Finnish Georeinforcement Research and Development Project

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ABSTRACT: The research work was started in 1989 in co-operation with Viatek-Yhtiöt and Helsinki University of Technology. The main purpose of the project has been to develop a suitable practice for the use of synthetic reinforcing materials in Finnish conditions. The effect of cold climate and soft clay or peat subgrade which are significant in Finland have been emphasized. The investigations have included tensile tests, periodic load tests and creep tests (1000 h) at different temperatures. Investigations of the soil-reinforcement interface friction and plate bearing tests in a big laboratory soil basin have also been performed. A part of the test results is still under treatment and the work will continue with full-scale trial structures. The results of the study of soil-reinforcement friction are presented in an other article by Forsman and Slunga (1994).

1 INTRODUCTION

The research work was started in 1989 in co-operation with Viatek-Yhtiöt and Helsinki University of Technology. The main purpose of the work was to develop a suitable practice for the use of georeinforcements in Finnish conditions and the work has put emphasis on the effects of cold climate and soft soils. Versatile equipment for the testing of georeinforcements at low temperatures has also been developed.

Both textiles and grids were used in the tensile and creep tests at different temperatures. In addition the friction at the soil-reinforcement interface and the anchor capacity of reinforcements were studied. The results of these direct shear and pull-out tests in sand, crushed rock (CR) and expanded clay aggregate (LECA) are presented in another article (Forsman and Slunga, 1994) at this conference.

Plate bearing tests and numeric analyses are used to study the behaviour of reinforced model structures on peat subgrade in a soil basin.

The tests with full-scale trial structures will be started in 1995. This article includes a brief presentation of the laboratory tests.

2 STANDARD TENSILE TESTS

Compression jaws were used in the tensile tests. The standard (ISO DP 10319) test results in Table 1 agreed very well with the corresponding tensile test results provided by the manufacturers.

Tensile test results with different standards have varied many times and caused disagreements between the constructors and suppliers of products. Therefore the tensile tests for the quality control should be done according to a common standard and preferably using compression jaws.

Table 1 Tensile test results.

Type of Reinforcement	Strength (kN/m) / Strain (%) at Failure			
	ISO DP 10319	Other Temperatures		
	+ 20 °C	+ 50 °C	+ 5 °C	- 8 °C
Polypropylene - woven	123,1/13,9	111,3/14,9	134,1/18,3	132,8/14,9
Polyester - woven	208,5/10,2	194,7/8,4	209,5/8,2	226,8/9,3
Polypropylene - drawn grid	34,8/11,4	26,7/12,3	38,2/11,8	39,0/12,6
Glass (I) - woven grid	40,8/3,9		53,3/3,5	53,4/3,9
Glass (II) - woven grid	50,8/1,8	51,3/1,8		

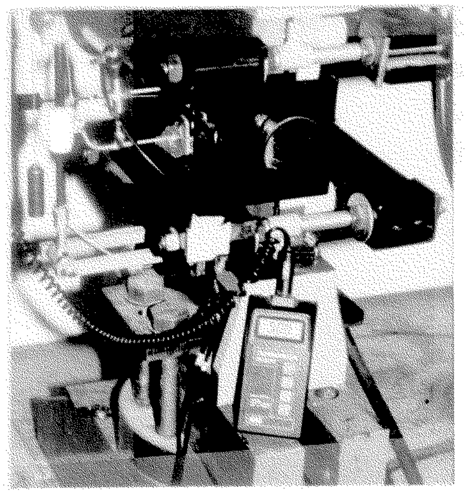

Figure 1 Compressive jaws with isolation box around the specimen.

3 TENSILE TESTS AT VARIOUS TEMPERATURES

The specimens were inside an isolated box during these strain controlled tests (Fig. 1). Temperatures of specimens were due to circulated warm or cold air and controlled with a thermometer installed on their surface. Each test started after the temperature of the specimen (+50°C, +5°C or -8°C) had become stable.

The strength of the glass grid seemed to be temperature independent. For all other tested materials the failure strengths seemed to increase with lowering the temperature, as shown in Table 1.

4 PERIODIC LOAD TESTS

The force controlled periodic load tests were done using the same equipment as in the earlier explained strain controlled tensile tests. After the periodic loading, each specimen was loaded to failure in the same way as during the standard tensile tests. The loading history of these tests is presented in Fig. 2.

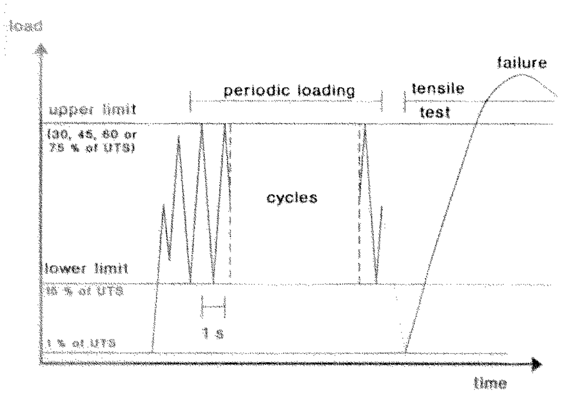

Figure 2 The scheme of periodic tests.

The failure strengths of the tested products are summarized in Table 2. The strengths of woven textiles increased due to the cyclic loading especially within the lower loading levels at normal temperature. The strength of woven textile made of polyester multi-filaments decreased within greater loading levels and at lower temperatures. The tensile strengths of polypropylene products (drawn grid and woven, tape-on-tape) seemed to increase due to the cyclic loading. The glass grid did not stand cyclic loadings very well.

Table 2 Tensile strength after periodic loading.

Temperature (°C) and Number of Cycles	Range of Applied Load	Polyester woven		Polypropylene drawn grid		Polypropylene woven	
	% of UTS	kN/m	% of UTS	kN/m	% of UTS	kN/m	% of UTS
1000	15 - 30	227,4	109	37,8	109	134,2	109
+ 20 1000	15 - 45	208,4	100	38,4	110	127,5	104
+ 20 1000	15 - 60	195,3	94	37,4	108	124,1	109
+ 20 1000	15 - 75	failed	---	34,8	100	126,4	103
+ 20 5000	15 - 30	227,1	109	37,6	108	130,4	106
+ 20 5000	15 - 45	192,8	93	39,2	113	128,7	105
+ 20 60000	15 - 30	214,4	103	36,4	105	129,8	105
+ 5 1000	15 - 30	200,4	96	49,4	129	128,8	96
+ 5 5000	15 - 30	198,9	95	47,7	125	132,3	99
- 8 1000	15 - 30	201,4	89	46,6	119	134,5	101
- 8 5000	15 - 30	204,9	90	50,3	129	138,4	104

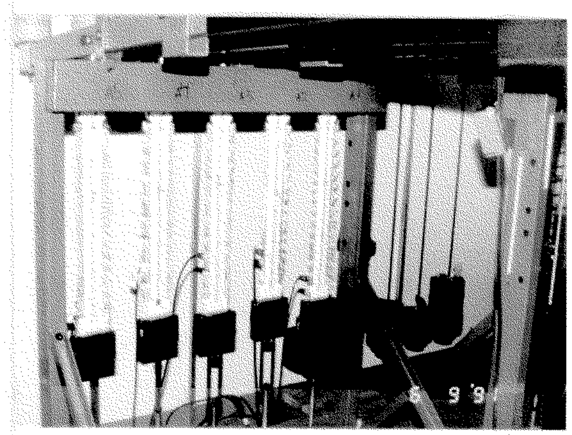

Figure 3 Creep test equipment.

5 CREEP TESTS

The creep tests were conducted using the equipment shown in Fig. 3. The creep tests were performed with four products at five temperatures (+50°C, +20°C, +5°C, -7°C and -20°C) and using five different load levels (15, 30, 45, 60 and 75 % of UTS). The length of specimens was 600 mm and the width was 50 mm or three tensile elements.

The strain in the middle of the specimen was measured using an electric extensometer with reference points at a distance of 250 mm from each other.
In addition, a device for optic measurements was installed on the specimens. The reference points of this device were at a distance of 500 mm from each other. After a quick load increment the creep tests lasted 1000 hours. The specimens were then unloaded to 1 % of UTS for 100 hours.

The effect of temperature on the total strain or creep of glass grid was negligible. In practice, the results were also the same when concerning woven polyester textile at normal temperature range (from +20 to -20 °C). For the products made of polypropylene the initial strain corresponding to the loading time 0,1 hour decreased by 50 % when the temperature decreased from +20°C to -20°C. Fig. 4 shows the significant influence of temperature on the creep of the drawn polypropylene grid.

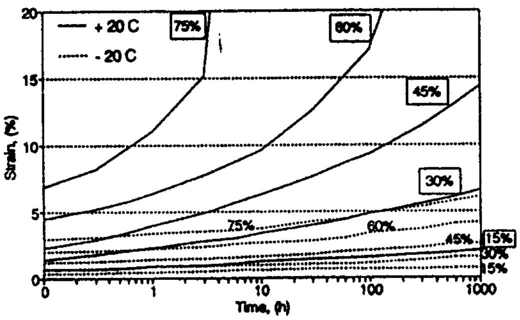

Figure 4 Creep test results for drawn polypropylene grid (loads are % of UTS).

6. MODEL TESTS IN SOIL BASIN

The model tests were done in a soil basin (Fig. 5a) where three different structures were made at same time, side by side, as shown in Figs 4b-g. The soft subgrade consisted of a torn compacted peat layer with a thickness of 0,5 m. The super structure was made of sand and in one case of light expanded clay aggregate and crushed rock. The used reinforcement products were: a woven polyester textile, a drawn polypropylene grid and a woven polyester grid. Some data of soils and reinforcements are given in Table 3.

The loading of a structure was performed as a plate bearing test. The diameter of the plate was 300 mm. The loading program included firstly two static loadings, secondly periodic loading with 10000 cycles and with the frequency of 1 Hz and finally again two static loadings.

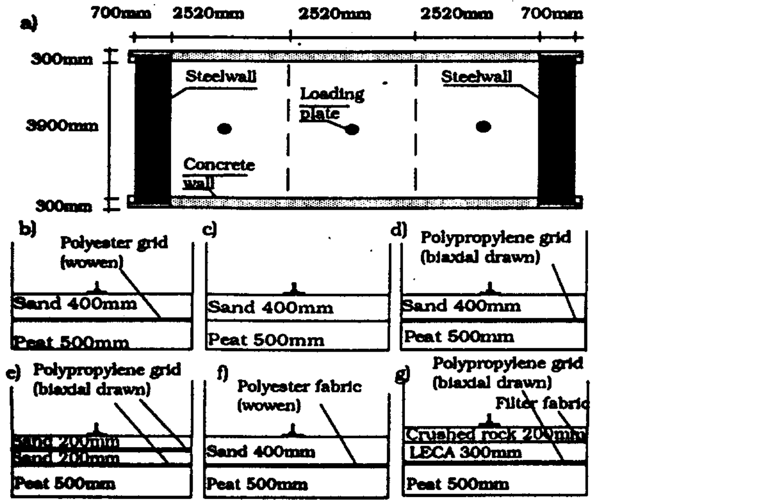

Figure 5 a) The soil basin and b)···g) different test structures.

Table 3 Data of reinforcements and soils used in test structures.

REINFORCEMENTS				
Type of Reinforcement	Secant Tensile Stiffness (kN/m)			
	J_{sec2}	J_{sec4}	J_{sec6}	J_{sec10}
Polyester, woven	1790	1770	2120	2110
Polyester, woven grid	430	300	300	380
Polypropylene, drawn grid	560	490	430	330

SOILS				
Properties	Peat	Sand	LECA	CR
Unit weigth, (kN/m³)	7	19	3	20
Cohesion, (kPa)	8	-	3	10
Friction angle, (°)	23	42	45	44

The last loading was continued until failure. Vertical stresses in the soil, horizontal displacements of reinforcements as well as relative strains of reinforcements were measured by transducers and strain gauges installed in the model structures. In addition, the vertical displacement of soil surface around the loading plate was measured. A part of test results are presented in Figs 6-8.
The test results seem to coincide with other model tests (Milligan et al., 1986) and results of numerical analysis (Rowe and Soderman, 1985).

Because of the soft subgrade the vertical displacements of soil surface were relatively large while the strains and mobilized forces measured from reinforcements remained small. A reinforcement between the soft subgrade and the sand did not significantly decrease settlements or increase the bearing capacity of the structure compared with an unreinforced structure in Fig. 5c.

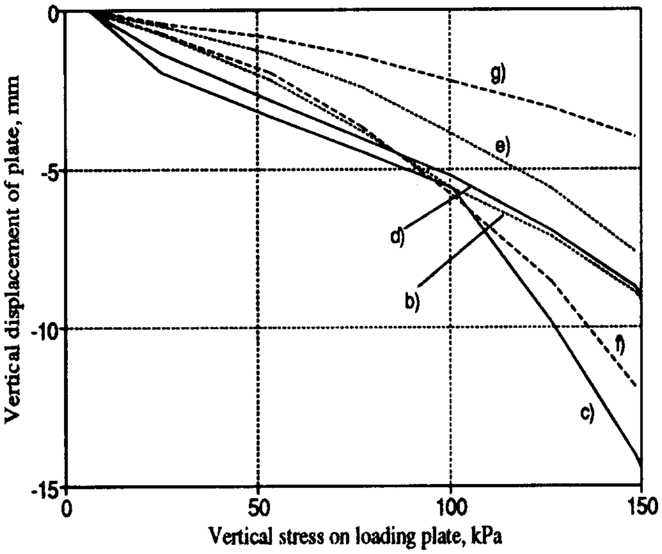

Figure 6 The vertical displacements of loading plate vs. vertical stress on loading plate at the first static loadings for the test structures shown in Fig. 5b-f.

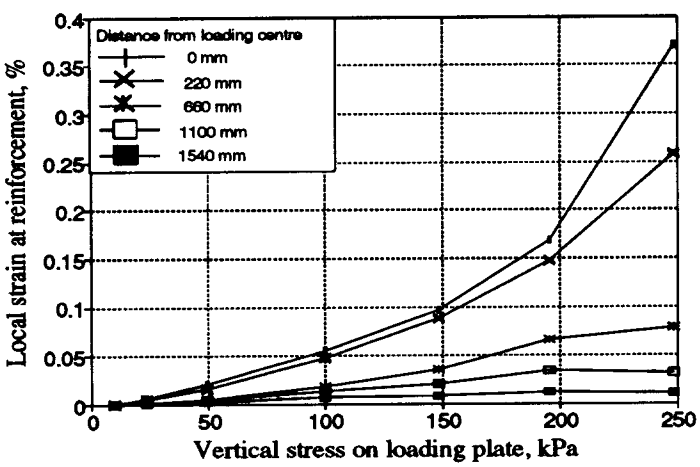

Figure 7 Strain of polypropylene grid during the first static loading (Fig. 5d).

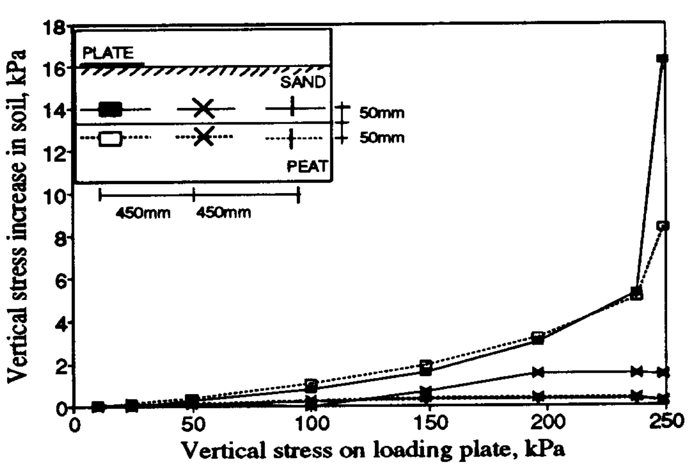

Figure 8 The increase of vertical stress in soil for the test structure in Fig. 5d.

In general, the positive effect of reinforcements was identified only after relative large settlements. The treatment of the test results was not finished when writing this article. After the periodic loading tests specimens of reinforcements for tensile tests were taken. The strengths of the grids did not decrease during periodic loading tests but the strength of textile was reduced by about 30 %.

7 CONCLUSIONS

The tensile test results show that the lowering of the temperature increases the tensile strength of reinforcements. The effect of temperature on the strain at failure is not so obvious. Further research is required for extending the knowledge of the behaviour of synthetic reinforcements at low temperatures.

During the periodic load tests the tensile strengths of reinforcements increased excluding the glass grid and woven textile made of polyester multifilaments within greater loading levels and at lower temperatures.

In creep tests an obvious decreasing of the rate of strain was seen as a function of the lowering of temperature.

The location of a reinforcement between a soft subgrade and embankment in structures which are loaded by traffic is not always the most favourable location from the point of view of the behaviour of the reinforcement. The reinforcement should, in many cases, be located closer to the traffic load.

Investigating the interaction between reinforcement and soil in laboratory is important. In particular, more instrumented model tests with different structures should be done.

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