Performance of a Woven Geotextile Reinforced Retaining Wall in the Centrifuge

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ABSTRACT: The results of two centrifuge model tests on woven geotextile reinforced wrap-around retaining walls are presented. The tests were performed to investigate the wall behaviour at different gravity levels under a strip surcharge load, and also to validate the effectiveness of a tension load cell developed at Cambridge for the model geotextile. The maximum tension measured tallies well with the predicted values. A method is proposed to determine the tension distribution along the reinforcement, which is also used as the facing.

1 INTRODUCTION

Geosynthetic reinforced soil retaining walls have been widely used in geotechnical engineering. Their performance will depend upon the material properties and soil-structure interaction, which can be rather complex. Investigative experiments should be carried out at appropriate stress levels with extensive instrumentation because scaled-down '1g' models behave differently from a prototype due to inherent dilatancy (Bolton, 1986). Full scale field tests are possible, but they are also time consuming and costly.

The centrifuge provides an excellent alternative controlled environment, in which soil structures can be studied as scaled-down models, while preserving the stress state required to develop the appropriate soil properties (Schofield, 1980). The effects of dilation or contraction in altering the normal effective stress on strips or bars can only be investigated authoritatively in such centrifuge model tests (Bolton, 1990).

This paper summarises the results and analysis of two centrifuge tests that were performed on scaled-down woven geotextile-reinforced wrap-around retaining walls (Fig. 1) to determine the tension distribution along the reinforcement, under self weight and strip surcharge load pertaining to highway, railway and bridge abutments. The effect of cyclic loading (due to intermittent loading from heavy vehicles) on the reinforcement tension is also studied.

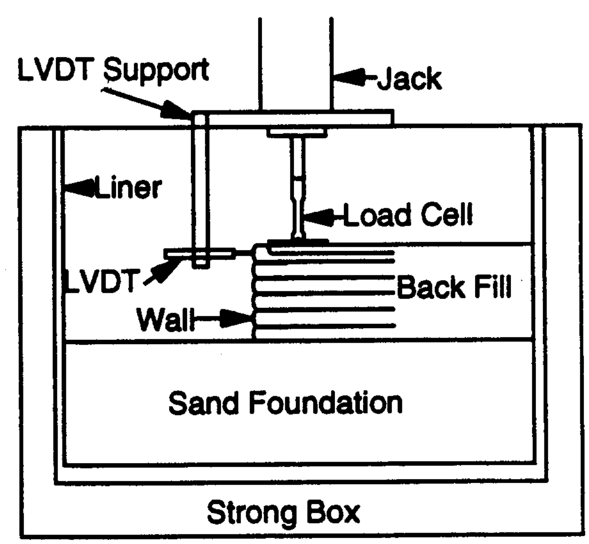

Figure 1 Model wall configuration

2 CENTRIFUGE MODELLING

To simulate prototype behaviour in the model as accurately as possible, model materials and dimensions should satisfy centrifuge scaling laws, and any boundary effects should be minimised.

2.1 Centrifuge scaling laws

Table 1 Centrifuge scaling laws

Parameter	Units	Scaling Relationship Prototype	Model
Gravity	m/s^2	1	n
Length	m	n	1
Area	m^2	n^2	1
Volume	m^3	n^3	1
Stress	kPa	1	1
Strain	%	1	1
Force	N	n^2	1
Deflection	m	n	1
Stiffness	kN/m	n	1

Table 1 summarises the prototype-model scaling factors for a model subjected to n gravities. The errors involved in transformation are small and are clearly explained by Schofield (1980). In reinforced walls, reinforcement tensile force per unit width T is defined as follows:

$$T = J.\varepsilon \quad (1)$$

where J is the tensile stiffness of the geotextile and ε is the reinforcement strain. The model-prototype strain should be the same, so model reinforcement stiffness should be n times less than the prototype reinforcement stiffness. Reinforcement modelling is explained by Springman et al (1992).

2.2 Model reinforcement

The model reinforcement is shown below.

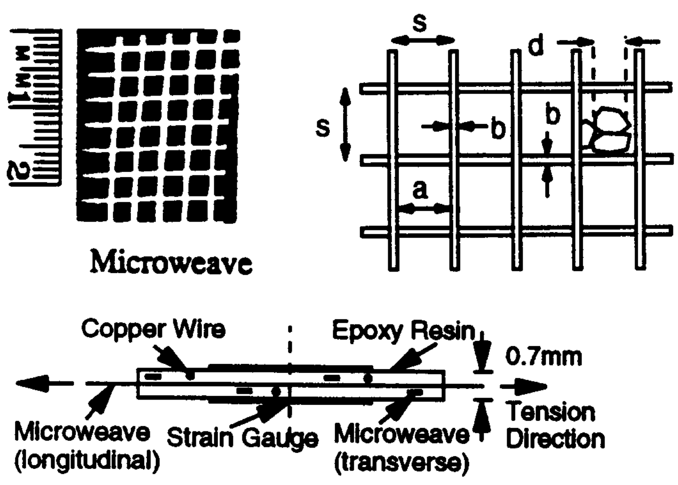

Figure 2 Model reinforcement with load cell

An ideal model centrifuged at n gravities, would comprise identical materials with all significant dimensions such as spacing between layers, diameter of, and spacing between, strands scaled down by a factor n. However, by keeping the strand as prototype diameter, b and increasing the spacing, s or by using a slightly weaker strand and selecting an appropriate spacing, the stiffness may be reduced by the requisite factor n. A key relationship will be the ratios of spacing s, to particle diameter d, s/d. Where s/d < 5, the soil particles will be trapped in the aperture so that a woven mesh acts as a perfectly rough sheet. Where s/d >>5, slip may occur at the woven joint and resistance will be reduced to adhesion on the longitudinal strands.

Extension tests on the model reinforcement, Microweave (b=0.7mm, s=3.35mm), were conducted 'in air' to failure to give the ultimate strength (U.T.S) and cyclically to estimate stiffness, using an Instron device, Fig. 3.

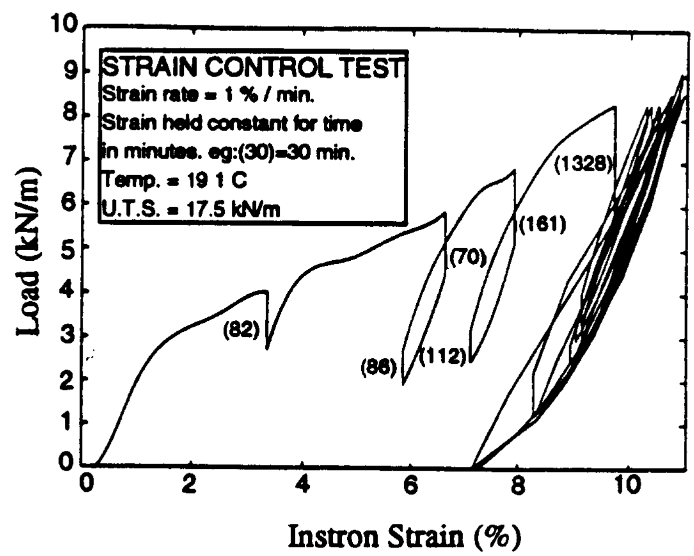

Figure 3 Tensile test: Microweave

The backfill material used was Leighton Buzzard 100/170 sand with mean size d_{50} = 0.12 mm, e_{min} = 0.613, e_{max} = 1.014, so s/d = 28, Critical angle of shearing resistance, $\phi = 32^o$.

A tensile load cell was developed at Cambridge, (Springman et al, 1992) by casting a thin stiff full width epoxy layer around the geotextile on which strain gauges were glued, Fig. 2. Strain measurement in the geotextile is complicated by creep and the localised strengthening caused by the epoxy resin. However a direct indication of tension is possible at discrete locations using this load cell.

3 TESTING PROCEDURE

3.1 Calibration of reinforcement load cell

Six layers of reinforcement were to be placed in the model wall and these were calibrated before each test by fixing both ends into clamps. The lower clamp was connected to a hanger and dead loads from 5kg to 20kg were maintained for a 5 min. duration at each 5kg loading step, then unloading was carried out by following the reverse procedure. Output voltages were monitored as this was carried out two more times, and it was observed that the repeatability was generally very high.

3.2 Model Construction

For both tests SB1 and SB2, a plane strain strongbox containing a liner of inner dimensions 675mm (length) x 535mm (height) x 192mm (width) was used for model construction. Grease was applied to both sides of the liner to reduce side wall friction and then a 200 mm deep sand layer was poured from a hopper to achieve 80% relative density. The model wall was constructed on top of this sand base. A temporary wooden support in six layers, shaped in the same configuration as the wall facing elements, was used to prevent lateral movement during construction and to maintain verticality.

The bottom wooden support was wedged in position. The first layer of instrumented reinforcement, was placed on top of the sand base and was wrapped around the inside of the wooden support. Sand was poured from a hopper to achieve 80% relative density. Coloured 100/170 sand was sprinkled at various levels to form a matrix of dots adjacent to the perspex for subsequent analysis of deformation. The first layer was formed by pouring 25mm of sand and then the reinforcement was folded over the completed sand layer to make the wrap-around construction. The second wooden support was located on top of the bottom one and this procedure was repeated until 6 layers of reinforcement and 150 mm in wall height had been placed.

The only difference between test SB1 and test SB2 was that 0.4mm thick greased latex rubber sheets were placed between the sand wall and liner to reduce the side friction acting on the wall.

3.3 Model testing

The model was tested on the Cambridge University 10m balanced beam centrifuge. A typical test procedure is shown in Fig. 4.

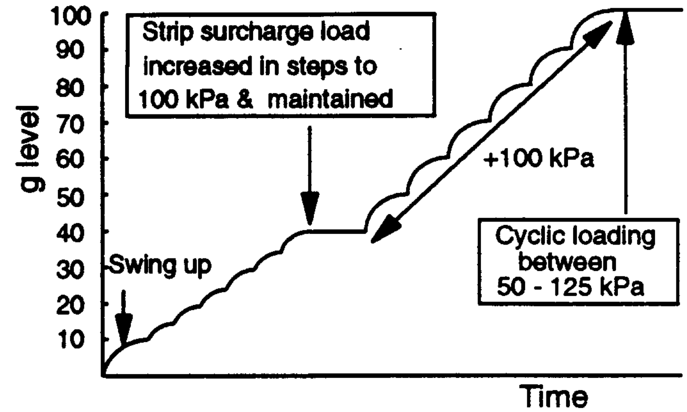

Figure 4 Typical test procedure

After each increment, which was held for 3 minutes to allow equalisation of the loading curve, photographs were taken of the deforming front face of the model wall.

4 TEST RESULTS

Results of centrifuge tests SB1 and SB2 (with latex liner) are shown in Figure 5: the tension distribution in the reinforcement layers at 40g + 100kPa and Figure 6: the tension distribution in the reinforcement layers at 100g +100kPa.

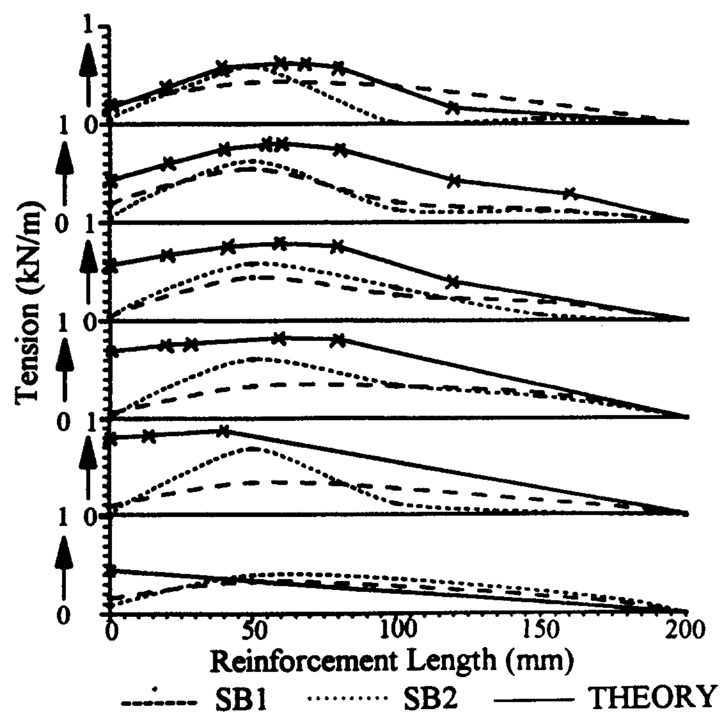

Figure 5 Tension distribution at 40g+100kPa

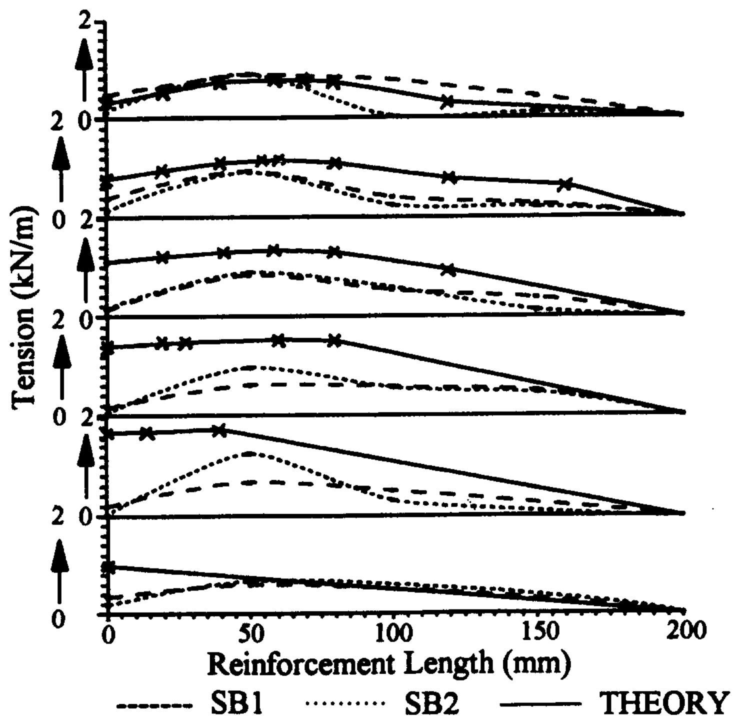

Figure 6 Tension distribution at 100g+100kPa

5 THEORETICAL CONSIDERATIONS

A simple theory is presented for immediate comparison, based on the following assumptions:

- Additional vertical stress due to the surcharge load is determined using Jurgenson's (1934) method.
- Tension at the face is generated by the active condition, and must drop to zero at the opposite end of each reinforcement layer.
- For sheet reinforcement, reinforcement tension, T is given by $K_a \times \sigma_v \times S_v$, where K_a is the coefficient of active earth pressure, σ_v is the vertical stress on the reinforcement level and S_v is the vertical spacing between reinforcement layers.
- Tension along the reinforcement at key points (marked by 'x' in Fig. 5 & Fig. 6) selected by inspection of the vertical stress distribution and allowing for zone separation at that location, is calculated using the above equation.
- Tension between these key points is assumed to have a linear variation.

It was apparent that the assumption of full active pressure at the wall face overestimates the tension measured. This may be due to some local reorientation of the stresses in the sand within the reinforcement wrap-around. This apparen relaxation at the face has also been observed l other experimentalists. However the prediction peak tension is generally conservative, with th best fit observed for reinforcement layers close t the top of the wall.

6 CONCLUSIONS

1. Centrifuge modelling provides an exceller way of examining soil-structure interaction a reinforced soil wall.
2. Loads cells have yielded experimental data reinforcement tension which has been we matched by simple theory.
3. Boundary effects due to side friction a significant (SB1 friction is generally great and more dispersed than SB2).

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