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Modeling of Geotextile in a Centrifuge Model Test.

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Abstract: The general principle of centrifuge model design is to reproduce similarly behavior of material for both in terms of strength and stiffness. Ideally the model reinforcement should be made up of the same material as that of the prototype reinforcement with all significant dimensions of reduced size. In this research, to model the prototype geotextile by the same material with ideal conditions was not available; therefor a nylon cloth was used as model geotextile. The physical properties and tensile strength were investigated to verify the scaling law in centrifuge model tests. It was found that to model geotextile in centrifuge model test can be achieved by using a simple fabric cloth, which has comparable material properties with prototype, instrumented with strain gauges. For property of interaction between soil and geotextile, it has to be studied further.

Introduction: There are many ways to get more clear understanding of the mechanism of reinforced embankments on soft ground. One of the powerful techniques is centrifuge modeling test which has been widely used in present day. The difficulty is to scale down the geotextile; no model can be a precise association of any particular structure in the field. It is necessary to evaluate significant prototype dimensions and properties, by multiplying up model parameters and separately considering whether there is a prevailing representative of real structures (Springman et al, 1992). For the extensible geotextile, quantifying the tension-extension distribution of the reinforcing elements is essential but it is usually difficult to achieve in practice. The main point of this paper is to investigate physical properties and tensile strength properties from the instrumentation of model geotextile, in preparation for centrifuge model tests of reinforced embankment on soft clay.

Physical Modeling: The basic of the woven geotextile structure is plain weave: the wrap and weft threads go 'one up' and 'one down' as shown in Figure 1. If all strands are simply taken to be circular section, the cross-section area of reinforcement/unit width of sheet, $A = \frac{\pi b_1^2}{4s_1}$. An ideal model, centrifuged at earth's gravity times N, would comprise identical materials with all significant dimensions scale down by a factor of N. Accordingly, the area A would be reduced by factor N, so that the strength T mobilized/unit width at any given strain would be reduced by factor N. If the material of reinforcement is the same, it can be achieved by reducing both strand diameter and spacing. In this research, to use the same material with prototype geotextile was not available, therefore, a nylon cloth was used to be model geotextile. From the geometric structure of prototype and model geotextiles observed by a microscope camera, the physical properties of model and prototype geotextiles are shown in Table 1. At 100g in centrifuge tests, the nylon cloth can be accepted since the physical dimensions are approximately scaled down by 100.

Tensile Strength Test: Tensile strength tests were conducted until failure to evaluate the strength and stiffness of uninstrumented model reinforcement 'in air' using a direct weight and simple clamping system. Figure 2 shows the device for the tensile strength tests of model geotextile. The sample size was 50mm wide (W) and 10mm long (L) for strip tensile test (ratio of W/L = 0.5). Six cycles of load were conducted until 50% of ultimate strain and then the sample was loaded to failure. The results of tensile force and strain from 6 samples are shown in Figure 3, combined with the regression curves for each sample. Up to 15% strain, the geotextile exhibits the bi-linear characteristic. At small strain the stiffness is smaller than that at large strain.

Instrumented Model Geotextile: In prototype scale, to evaluate the local stress and strain in geotextile may be achieved by several ways but it has proved difficult at model scale. The idea is to mount the strain gauge on the geotextile by a relative stiffness adhesive and then to cover it by a very thin and low stiffness protective material. When the geotextile is stretched, the bond between the geotextile and the material of the strain gauge helps in transferring the tensile strains in the geotextile to strain gauge material. The output from strain gauge can be interpreted in terms of tension in the geotextile by calibration. The epoxy resin was used to mount strain gauges on the geotextile and Vinyl tape was used for the protective material. Five strain gauges (120Ω, 11mm long) were cast at the position as shown in Figure 4.

In model scale, the stiffness of the adhesive and the protective material are not able to neglect, compared to the stiffness of the model geotextile. To find out the real strain occurring in the geotextile is based on the composite modulus of composite material. There is a very simple way to estimate the modulus of a composite material, which contains a volume ratio of stiff material, V_s, parallel with flexible material as shown in Figure 5. It is reasonable to assume that the stresses in the two components are equal, composite modulus can be calculated by the following equation.

$$E_{composite} = 1 \Big/ \left(\frac{V_s}{E_s} + \frac{(1-V_s)}{E_f} \right) \tag{1}$$

where V_s = Volume ratio of stiff material,

E_s = Modulus of stiff material,

E_f = Modulus of flexible material.

Although it is not obvious that this is a lower limit for the modulus but it cannot be less than this equation.

In centrifuge test, the strain gauges were placed unsymmetrical so it was necessary to check the influence of unsymmetrical of composite material. Three samples of model geotextile with 1, 3 and 5 strain gauges symmetrically and one sample which had 5 strain gauges at the same position as one used in centrifuge test, were pulled until failure. The composite moduli of all samples are compared with calculated value from Eq. (1) as shown in Figure 6. Figure 7 shows load-extension curves of uninstrumented and instrumented model geotextile, compared with a typical stress-strain relationship of prototype geotextile.

Conclusions: To model geotextile in centrifuge model test can be achieved by using simple fabric cloth, which has comparable properties with prototype, instrumented with strain gauges in term of material properties. In the case of interaction between soil and geotextile, it has to be studied in more detail.

References:

1. Springman, S.M, Bolton, M.D., Sharma, J. and Balachandran, S. 1992. Modeling and instrumentation of a geotextile in the geotechnical centrifuge. Proc. Int. Symp. On Earth Reinforcement Practice, Kyushu: 167-172.

Table 1 Physical properties of prototype and model geotextiles

Geotextile Prototype & Model	Type of geotextile	Area per unit width mm^2/m	Thick-ness mm	b_1& b_2 mm	S_1& s_2 mm
Kurashi #7895	Polypropylene	$23x10^4$	1.15	2.0	0.01
Cloth	Nylon	$35x10^2$	0.09	0.09	0.18

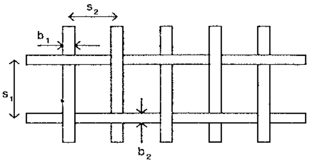

Figure 1 The basic structure of woven geotextile.

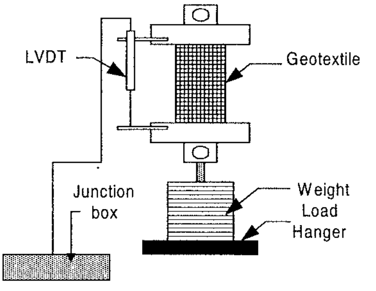

Figure 2 Set up of Tensile strength test

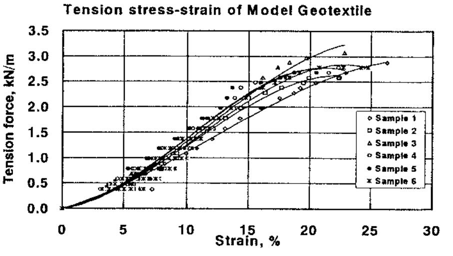

Figure 3 Load-extension curve of model geotextile

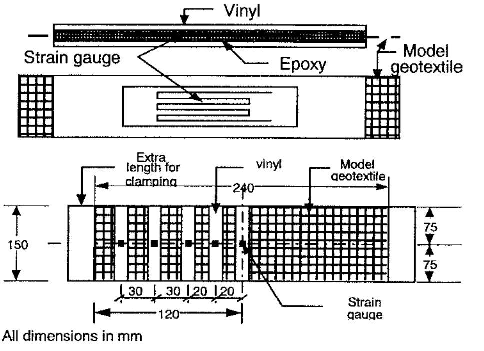

Figure 4 Strain gauges on model geotextile

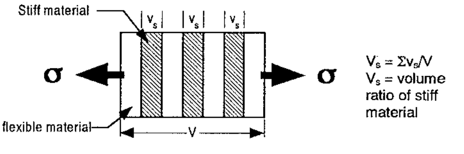

Figure 5 A composite material loaded (minimum modulus)

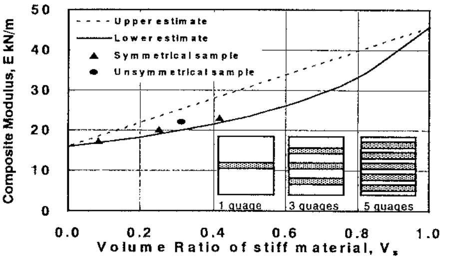

Figure 6 Composite modulus of model geotextile

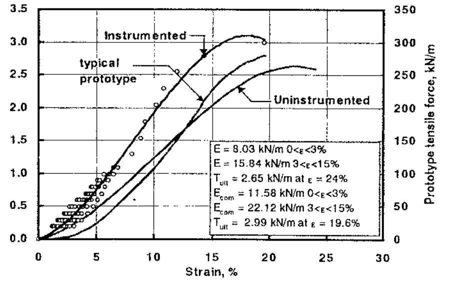

Figure 7 Load-extension curve of model compare with prototype