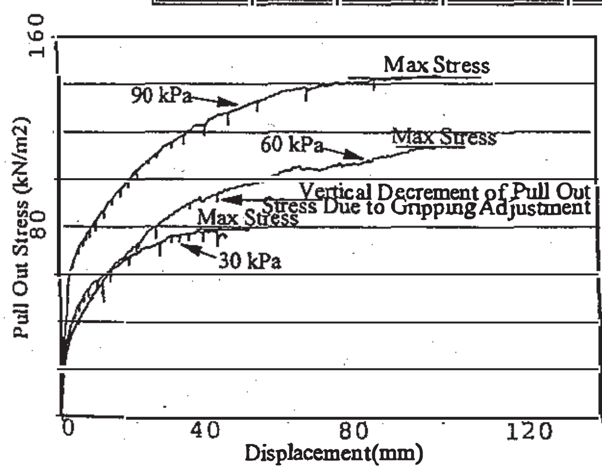

Fig.6 Pull out Stress vs Displacement of G. scorthecinii at Different Confining Pressure

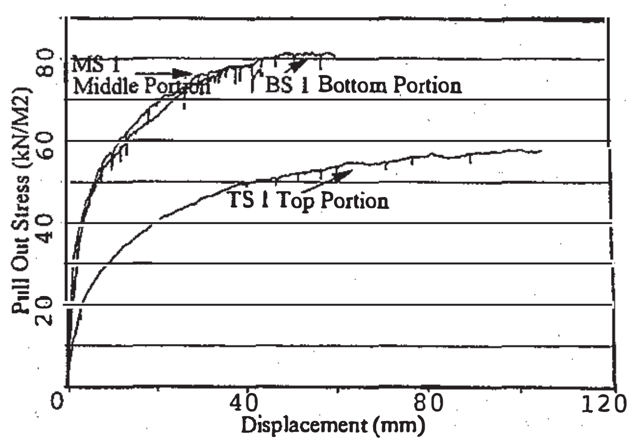

Fig.8 Pull out Stress vs Displacement of Different Portions of G. scorthecinii

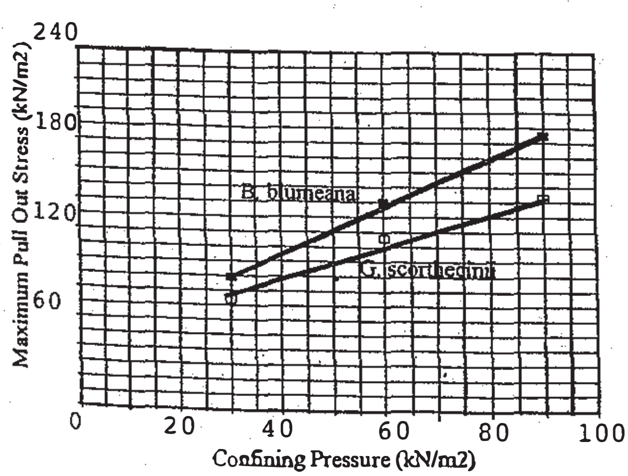

Fig.7 Maximum Pull out Stress vs Confining Pressure of B. Blumeana and G. scorthecinii

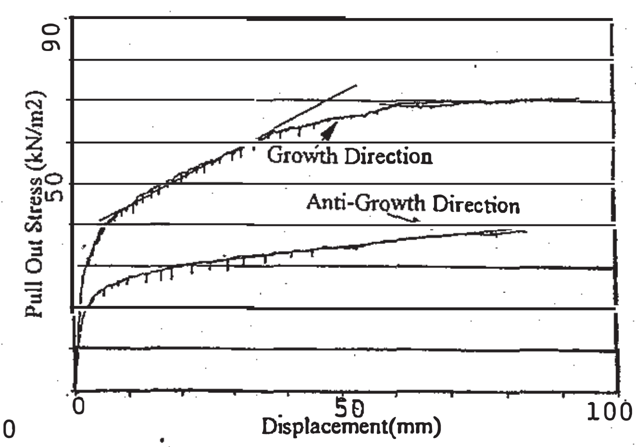

Fig.9 Pull out Stress vs Displacement of Different Pullout Directions on G. scorthecinii

portion is slightly higher than the bottom portion because the nodes' sharp edges are more distinct.

The results of tests for different pull out directions are shown in Fig. 9. It can be seen that pull out stress in growth direction is higher than anti-growth direction. The difference is in the order of 40% -50% of the maximum pull-out stress for the growth direction. This difference is caused by the fact that the sharper edges at the nodes are facing the growth direction.

5 CONCLUSION

Based on the results of the tests carried out, the following conclusions can be made:

1) In term of maximum pull out stress, bamboo gives the same order of magnitude as the smooth metallic reinforcement. It is less stiffer than metallic reinforcement but stiffer than geotextile.
2) B. blumeana is a better reinforcement than G. scorthecinii because it produces higher maximum pull out stress.
3) Overall size or diameter of bamboo should not be a selection factor for reinforcement in bamboo but the distinct physical factor should be considered instead.
4) Both the physical and mechanical properties of bamboo should be given equal consideration in the selection criteria of bamboo as reinforcement.
5) The frictional resistance of bamboo is influence by number of factors such as portions of bamboo and placement orientation.
6) The middle and bottom portions are more suitable portions to be used as reinforcements as they provide higher frictional resistance.
7) The bamboo should be placed in such a way that the direction of pull out is in the growth direction.
8) Even though the adhesion obtained from the pull out test is slightly lower than soil cohesion value (obtained from direct shear box), the angle of friction is more or less the same as the angle of internal resistance (obtained from direct shear box) in G. scorthecinii but significantly higher in B. blumeana.

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REFERENCES

Abd. Latif, M "Effect of Age and Height on Selected Properties of Three Malaysian Bamboo Species", Master's Thesis 1991.

Binquet, J " Analysis of Failure of Reinforced Earth Wall", Symposium on Earth Reinforcement, ASCE Annual Conventions, Pittsburgh, Pennyslavania 1979, pg 232-251.

E.M Palmeira and G.W.E Milligan " Scale and Other Factors Affecting the Results of Pull Out Tests of Grids Buried in Sand", Geotechnique , 1989 vol 39, No. 3, pg 511-524.

R.A. Jewel " Interaction Between Soil and Geogrids" Conference on Polymer Grid Reinforcement: 1984, pg18-29.