A REINFORCEMENT METHOD APPLIED TO A SHALY ROCK SLOPE FAILURE IN LIEGE, BELGIUM

Ch. SCHROEDER
Laboratoire de Géologie de l'Ingénieur, d'Hydrogéologie
et de Prospection Géophysique.
Université de Liège.

Summary

A rock instability on a steep slope of the valley of the Ourthe river, in the suburb area of Liege (Belgium) has been stabilized with a network of reinforced concrete beams anchored in the sound bed-rock. The lengths and strengths of the anchors have been determined after an extensive study including a geological survey, a geophysical prospection by seismic-refraction and well-logging, mechanical test in situ (pressuremeter tests) and laboratory testing. The stability computations are performed using the Janbu's method, the parameters being deduced from the results of the soil survey and from back calculations analyses.

1. INTRODUCTION

In the neighbourhood of Liège (Belgium), a reactivation of an ancient rock instability has been detected in the left slope of the valley of the river Ourthe. The ancient rock instability has consisted of some rock falls and a retaining wall has been built, in the past, at the toe of the slope, in order to protect the road below.

The present sliding area is about 2000 m2 wide. The slope, oriented W-E dipping to the South, is rather steep (40°-45°). It is composed of primary (Famennian) sedimentary rocks. The stratification dips in the direction of the valley (figure 1).

The rocks consist, from top to bottom, of :

- a succession of thin layers of micaceous siltites, rather clayey. The upper part of the siltites contains a strong sandstone bed, about 50 cm thick.
- a succession of micaceous sandstones, more or less clayey, located just above the sliding, up to the top of the hillside. Their thickness is about 10-20 cm and, sometimes, could reach 1 m in more sandy formations. One of those sandstone beds appears to have been worked in the former times.

The rock mass is divided by two sets of diaclases, perpendicular to the stratification. One of those sets is subvertical. Its direction is W-E, i.e. parallel to the direction of the slope.

A clear head scarp could be seen at the bottom of the clayey sandstones.

The general instability of this zone is confirmed by some cracks observed in the neighbourhood of the sliding area.

2. GEOLOGICAL AND GEOTECHNICAL CONDITIONS

An extensive soil survey has been carried out, including a geological mapping and a gephysical prospection by seismic refraction, very appropriate method in this case. This prospection has consisted of 29 shorts "hammer" soundings and 3 long profiles using the "air-gun" technique for a deeper investigation.

The prospection has been completed with 5 tube sample borings with well-logging, pressuremeter tests in one borehole and 10 laboratory shear tests.

The results of those investigations are reported on figure 2 which shows one geophysical cross-section of the slope. They could be summarized as follows.

Under the top soil whose seismic velocities are in the range 150-450 m/s, the superficial weakened layers (colluvium and weathered bed-rock) have seismic velocities smaller than 800 m/s for the colluvium and under 1200 m/s for the weathered substratum. The sound bed-rock has velocities less than 1500 m/s in the upper part of the slope, what means that the compact bed-rock hasn't been reached by the seismic survey in this zone. The compact bed-rock seismic velocities, above 2000 m/s, are measured in the lower part of the slope.

The colluvium is about 4 to 8 m thick. In the upper part of the slope, it surrounds directly the "sound" bed-rock. In the lower part, the colluvium surrounds up to 12 m of strongly weathered rock. These weakened zones have been investigated by boreholes and well-logging : gamma-ray for determination of clay content and gamma-gamma for the determination of the density. The density is around 1.5 to 1.6 g/cm3 in the weakened zone, decreasing sometimes up to 1.2 g/cm3. Below 9 m depth, the density increases up to 1.7 to 2.4 g/cm3.

Pressuremeter tests give the in-situ mechanical properties of the grounds: limit pressure under 2 MPa and pressuremeter modulus under 24 MPa for the weakened zone. In the sound bed rock, the pressuremeter modulus increases with the depth, from 100 MPa up to 880 MPa at 17 m depth.

The laboratory shear tests results are rather scattered (cohesion between 0 and 0.15 MPa, internal friction angle between 15° and 32°). The scattering is due to the difficulties of taking undisturbed samples in such formations. In addition, the samples could only be are taken in the strongest parts of the formations what gives too optimistic values of the mechanical characteristics. Therefore, a back-calculation analysis has been carried out.

For the back analysis, the failure surface, C1 on figure 2, is well defined with the head scarp for the starting point. The failure surface is tangent to the basis of the colluvium and its emergence is defined by the extend of the sliding zone. For this failure line, the assumption of a safety factor equal to 1 gives the cohesion-friction pairs which could be considered in the future calculations.

3. STABILIZATION

The thickness of the instable area rules out the possibility of a superficial treatment of the slide, like gunite or shotcrete for example.

The feasibility of a stabilization by anchoring has been studied, using, a.o., the failure surfaces C2 and C3 of figure 2.

The stability analyses have been carried out with the Fellenius, Bishop (simplified) and Janbu methods.

From the stability analyses, it results that only the zone located above present sliding area could have an almost satisfactory safety factor, tough rather small (F = 1.37 for the C2 line) without anchors. It comes from the smaller steepness of the slope at this location.
For the lower part of the slope, the computations indicate that a safety factor of 1.2 could be obtained by an anchor stress of about 1.7 T/m2, what represents one 15 T anchor each 25 m2.

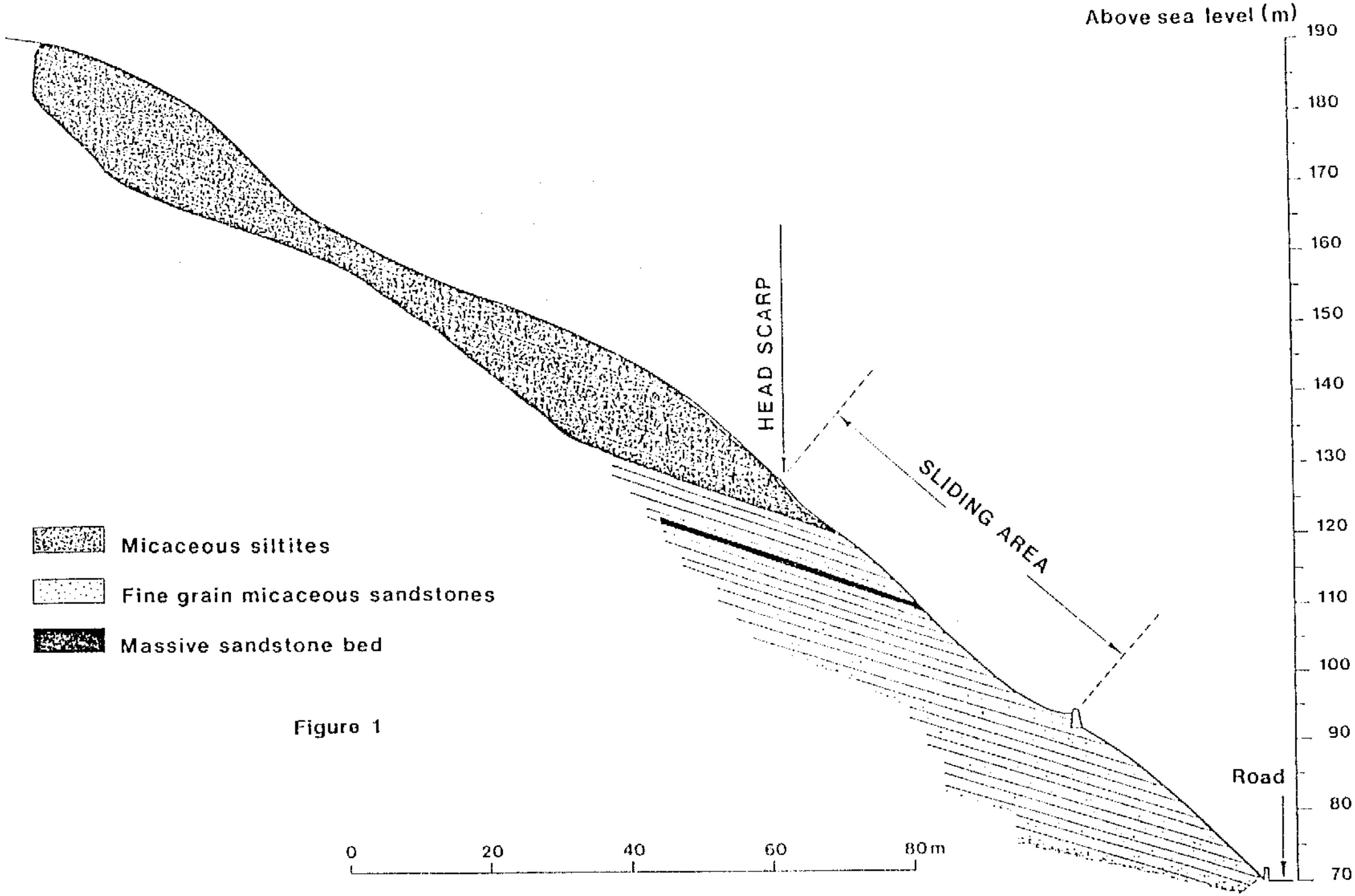
A global solution, giving enough safety, could consist of a network of reinforced concrete beams extended up to the toe of the slope, bearing upon a retaining wall and anchored at required depth as a function of the thickness of the weakened zones.

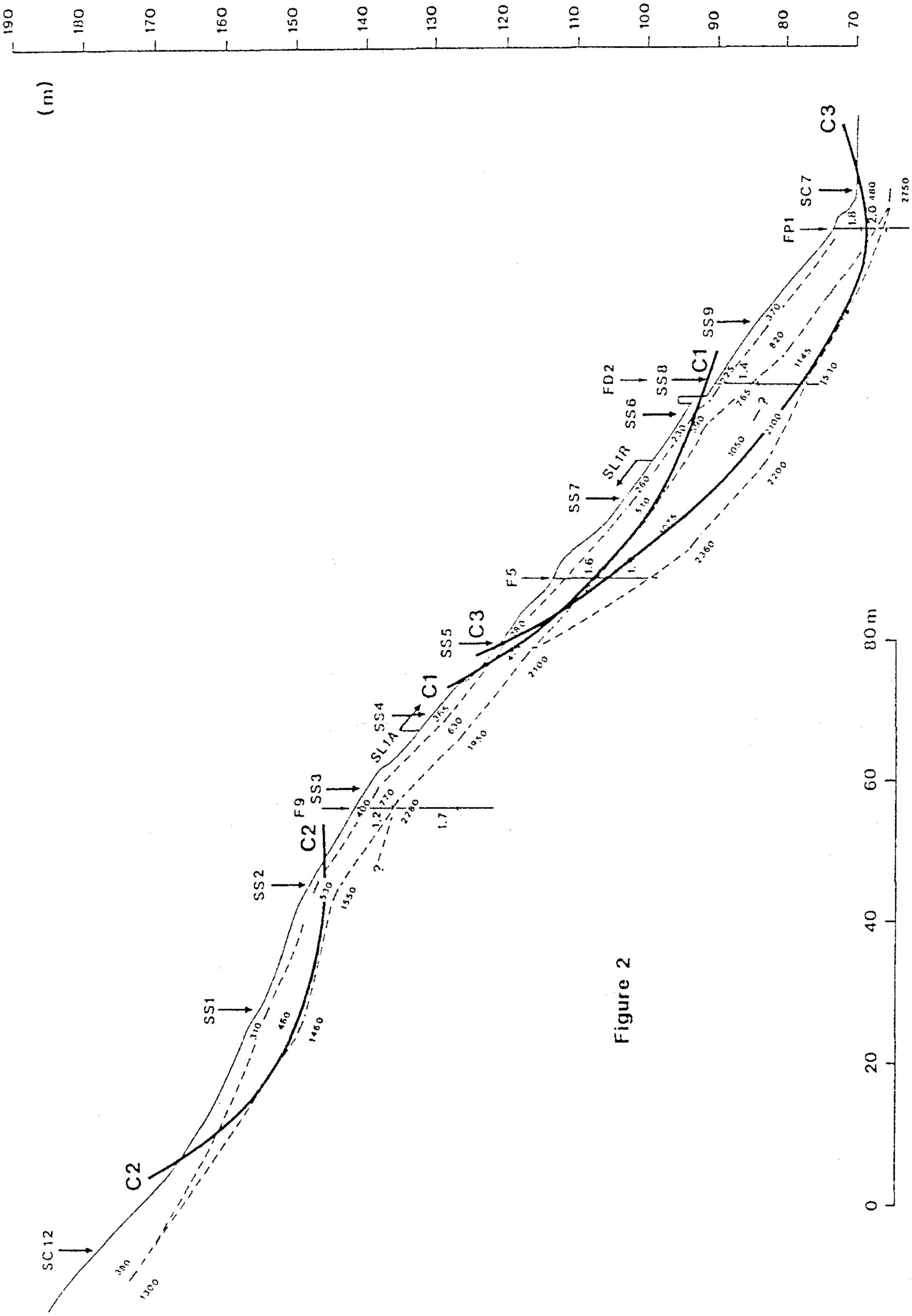
In a first phase of the stabilizing works, for insuring the immediate safety, the reinforcement has consisted of 22 anchors disposed in alternate rows with a 5 m mesh, located in the sliding area, in the zone of the thick sandstone beds. The anchors have a strength of 15 T and are 10 m long. They are binded by a network of reinforced concrete beams. No gunite or plantation are foreseen between the beams. The natural vegetation should normally assure the afforestation within a couple of years.

REFERENCES

MONJOIE,A., DEBATY,J.M. and FUNCKEN,L. (1988). Glissement d'un talus rocheux à Streupas. Etude géologique et géophysique.Rapport de synthèse. Confidential report of the Laboratoires de Géologie de l'Ingénieur, d'Hydrogéologie et de Prospection géophysique de l'Université de Liège.

POLO-CHIAPOLINI, Cl. (1989). Stabilité des talus rocheux. Séminaire sur les glissements de terrain. Laboratoire des Travaux Publics de l'Est. Constantine (Algérie).


Above sea level (m)
190
180
170
160
150
140
130
120
110
100
90
80
70
Road
HEAD SCARP
SLIDING AREA
Micaceous siltites
Fine grain micaceous sandstones
Massive sandstone bed
0
20
40
60
80m
Figure 1



(m)
190
180
170
160
150
140
130
120
110
100
90
80
70
SC12
C2
SS1
SS2
F9
SS3
SL1A
SS4
C1
SS5
C3
F5
SS7
SL1R
SS6
FD2
SS8
SS9
FP1
SC7
0
20
40
60
80 m

Figure 2