GEOTECHNICAL ASPECTS AND OBSERVATIONS OF A QUARRY RECLAMATION

GEOTECHNISCHE ASPEKTE BEI DER WIEDERVERFÜLLUNG EINES STEINBRUCHS

ASPECTS GEOTECHNIQUES DU REMPLISSAGE D'UNE CARRIERE

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SUMMARY

A disused quarry was refilled with mainly cohesive soil from excavations from the local area. During the refilling slip movements took place. The stabilisation methods used and the measurement and analysis of the movements that took place during the filling are described.

ZUSAMMENFASSUNG

Ein ausgebeuteter Steinbruch sollte mit bindigem Material aus der Umgebung – überwiegend Löss- und Verwitterungslehmen – verfüllt werden. Bei der Verfüllung traten trotz der Stabilisierungsmaßnahmen (Sandwichbauweise und Geokunststoffbewehrung) Rutschungen und größere Bewegungen auf. Eine Ergänzung dieser Maßnahmen durch Betonscheiben und einen Schotterfuß reduzierte die Verschiebungsgeschwindigkeit auf das bei Erddeponien übliche Maß. Durch die Langzeitbeobachtungen wurde es möglich, ein Kriechgesetz für die Bewegungen anzugeben.

RESUME

Une carrière désaffectée a été remplie avec des excavations de la région, principalement des sols cohérents. Pendant le remplissage, des glissements ont eu lieu. Les méthodes de stabilisation employées sont décrites, ainsi que les mesures et l'analyse des déplacements qui ont eu lieu pendant le remplissage.

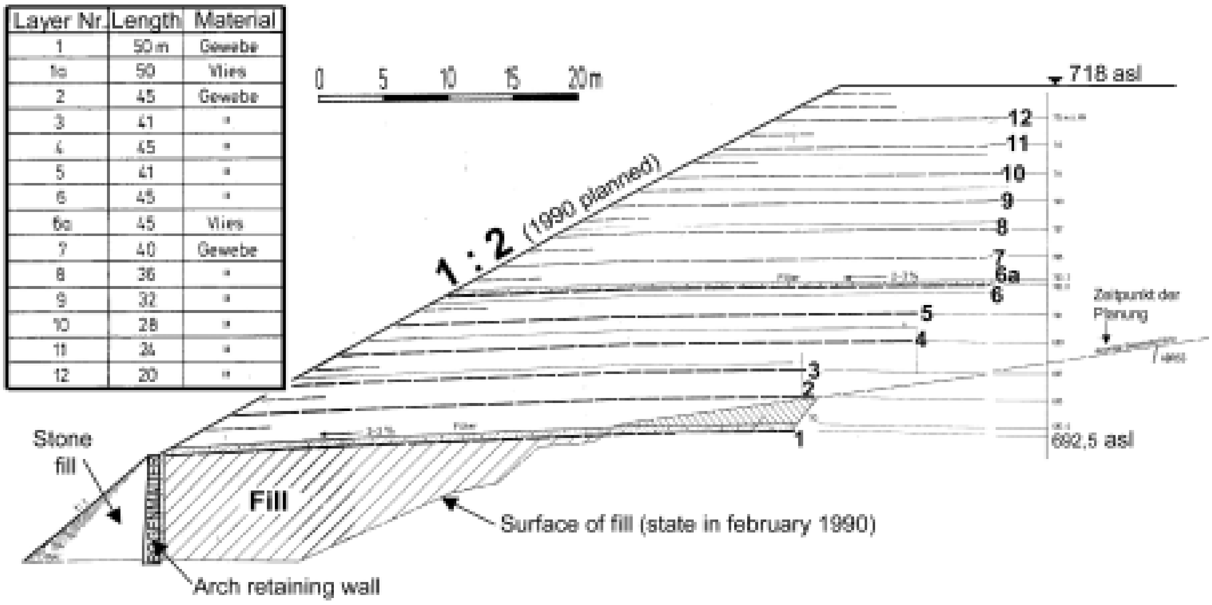
KEYWORDS: Limestone quarry, slip movement, stabilisation, refilling, geotextiles

1. INTRODUCTION

In 1985 it was decided to refill and recultivate part of a limestone quarry in the south west of Germany near Neuffen in the state of Baden-Württemberg. The quarry had been used for the production of crushed limestone mainly for the use in road construction. An aerial photograph of this stage of the refilling is shown in fig. 1.

Fig. 1: Aerial photograph of first stage of refilling 24.4.1988

In 1989 it was decided to refill a further part of the quarry. It was soon realised that the planned slope of 1:2 was not possible using conventional earth works construction methods so an arched retaining wall was planned at the foot of the slope and the fill was to be reinforced using geotextiles. The refilling was to be carried out using mainly cohesive soil from excavations in the vicinity. A cross-section of the planned refilling is shown in fig. 2. Later the slope was flattened to 1:2.5.



Layer Nr.	Length	Material
1	50 m	Gewebe
1a	50	Vlies
2	45	Gewebe
3	41	"
4	45	"
5	41	"
6	45	"
6a	45	Vlies
7	40	Gewebe
8	36	"
9	32	"
10	28	"
11	24	"
12	20	"

Fig. 2: Cross-section of second stage of the refilling 1990

2 SLIP MOVEMENTS AND STABILISATION

In November 1997 it was noticed that relatively large slip movements must have taken place because a natural stone wall surrounding a manhole had been deformed considerably. (see fig. 3). The refilling was not complete at this time.

Fig. 3: Deformed natural stone wall

It was therefore decided to set up a grid of measuring points to observe the movements of the slope. The grid points are shown in fig. 4.

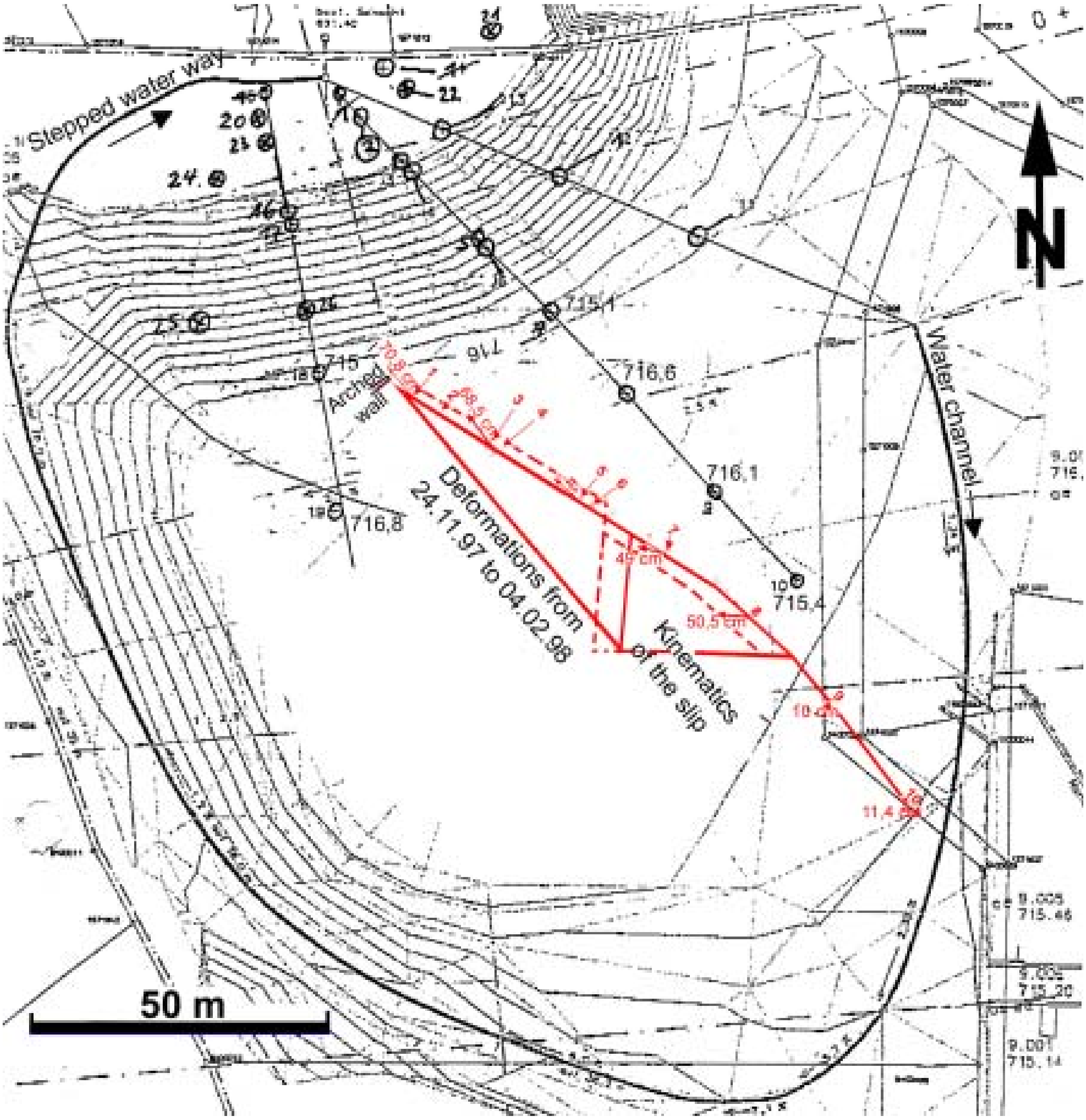


Fig. 4: Plan of grid points used between 24.11.97 and 21.11.00

The first measurement took place in November 1997. After the first two measurements with a weeks difference between them it appeared that the deformation rate was slowing down. It had reduced from 9mm/d to 5mm/d. In the third week however the speed increased to 20mm/d so it was decided to increase the factor of safety by stabilising the foot of the slope using concrete buttresses with crushed rock between them as shown in figs. 5 and 6.

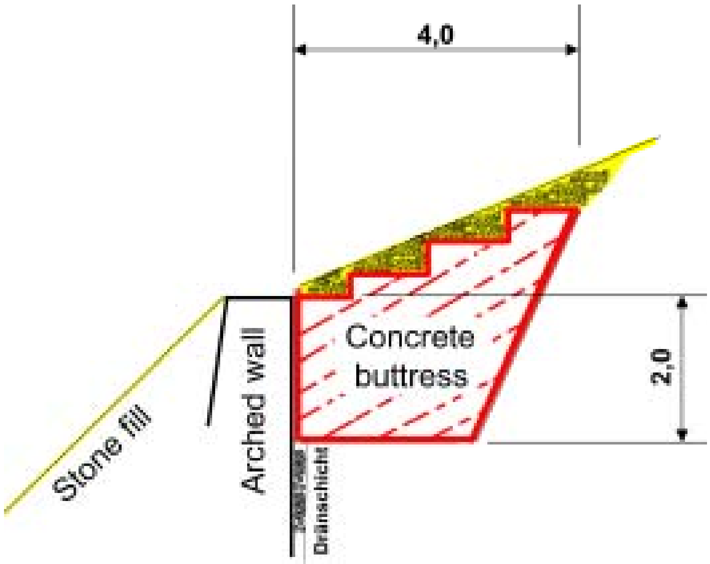


Fig. 5: Section through concrete buttress

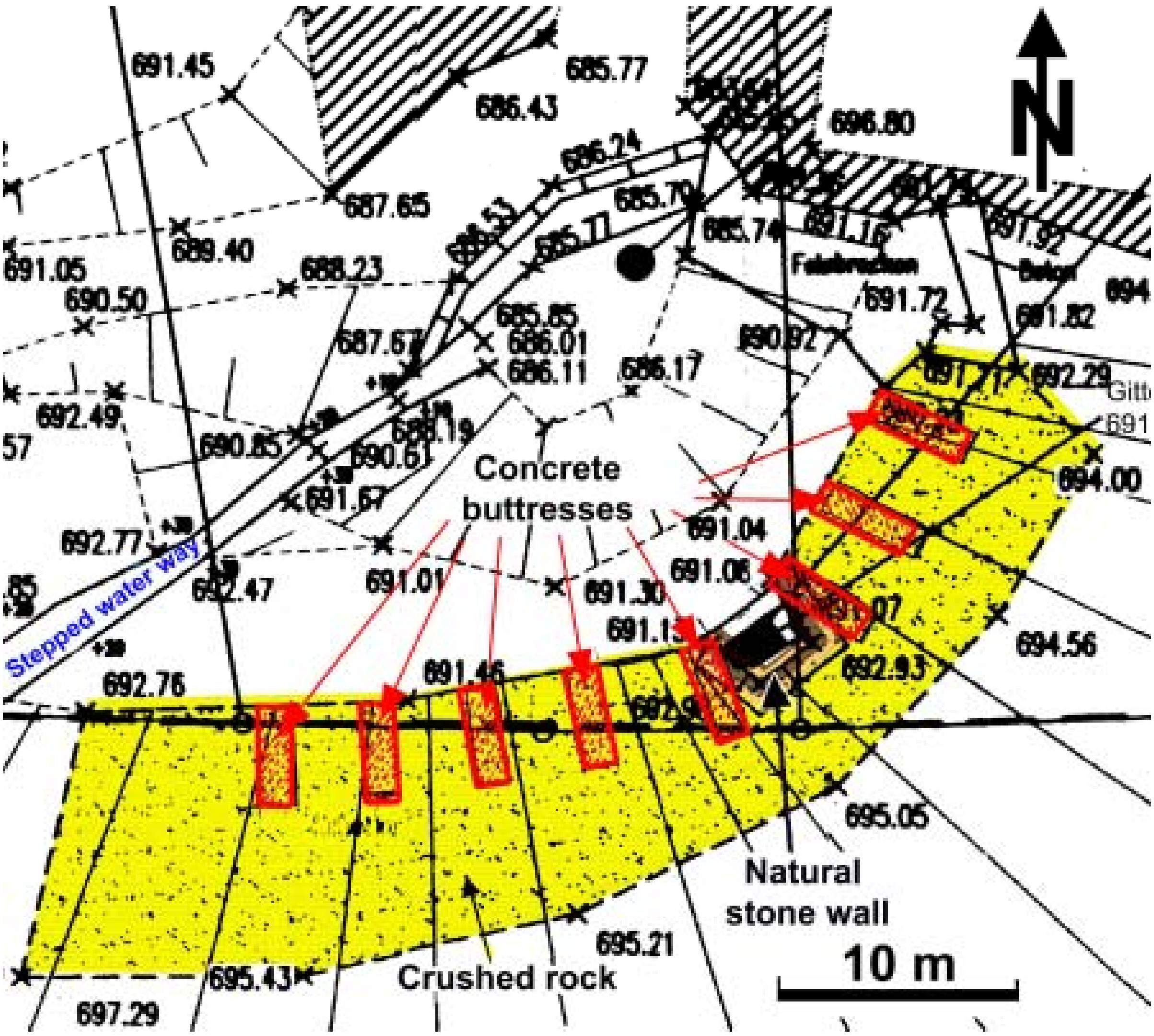


Fig. 6: Plan of concrete buttresses with crushed rock filling

The concrete buttresses were used as a supporting element and the crushed rock as a drainage. Grid point measurements on the 23.12.97 showed a further increase in the deformation rate (37mm/d). It was therefore decided to fill the volume between the concrete buttresses with a well graded crushed rock instead of the coarse crushed rock as planned. The deformation rate slowed down considerably (see Section 3). At first it was not clear whether this was due to a frost period between 21.1.98 and 4.2.98.

A slope stability calculation showed that for a factor of safety of 1.0 the shear parameters in the horizontal direction have to be $\varphi = 10.21°$ and c = 0 kN/m² and in the vertical direction $\varphi = 20°$ and c = 0 kN/m² (see fig. 7).

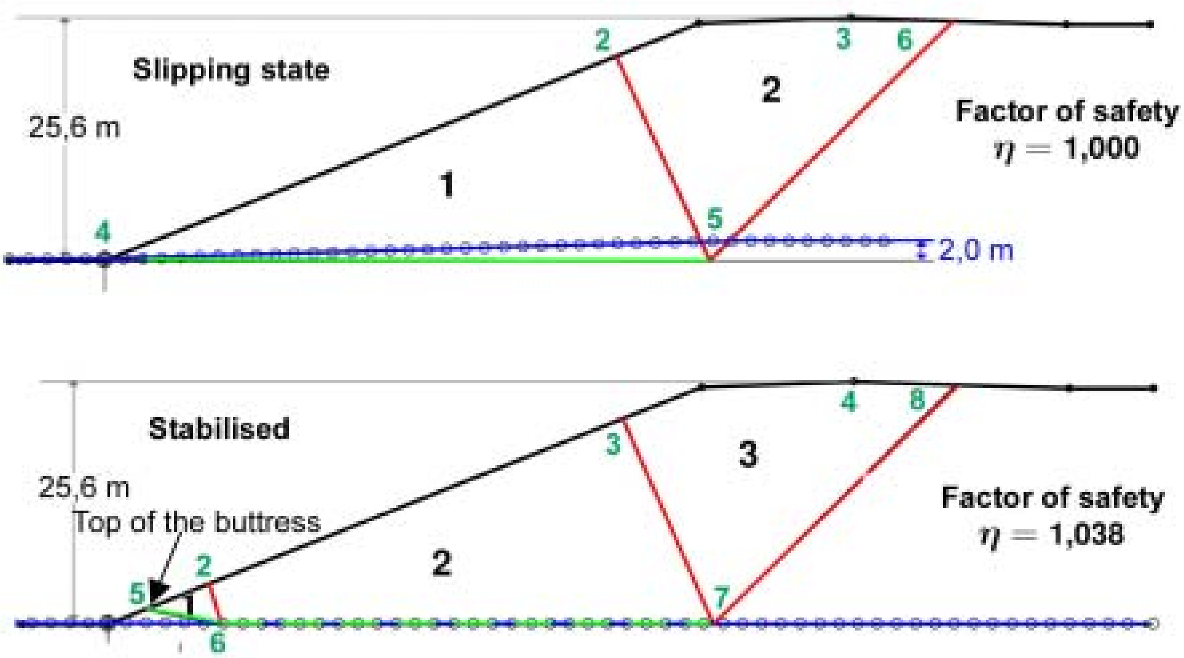


Fig. 7: Elements for slope stability calculations

Calculations with the Kinematical Elements Methods (Gussmann et al. 2002) for the stabilised state showed that the increase in stability factor due to the concrete buttresses and the lowering of the water table by 2m was relatively small (0.04). In the long term however an increase in the shear strength due to consolidation and "age hardening" is to be reckoned with. Under the phenomena "age hardening" is understood that when a cohesive soil is placed, especially in wet weather, there is a relative large amount of water between the soil aggregates and the soil is very soft or even "liquid". In the course of time this free water is absorbed by soil aggregates. This reduction in free water leads to an increase in strength.

3 RESULTS OF DEFORMATION MEASUREMENTS

The deformation measurements are divided into two phases:

- Phase 1 between 24.11.97 and 22.11.00
  In this phase the 19 grid points were placed. Some of these were damaged during the earthworks and had to be replaced.
- Phase 2 between 22.11.00 and 4.4.00
  After the earth works were completed new grid points were put in place (see fig. 8).

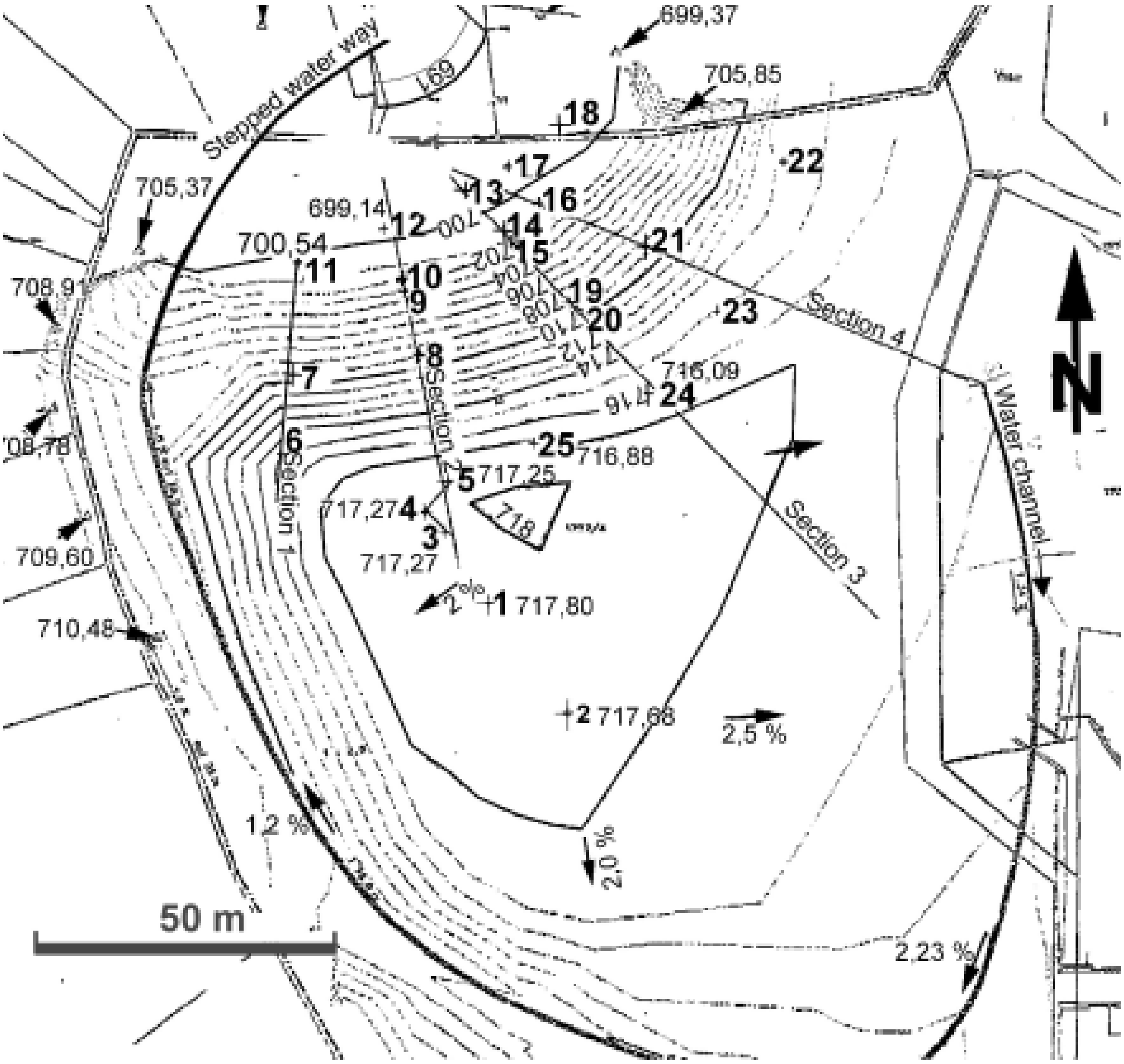


Fig. 8: New grid points after 21.11.00

The decisive deformation kinematics as derived from the deformation measurements between 24.11.97 and 8.2.98 are shown in fig. 4. It can be seen that the part which is reinforced with geotextiles moved horizontally as a block.

The displacement rates of the points 16 and 17 (fig. 4) are characteristic for the lower part of the slope. The average deformations and the resulting deformation rates are shown in the following diagram.

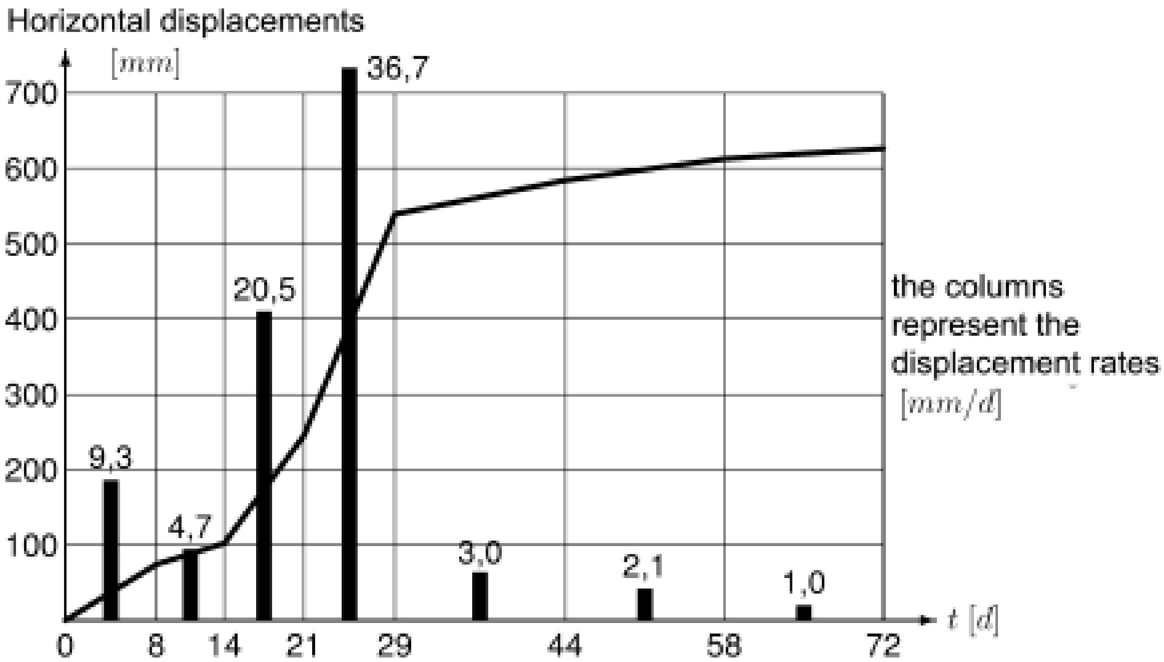


Fig. 9: Displacements of the lower part during the first 72 days

After construction was completed a horizontal deformation of 16mm in the course of 1.5 years was measured at grid point 5 (see fig. 8). The vertical deformations of this point during the same time interval were 36mm. The maximum settlement measured on the “plateau” was 48mm. At the foot of the slope the maximum deformations at grid point 10 were horizontal 14mm and vertical 3mm. Of special note is the similarity of the settlements of the grid points 1 to 5 on the “plateau”. Inside 1.5 years (21.11.00 to 4.4.02) they were 40mm, 48mm, 39mm, 36mm and 35mm as shown in fig. 10.

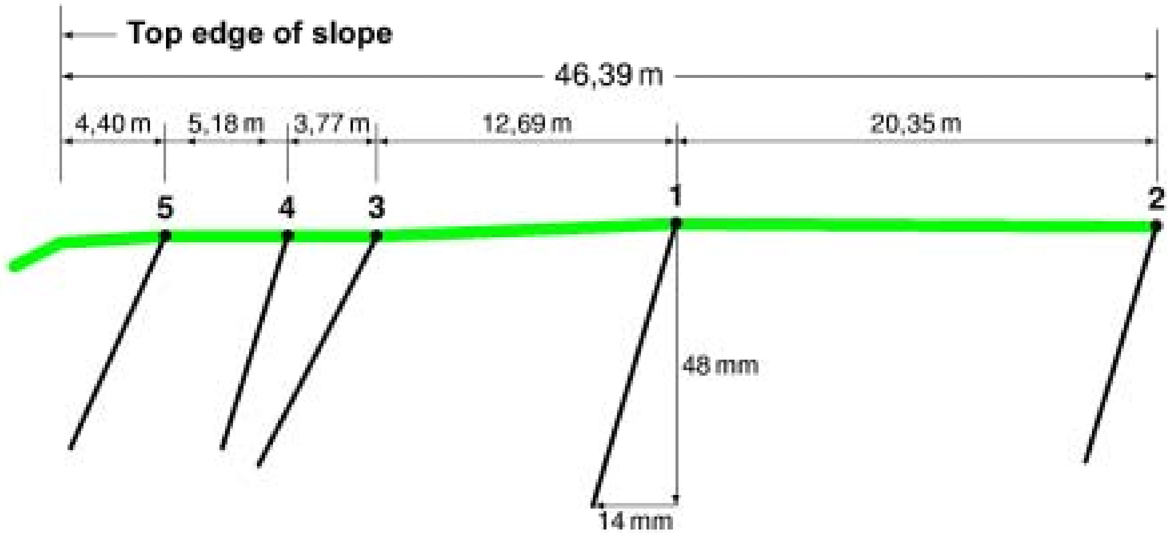


Fig. 10: Displacements of the plateau in the second phase

4 INTERPRETATION OF THE MEASUREMENTS

In the following diagram (fig. 11) the average time deformation curves with the time on a logarithmic scale are plotted. It can be seen that up to 68 days after the start of the measurements slipping took place. After that the creep phase started.

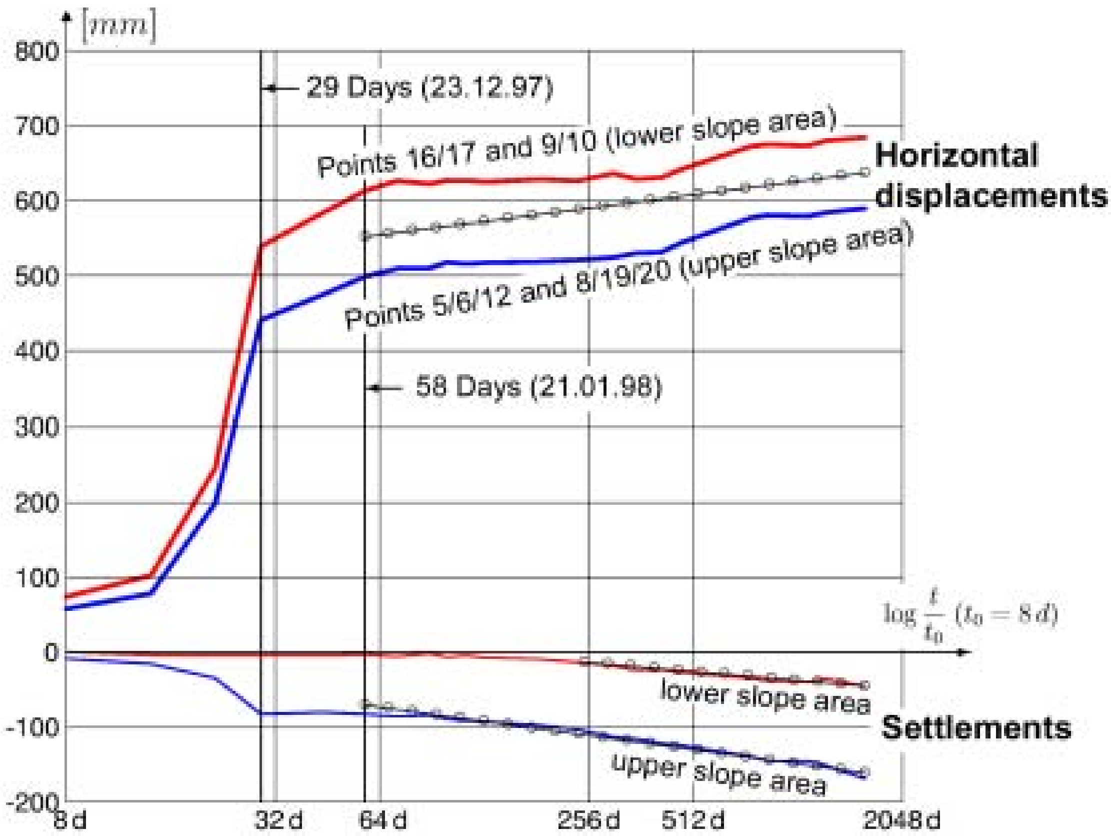


Fig. 11: Displacements as function of time

In the semi-logarithmic plot the creep phases approximate to straight lines which can be represented to a good approximation by the black lines with circles as points. Using logarithms to the base 10 the following relationships are obtained. This logarithmic creep is often observed in soil but a lot of other rheological models could be used (e. g. Schad/Breinlinger 1991).

Using logarithms to the base 10 ($\log$) the following relationships are obtained:

Horizontal displacement: $v = \alpha_h \log \frac{t_2}{t_1} = 59 \log \frac{t_2}{t_1} \quad [mm]$

Settlements in the **u**pper area of the slope: $s_u = \alpha_{s,M} \log \frac{t_2}{t_1} = 63 \log \frac{t_2}{t_1} \quad [mm]$

Settlements in the lower area of the slope: $s_l = \alpha_{s,F} \log \frac{t_2}{t_1} = 40 \log \frac{t_2}{t_1} \quad [mm]$

This means that horizontal deformations in the magnitude of

$$v \approx s \approx 50 \log \frac{t_2}{t_1} \quad \text{to} \quad 100 \log \frac{t_2}{t_1} \quad [mm]$$

are to be expected.

In the next 10 years horizontal deformations of 5 to 10 cm. are to be expected and that similar deformations are to be expected in the next 90 years.

5 LITERATURE

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