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VINCENZO COTECCHIA (*)

2nd SEMINAR ON LANDSLIDE HAZARDS: FOREWORD

Dear Friends and Colleagues,

I've been entrusted with the pleasant task of introducing the different topics of this seminar, whose interest and importance may not need to be commented on. Since the progress in the state of the knowledge in our field is continuous, extremely useful are the opportunities for updating and exchange of information among researchers. Here lies the importance of meetings such as the one prepared for today and tomorrow by the Cosenza CNR-IRPI Institute. Therefore, we are very grateful to the Director of this Institute for having made all this possible.

I believe it is well known, also to our colleagues from the United States Geological Survey, that for more than fifteen years a constant and well, coordinated research on mass movements and seismic hazards has been conducted in Italy. That has been accomplished through large-scale projects carried out by many Operating Units spread throughout the Italian territory, through special C.N.R. (National Research Council) projects and through research channels promoted by the National Research Group on Hydrogeologic Hazards and by the Ministero della Protezione Civile.

I am also sure that everybody is aware that our country, from the Alps to Sicily, is highly exposed to the landslide hazards considered in this seminar in relation to hydrological and seismic events.

As regards the landslide hazard and hydrological events, the studies of the relationships existing between rainfall and initiation of landslide movements, aimed at the establishment of threshold levels, and, in the long run, at the identification of the recurrence intervals, are of prime importance. As it is well known, the infiltration of water in soils produces an increase of pore pressure, and thus, a decrease of the effective stress. This in turn results in lowering of the shear strength which is accompanied by the corresponding reduction of the safety factor.

The theoretical basis of models of soil mechanics are quite simple. However, it is not that simple to incorporate the geo-structural model in hydrogeological, and then, in geotechnical model, that is required in stability analysis. In addition, the landslide hazard is variably influenced by the precipitations, depending on their length, daily peaks and hourly intensity peaks, and soil conditions during the precipitation season.

With respect to the above mentioned problems, it should be re-called that in case of overconsolidated fissured clays, the increase of pore pressures can lead to softening phenomena, and following reduction of shear strength towards the state that SKEMPTON defines as «fully softened strength».

Another factor, which should not be neglected, (despite the controversies and uncertainities surrounding it), regards the leaching (progressive dissolution) of salt contents present in marine clays by groundwaters. The technical literature shows that higher salt content in pore waters results in an increase of strength of soils. In Italy we deal with this problem, especially in relation to mass movements occuring in Pliocene-Pleistocene fissured Blue Clays.

Many other considerations could be made on the relationship rainfall-initiation of landsliding, and I am sure this will be discussed further by the invited speakers.

With respect to other form of seismic-hazard, it seems redundant to recall its role in triggering off the landslides. Earthquakes can cause various forms of rupture and instability in the ground, such as ground displacements both horizontal and vertical, alteration of hydrological regimes, soil liquefaction and mass movements.

Although there are many who still doubt whether landslides can cause big earthquakes, there can be no question that earthquakes very often are the cause of large landslides with disastrous consequences for people and properties. And sometimes even modest seismic accelerations may be sufficient to trigger movements on a slope close to the conditions of limit equilibrium.

(*) *Istituto di Geologia Applicata e Geotecnica, Fac. Ingegneria, Politecnico di Bari.*

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Among the most recent cases, I would like to recall a large mass movement which affected a portion of the town of Senise, in Basilicata. The movement initiated on 26 July 1986, only three days after the earthquake, and affected the Plio-Pleistocene formation of Aliano Sands. The thin clay interbeds dipping about fifteen degrees down slope, represented convenient slip planes characterized by very low residual strength values (in some cases less than ten degrees).

The landslide, which should be seen in a geomorphological context characterized by many retrogressive mass movements, occurred in a dry period. It may be added that a few years before the event, in the lower part of the slope some cuts were executed for the construction of buildings. It is probable that the area was affected by a slow phenomenon of progressive failure, which the modest quake might have speeded up provoking a sudden movement.

In terms of energy, every slope has a threshold value above which mass movements are triggered off. This value gradually falls in the course of time owing to weathering and decompression, while small movements in the rock mass slowly accumulate until configurations are reached where potential energy is transformed into kinetic energy.

Some mass movements can occur due to disturbance of equilibria already close to instability, even after very weak shocks. Frequently an earthquake also accelerates ongoing movements of reactivates previously slipped masses. Ample evidence of such events was provided by the 1980 earthquake that hit a vast area of Southern Italy, along the border between Campania and Basilicata.

In other situations an earthquake can initiate landslides on intact slopes; this was the case with most of the 40 historical earthquakes considered in a study of KEEFER (1984), designed to determine the effect of geological environment on landslide type. Fourteen different types were recognized, initiation of which depends on the magnitude of the earthquake and the distance from the point of rupture.

By the way, two additional examples corresponding to the Paola and Torrente Sauro landslides which occurred in Southern Italy following the 1980 earthquake, when plotted on Keefer's diagram, fall very close to the trend proposed by KEEFER. This confirms the validity of his diagram. The paleo-landslide of Paola, despite the distance of around two hundred km from the epicentre, was influenced by the earthquake. In fact, its deposits were remobilized only few weeks later in concomitance of a non-exceptional rainfall event.

Lithological, geomorphological and structural configuration of Italy, is such that earthquakes are often accompanied by mass movements and by changes in the natural drainage system. In fact from the morphologic point of view, significant part of the Italian territory is shaped by mass movements generated by earthquakes. Since we are in Cosenza I cannot but re-propose one more time, and in particular for our American Colleagues, the case of 215 lakes between Aspromonte and Serra San Bruno which were created by large landslides following the 1783 earthquake of the Calabrie. We studied this earthquake using among other things detailed descriptions from historical sources and conducting geo-environmental reconstructions within the framework of geomorphological studies carried out during the analysis of the historic seismicity regarding the entire Italian territory.

For the record it should be mentioned the study of the «seismotectonic lines» in Calabria performed by HOBBS in 1907. Although some of the geostructural elements adopted may not be above criticism, it is useful to observe that according to Hobbs'old map several «seismotectonic lines» intersect in the epicentral area of the earthquake that occurred in February 1783. Even today this area is subject to severe geomorphogenetic action resulting from the ongoing uplift.

At this point, following a common practice of those who introduce seminar topics, I will present few examples from my personal experience with landslide hazard in the last ten years. Some of them regard works still in progress. I will begin with two cases of landslides generated by the 1980 earthquake of Campania and Basilicata. First case regards the mass movements occurred along the left side of the Sele river valley, which involved among other urban centers, the town of Senerchia. This town was hit hard by the earthquake: many human life losses were due to the failure of its entire southern part affected by a large earthflow.

Most of the landslides in the area originate at the tectonic contact between the carbonate massif and the Miocene flysch and varicoloured clays. The clays plug the large limestone-dolomite aquifer and are subject to high pore pressures. The numerous farm buildings present in the landslide area before the earthquake testify to the long quiescent period which lasted at least thirty years.

The Senerchia earthflow started about four hours after the main shock with a slow movement of separate slabs on which there were buildings and abundant tree cover. Movement of the accumulation zone started three days later, after a strong uplift at the foot of the channel. The deep-seated slip plane of the earthflow, identified on the basis of borings and inclinometer measurements, is roughly parallel to the hillslope and runs at a maximum depth of around 40 m. Stability analyses indicate that the safety conditions of the main body of Senerchia landslide were close to limit equilibrium even without considering the seismic shaking.

The other landslide phenomenon, which stands out for its dimensions and peculiar characteristics, is that of Buoninventre. The landslide body was about 3 km long and had estimated volume of thirty milion of cubic meters. The Buoninventre event is of extreme interest due to its different failure mechanisms activated by the 1980 earthquake. The mass movement involved mostly old landslide debris, and in the upper part, also flysch type rocks.

The entire Buoninventre landslide developed in a period of twelve days, but it underwent important modifications. In particular, we were able to distinguish four zones which became mobilized successively from the top downwards, and then experienced different evolution. Furthermore, our investigations revealed that the causes of mobilization in each zone differed substantially.

It might be added that less than four weeks after the first tremors all the houses in the lower part of the slide were tilted and badly cracked. One house located in the middle portion of the slide travelled over 600 meters at a speed of about 17 m/day. After four months the landslide body was considered practically immobile.

Damage also occurred in towns and villages several weeks after the earthquake. This was particularly the case in Calitri (Avellino) which was found to be more of less intact the day after the earthquake, but was subsequently affected by rototranslational failure and by a mudslide. This started from the foot of the main landslide and reached the left bank of the Ofanto river.

Now, as regards the hazard connected with exceptional pluviometric events, I would like to go back to the problem of overconsolidated fissured clays, which I mentioned before. I will take as an example the large Ancona landslide, which was remobilized on December 1982. The movement affected the slopes of the Montagnolo hill in the coastal area just west of the town of Ancona. This compound rototranslational mass movement reached the maximum depth of 90 meters; the volume of the remobilized material was about 100 millions of cubic meters and the affected area was seven square km. The damages included the interruption of the Adriatic railway and other important lifelines. In addition several buildings were displaced or fell down.

The Ancona landslide followed a period of very intensive precipitations. I should add that the 1982 fall season was particularly rainy and that it was preceded by a very dry summer. The comparison of the 1982 monthly precipitations with the average values based on a long period of time shows that 1982 year hydrologic event was the most intense event of last sixty years.

It is very important to note that the trend of piezometric levels measured along the sliding body shows the confined groundwater present inside thin permeable strata interbedded with the blue clays; the highest pore pressures were measured right in the retaining zone at the foot of sliding body. Among the topics of this Seminar, «Hazard and mitigation of landslide dams» is of particular interest to our country. As Dr. Schuster will show later, the United States Geological Survey conducted several interesting studies on this subject. At this point I cannot avoid mentioning the Valtellina case, which is a highly topical issue today. This is because after the tragic Val Pola landslide complex technical problems need to be addressed in order to identify the best solutions for the stabilization and protection of that area.

Often, floods may produce risks even more serious than the flooding itself. In these cases geologic vulnerability plays a decisive role in triggering chain reactions between diferent hazards. This happened in July 1987 in Valtellina (Southern Alps), where a large flooding caused the great landslide of Val Pola and sudden formation of a natural dam of considerable dimensions (height about 50 m) along the course of the Adda river. It was observed that the landslide body (about forty milion of cubic m) moved 300 meters up-hill on the opposite side of the valley. Obstructive dams of this kind are also often induced by seismic events, as was the case in Calabria, following the mentioned before 1780 earthquake.

But going back to the Valtellina case, once again this tragic event was linked to progressive rupture and to exceptional rainfall. In some pluviometer stations (hydrologically significative), the variable maximum daily rainfall in July of 1987 reached, and in two situations, even exceeded the first critical case. At Scais the maximum daily rainfall reached 305 mm. The landslide zone, besides the summit glacial deposits and collouvium, includes the Mount Tonale Gneiss Formation tectonically overlying the Sondalo Gabbro Formation.

It should be noted that the July 1987 landslide event remobilized older landslide deposits made of weathered rocks and debris, located over 2000 meters above sea level. This old landslide is already present on air photos from 1954. The 1987 landslide movement was favoured by the presence of two important structural discontinuity systems including down-slope dipping surfaces.

In any case the triggering factor was linked to the prolonged and abundant precipitations, consequent infiltration of water in the paleo-landslide deposits, removal of the material from the landslide body by groundwater flows, and finally, significant increase of pore pressures. A decisive role was played by the marked erosion which made deeper the gorge of Val Pola, resulting in loss of lateral support of the sliding body.

It was thanks to the engineering geology investigations previously carried out that this region had been indicated as great landslide risk area. The 1987 landslide was thus forecast and most of the inhabitants of the towns at high risk evacuated beforehand. This was an important effort considering the fact that this landslide caused the disappearance of four villages: Morignone, S. Martino di Serravalle, S. Antonio Morignone and Aquilone. The history of the region records tens of towns destroyed by these events. The documentation often includes drawings, such as those regarding the disappearance of Piuro in 1618, one of the most flourishing urban centers of Valtellina.

Hydraulics and Engineering Geology scholars are now deeply engaged in the control of processes which caused the Val Pola event, as well as in carrying out all the measures needed to protect people from new rock falls and to restore all services in the entire valley.

Since I have been directly involved in the Valtellina case I would like now to present some conclusions regarding interventions planned for the Val Pola landslide area:

— we need a significant enlargement of the tunnels constituting the by-pass originally constructed in the emergency period, and at the time of draining the dam; in addition their base level has to be lowered. These measures will increase the effectivness of the system and the overall security in case of high discharges;

— the intakes of the tunnels need to be lowered in order to avoid the formation of reservoirs up-valley;

— an up-stream extension of the existing by-pass should be taken under the consideration;

— problem of a possible blockage of the intakes need to be addressed;

— an open-air flow of the Adda river above the landslide body has to be made possible, (at least for certain discharge values), by most adequate geotechnical interventions; before, however, we need to check whether it is feasible to lower the bed of the artificial channel without creating new instability conditions on the valley slopes and on the emergency embankment constructed at the foot the slide.

Certainly the cost of these operations is high. I might add that until today several hundred millions of dollars have been already spent in order to control the emergency situation created by the landslide and to assure the survival of the people living in the hazard area.

CONCLUSIONS

Finally, I would like to remind that some of the examples provided, and several others related not only to the Italian territory, were widely discussed in the section devoted to *«Landslide hazard with respect to seismic events»* at the IAEG Symposium that took place in Bari in 1986.

However, many scientific issues still remain open. The application of mathematical models throws litht on some special circumstances of the local behaviour of landslide bodies.

There are few landslides which occur without some prior warning. This is why it is so essential to carry out a careful survey and to make a systematic record of the phenomena. As Heim wrote so wisely back in 1932: «No landslide breaks away from the mountain side from one moment to the next. Every slide is the result of a breakdown in equilibrium. We know case in which the break took 30 to 50 years or more to form».

However, we still need to examine the possibility of applying simplified methods for the forecasting and prevention of landslide events caused by seismic shaking. This is a field which requires a more extensive use of mathematical calculations, a more accurate definition of the stiffness of soils and modes of energy attenuation. Are the attenuation expressions available today sufficient? And how can we apply them to soils under cyclic loading, which have so different mechanical characteristics, such as clayey, flysch or sandy formations?

In recent years considerable advances have been made in the studies and methods of investigation of problems connected with slope stability and in the way of mapping these. Yet, despite the great advances in theoretical and practical knowledge regarding the relevant phenomenon, there are many doubts as to whether it is possible to prepare accurate, simple landslide prediction and hazard maps which can be understood by the more or less non-professional user.

And to continue with my list of open issues, how much do we know about the change of pore pressures in real situations, when exceptional events such as earthquakes or storm rainfall occur?

Are the applications of laboratory tests adeguate? In this respect it is clear that the productivity of these research lines depends basically on direct observations of the behaviour of soils; to test theoretical, empirical and analitical models we need to choose adequate landslide type areas from a geological and geotechnical point of view, convenientely instrumented and systematically controlled. If we want to obtain direct and concrete information while the shake is taking place we need to establish the most appropriate correlations between the different factors contributing to the landsliding, case by case.

I apologize if I took some extra time, and now I would like to give the floor to the colleagues from the United States Geological Survey whom I thank sincerely for coming here.