A LARGE SCALE SHEAR TEST FOR DETERMINING THE BEARING BEHAVIOUR OF SOIL NAILS IN COHESIVE SOIL

ESSAI DE CISAILLEMENT EN GROS PLAN POUR DÉTERMINER LA CAPACITÉ DE PORTANCE DE CLOUS DE SOL DANS UN SOL COHESIF

EIN GROSSVERSUCH ZUM TRAGVERHALTEN VON BODENNÄGELN IN BINDIGEN BÖDEN

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Summary: A report is given about a large scale shear test on a soil nail in cohesive soil. It was the aim of the test to determine the bearing behaviour of the nail by means of mounted strain gauges. The nail (steel pipe) was installed in loess in a shear box with a shear plane size of 1 m x 2 m and submitted to shearing. The test results show that already at low shear displacements the yield point of steel is reached if the nail is placed perpendicular to the shearing surface. The resistance to shearing is very small. Calculation methods for soil nailing in which nails as well as tensile forces should carry bending moments, don't correspond to the real bearing capacity.

Zusammenfassung: Es wird über einen Großscherversuch an einem Bodennagel in bindigem Boden berichtet. Der Versuch diente dazu, das Tragverhalten des Nagels mit Hilfe von aufgeklebten Dehnungsmeßstreifen zu ermitteln. Der Nagel (Stahlrohr) wurde in einem Schergerät von 1 m x 2 m Scherfläche in Löß eingebaut und abgeschert. Die Versuchsergebnisse zeigen, daß bereits bei geringen Scherverschiebungen die Fließgrenze des Stahls erreicht wird, wenn der Nagel senkrecht zur Scherfläche angeordnet wird. Die Aufnahmefähigkeit für Querkraftbeanspruchung ist sehr gering. Bemessungsansätze für Bodenvernagelungsmaßnahmen, die den Nägeln außer der Aufnahme von Zugkräften auch eine Momentenaufnahme zuweisen, sind also dem tatsächlichen Tragverhalten nicht angemessen.

Résumé: Un rapport est donné sur un essai de cisaillement en gros plan sur un clou de sol dans un sol cohésif. Il est le but de l'essai de déterminer la capacité de portance de clous par des extensomètres montés. Le clou (tube an acier) dans un dispositif de cisaillement avec un niveau de cisaillement de 1 m x 2 m a été installé dans le loess et soumis à des efforts de cisaillement. Les résultats d'essai montrent que déjà lors de déplacements de cisaillement minimes la limite d'élasticité de l'acie est atteinte si le clou est placé verticalement à la surface de cisaillement. La résistance au cisaillement vertical est très petite. Les méthodes du calcul pour le clouage de sol selon lesquelles

les clous devraient résister à côté des forces de traction aux moments fléchissants, ne correspondent pas à la capacité de portance réelle.

Key words: Soil nails, large scale direct shear test, bearing behaviour, cohesive soil

1. INTRODUCTION

The stabilization of steep slopes (e.q. foundation trench walls) using "nailed" supporting constructions is a construction method which found entrance into the practice about 10 years ago in Germany mainly in the southern part. In other countries - France, Great Britain, Japan, USA - this construction method is also used. The stabilization of landslide-endangered slopes using soil nails, often in connection with a cement grout injection, is a method which has been used for a long while [1], [2]. The prinicples of using soil nails (see fig. 1) is to bring unstressed tension rods (structural steel, pipes, and quite recently even glass fiber rods) in boreholes, which are bonded with the surrounding soil using cement grout. When a shear displacement in the region of the nails takes place, some load is carried by the nails and the soil body is stabilized.

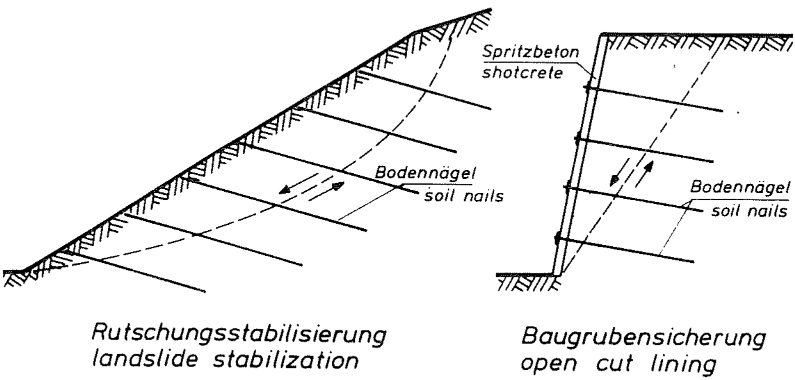

Fig. 1 Stabilization of soil bodies using soil nails

The calculation of nailed supporting constructions in Germany usually is carried out using a hypothesis in which the retaining forces act as tensile forces in the nail, which are transferred to the soil by shear bonds between the steel surface and the grout resp. the grout and the borehole surface. Proposals for a calculation method are given in [3] and [4]. There are also hypotheses which allow shear forces in the nails. Observations on nailed slopes, in which the nailing direction was chosen in a way that firstly shear forces are activated, point out, that the bearing capacity for this type loading is comparatively low. Fig. 2 shows schematically the loading of a nail which is sheared normal to the nail axis.

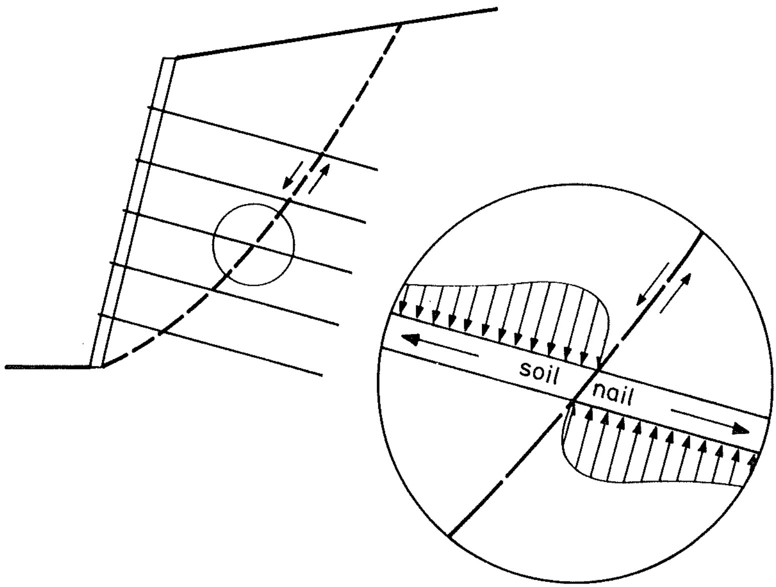

Fig. 2 Stressing of a soil nail penetrating a slip plane

In order to use the bearing capacity of the nails in a soil nailing work as effectively as possible they must be orientated in a direction such that they start to carry load at an early stage and as far as possible that all nails are loaded at the same time. Therefore a knowledge about the loading in the nails is necessary. In order to determinate the loading conditions in a pipe soil nail, as it is used often in Germany for landslide stabilization purposes, a pipe soil nail was installed in cohesive soil in a large shear box and then sheared off. The test results are dealt with in the following.

2. TESTING APPARATUS AND TEST PERFORMANCE

Shear box

The test was carried out in a large shear box with a shear plane size of 2 m x 1 m. The device consists of iron frames IPB 100 piled up one over the other and then screwed vertically. The maximum height of the box is 4 m.

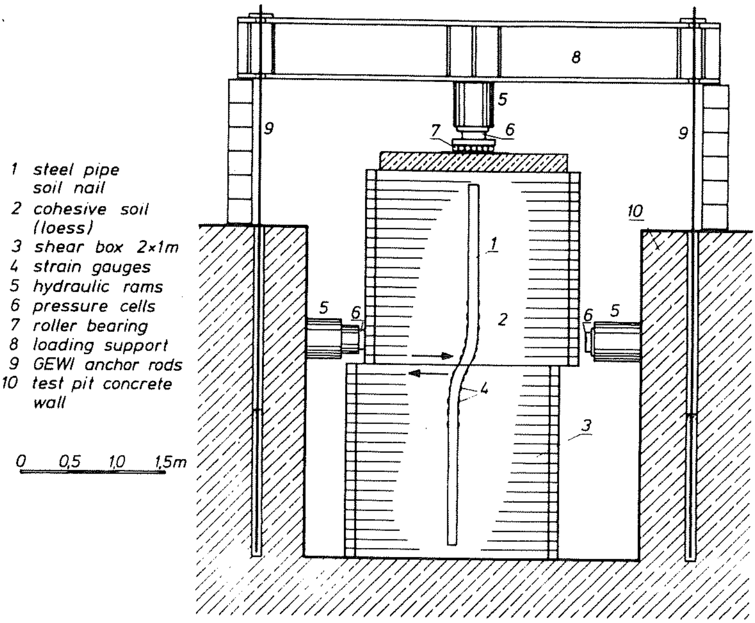

Fig. 3 Cross-section of the testing apparatus

Shear displacement is produced pushing the upper part of the box against the lower. For this purpose hydraulic rams are used which are supported against the wall of the test pit, in which the device is installed. The normal force in the slip plane is produced using a hydraulic ram which is supported against a heavy steel profile cross-beam over the shear box. The cross-beam is held down by steel rod anchors fixed in the concrete of the test pit wall. Fig. 3 shows a cross-section of the shear box and test pit.

Test soil

For the test a loess soil taken from a site of the new express railway Mannheim-Stuttgart near Pulverdingen was used. The loess had the following parameters:

consistency:	stiff to half-firm
lime content:	6,4 %
water content:	21,5-24,0 %
Proctor-density:	17,2 kN/m^3
shear-strength (in a shear-box 6 cm x 6 cm) friction angle:	ϕ = 37 °
cohesion (at 21 % water content):	c = 19,2 kN/m^2

Fig. 4 shows the grain size distribution of the soil. The soil was placed in layers of 20 cm - 25 cm thickness in the shear box with an average water content of 21,5 % and then compacted using a fixed procedure with an electric tamper (tamping area 25 cm x 30 cm). An average density (dry) of 17,3 kN/m^3 was achieved, which was checked during the filling of the shear box several times.

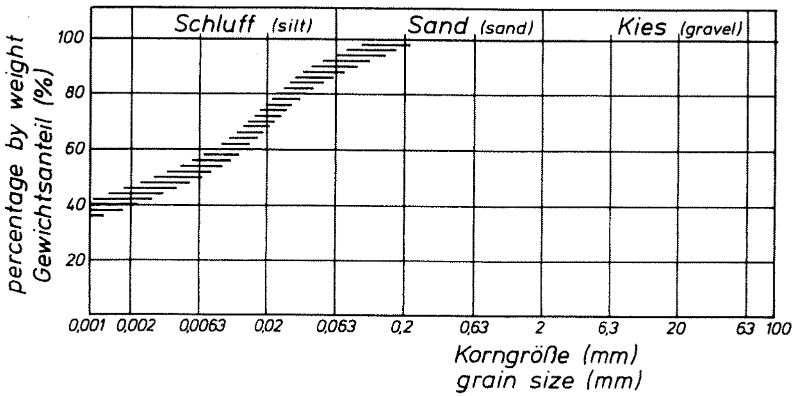

Fig. 4 Grain size distribution of the test soil

Test soil nail

A weldless steel pipe according to DIN 2440 was used as soil nail. The pipe had an outer diameter of 60.3 mm and a wall thickness of 3.65 mm. Along two diametrically opposite lines (in shear direction) strain gauges were mounted in order to measure the extreme fibre strains during progressing shear displacement. These strains were used to calculate the loads, divided in bending moments and shear forces.

Testing procedure

The test was carried out using a constant shear displacement velocity of 1 mm/min. The test values were recorded and stored electronically. Before the test with the nails was carried out a shear plane was formed in the soil by shearing the sample backwords and forwards several times to determine the residual strength of the soil alone. A comparison of the shear strength before and after nailing allowed a calculation of the contribution of nails to the shear resistence.

3. TEST RESULTS

Fig. 5 shows the nail section near the shear plane after the test.

Fig. 5 Nail section near the shear plane after the test

Fig. 6 shows the extreme fibre strains and extreme fibre stresses along the test nail as a function of the shear displacement.

Fig. 7 shows the bending moments and shear forces calculated from the values of fig. 6.

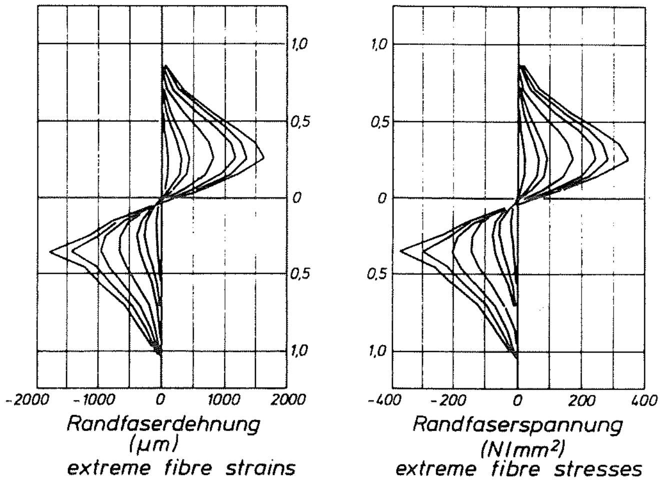

Fig. 6 Extreme fibre stresses and strains along the test nail

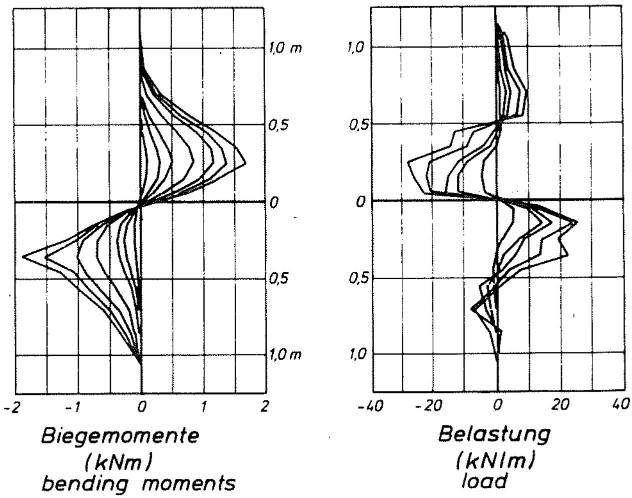

Fig. 7 Bending moments and shear forces along the test nail

A shear displacement of 30 mm already leads to an exceeding of the yield point of the steel (about 235 N/mm^2). The maximum bending moments are found in about 30 cm distance from the shear plane for the test combination of soil and nail used here.

4. CONCLUSIONS

The effectiveness of a soil nailing measure depends very much on the choice of the direction of the nails. If the nails are placed normal to the (expected) shear plane they are loaded by shear forces which lead to the exceeding of allowable the yield point of the steel after comparatively small shear displacements. All calculation hypotheses in construction world are aimed at keeping stresses well below the yield point. If a stability analysis for the stabilization of an active land slide using soil nails is based on taking advantage of the nail shear forces it is therefore not in accordance with the acknowledged rules of construction world.

When steel elements are used for stabilizing landslips it is important that they are permanently protected against corrosion. With the stabilizing method discussed in this article this permanent protection is only present when the slip displacements are small. Large slip displacements cause cracking and rupture of the cement grout round the outside of the steel elements and its corrosion protective properties are lost.

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