The Geotechnics of Hard Soils – Soft Rocks

3

ALDO EVANGELISTA & LUCIANO PICARELLI
EDITORS

PROCEEDINGS OF THE SECOND INTERNATIONAL SYMPOSIUM
ON HARD SOILS – SOFT ROCKS / NAPLES / ITALY / 12-14 OCTOBER 1998

The Geotechnics of Hard Soils – Soft Rocks

Editors
A. EVANGELISTA
Dipartimento di Ingegneria Geotecnica, Università degli Studi di Napoli Federico II, Italy
L. PICARELLI
Dipartimento di Ingegneria Civile, Seconda Università di Napoli, Italy

VOLUME 3
1 *Opening ceremony*
2 *Introductory reports*
3 *Keynote lectures*
4 *Main sessions and discussion sessions*
5 *Special lecture*
6 *Round table*
7 *Closing ceremony*
8 *Miscellaneous*

A.A. BALKEMA / ROTTERDAM / BROOKFIELD / 2000

The Geotechnics of Hard Soils – Soft Rocks, Evangelista & Picarelli (eds) © 2000 Balkema, Rotterdam, ISBN 90 5809 018 3

Post-symposium written discussion: Ground movements in highly tectonized soil slopes – The Vadoncello-Serra dell'Acquara landslides

F. Santaloia & F. Cotecchia
Technical University, Bari, Italy

M. Polemio
CNR-C.E.R.I.S.T., Bari, Italy

1 INTRODUCTION

The town of Senerchia (Sele river valley - southern Apennines) lies in a tectonically active area close to the epicentre of the 1980 earthquake (M=6.8). The slope south-east of the town includes three major landslides (Figure 1), principally in structurally complex formations. The Serra dell'Acquara mudslide involves clays and marls of the Sicilide Unit and is 33 m deep at maximum (Cotecchia V. et al. 1986). The 1980 earthquake remobilized it. Its left flank is bordered upslope by a detrital slab crossed by the crown of the Cimitero landslide, deep seated in the clayey units, which was not remobilized by the earthquake. In 1980 ground movements took place on this side of the slope shortly south of the slab, where more clayey soils outcrop, giving rise to the subsidiary Vadoncello landslide. The topography of the Vadoncello slope is shown in Figure 2. Since 1980 this slope had not undergone significant deformations until 1993, except for some retrogression of the crown. On 29 December 1993 major movements started, giving rise to a significant extension of the Vadoncello landslide, which is currently still active (Figure 2). The development of this landslide has been under monitoring during 1995 and 1996 (Figure 1) as part of a research project funded by the European Community (EEC 1996). Although shallow mudsliding downslope and crown retrogression at the top are the fastest processes on the slope, these are not the leading instability processes. They are related to deeper, although slower, soil deformations, which interact with the other landslide bodies in Figure 1, as briefly discussed in the following.

Figure 1. Geological map: 1. 1993 Valdoncello mudslide, 2. Serra dell'Acquara mudslide, 3. recent debris, 4. detrital slab, 5. Sicilide Unit, 6. limestone; 7. faults, 8. main scarps, 9. 1980 reactivated toe of Serra dell'Acquara mudslide, 10. 1996 scarp of Valdoncello mudslide, 11. boreholes (data from EEC, 1996).

2 GROUND MOVEMENTS AND MATERIALS INVOLVED

The schematic section in Figure 2 outlines the main lithological complexes identified in the Vadoncello slope, based upon an analysis of the lithological profiles (Wasowski 1995), the soil index properties and surveys in situ. Complex G relates to the mudslide activated in 1993.

Complex A represents the south-east margin of the detrital slab in Figure 1, and floats on complexes principally formed of scaly clays, clayey marls and scaly marls including calcareous clasts and interbeddings. At the toe, the mudslide (G) overlies the 1980 Serra dell'Acquara landslide body and is bordered by a detrital block. In stationary conditions, the water table is about 8 m depth. Full details about the soil complexes, their set-up and the hydrogeology of the slope are reported in Santaloia et al. (*in prep.*).

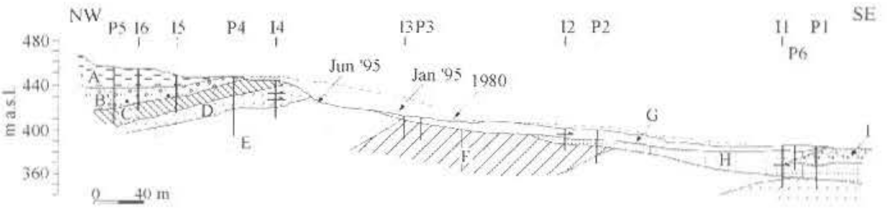

Figure 2. Schematic section through Valdoncello slope - A. detrital slab; Sicilide Unit: B. scaly clay more or less marly with calcareous clasts, C. marly scaly clay with sandy interbedding, D. scaly silty clay with interbedding of marly limestone, E. marly scaly clay with cobbles of marls, F. silty marly clay, G. 1993-'95 mudslide, H. 1980 Serra dell'Acquara mudslide; also shown are the inclinometers (I) and the piezometers (P) (data from EEC, 1996).

Since December 1993, downslope superficial displacements have had intermittent accelerations (rates up to 1.6 m/day) from below the scarp to the toe, meanwhile soils back of the crown have slipped progressively. The study of the cumulative daily rainfalls before 29 December 1993, by means of a hydrologic-statistical approach as discussed in Polemio (1997), shows that the 1993 December rainfalls were of low return period (Figure 3) and so were not the main triggering factor for the landslide reactivation. Rather this should be connected to deeper deformations relating to the boundary conditions for the equilibrium of the Vadoncello slope (Figure 1).

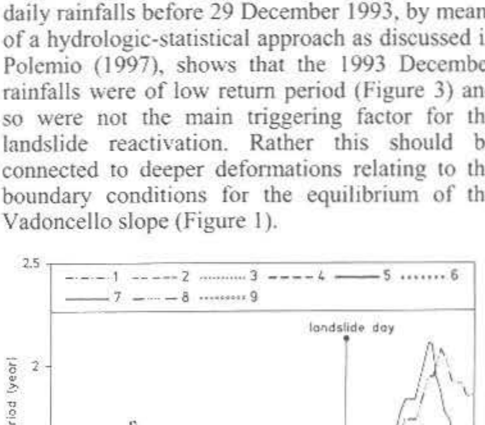

Figure 3. Return period of cumulative daily rainfall - 1) 1, 2) 5, 3) 10, 4) 20, 5) 30, 6) 60, 7) 90, 8) 120, 9) 180 days of cumulative rainfall. The return period is calculated using the generalised extreme value distribution function.

This hypothesis is supported by the 1995 inclinometer data (Figure 2). The inclinometers were bent at 16-17 m depth at the toe (I1) and 9 to 15 m depths at the top (I4), whereas in the central part of the slope inclinometers either floated 17.5 m deep or were broken at 4-5 m depth due to local very fast displacements. Later on, in 1996, the top inclinometer (I4) has been involved in the retrogression of the rear scarp down to a depth higher than 14 m. Thus deformation processes seem to occur, which are at least 17 m deep at the toe and deeper than 17.5 m in the central part of the slope. The data do not exclude deeper depths for these processes. Slow deep deformations have probably caused the retrogression of the crown over the years before 1993, till the onset of high displacement rates when the shallow soils definitely lost limit equilibrium. A finite difference study of the slope behaviour shows that the slope equilibrium implies extensive yielding of the soils upslope the current crown and displacements at large depth (Santoro & Cotecchia *in prep.*).

Other factors which trigger deformations in the slope are the frequent seismic shakes, some of which were monitored during the project (max. acc.= 0.06 g) (Del Gaudio et al. 1997). However the instability of the Vadoncello slope is inherently due to the poor mechanical properties of the clayey soils relating to their tectonized structure. They generally exhibit contractive and strain-hardening behaviour to pseudo-critical states characterised by particularly low friction angles, 15° to 18° (Fearon 1998; Fearon & Coop *in prep.*). Only the shallowest soils (to 5-7 m depth) exhibit some plastic dilation and higher maximum stress ratios (ϕ'_{peak}=20°-25°). They generally yield to the left of the normal compression line of the reconstituted, with high pre-yield compressibilities and converge with the reconstituted at very high pressures (Figure 4).

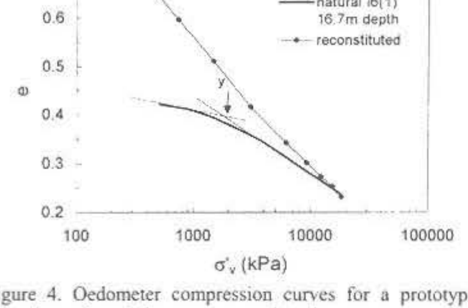

Figure 4. Oedometer compression curves for a prototype natural sample and the same reconstituted

ACKNOWLEDGMENTS

We wish to thank the European Community for funding the project and the coordinator Prof. V. Cotecchia for his advice and supervision.

REFERENCES

Cotecchia, V., M. Del Prete & N. Tafuni 1986. Effects of earthquake of 23th November 1980 on pre-existing landslides in the Senerchia area (Southern Italy). *Geol App. & Idrogeol.* 21:177-198

EEC 1996. Landslide evolution controlled by climatic factors in a seismic area. Prediction methods and warning criteria: Final Technical Report. Project coordinator Prof. V. Cotecchia

Polemio M. 1997. Rainfall and Senerchia landslides, southern Italy. Proc. *2nd Pan-Am. Symp. on Landslides, 2nd COBRAE, Rio de Janeiro*, 175-184.

Del Gaudio, V., G. Calcagnile, A. Calvaruso, P. Pierri & R. Trizzino 1997. Attività sismica e franosità: il caso della frana di Serra dell'Acquara (Senerchia, Av). *Atti 16th Incontro Nazionale del Gruppo Nazionale di Geofisica della Terra Solida, CNR, Roma.*

Fearon R. 1998. The behaviour of a structurally complex clay from an italian landslide. *PhD Thesis, City University.*

Wasowski J. 1995. The 1993 Acquara-Valdoncello landslide: detailed description of borehole stratigraphy. *CNR-CERIST, Bari, Rapp. Tecn. Int.*, 40.