Discussion

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LANDSLIDES IN PUERTO RICO

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These comments refer to a series of catastrophic Landslides in Puerto Rico. They are intended to amplify the remarks of Radbruch-Hall concerning the new landslide map that she described this morning. That map sets out to deal only with the conterminous United States. It does not cover Hawaii, Alaska, or the territory of Puerto Rico. On the scale used Puerto Rico would have shown as little more than a pinpoint in any case.

But it is noteworthy that the largescale maps of Puerto Rico, issued in the I-series (1 : 20,000) of the U.S. Geological Survey, show evaluations of rock units in terms of several engineering characteristics that include landslide susceptibility. The geologic map coverage there is unusually complete in this respect.

In the autumn of 1970 landslides in Puerto Rico were particularly severe. Because of prolonged heavy rains, amounting to almost 1000 mm in about one month, numerous slides occurred throughout the island in a short span of time. Locations most affected were steep slopes and highway cuts.

Due to poor soil and questionable slope stability in the volcanic and limestone hills of the island, landslides precipitated by natural valley erosion and by man-made excavation have perpetually posed a threat to the environment. The structural and mineralogical reasons require continued investigation.

When the 1970 events in Puerto Rico took place, Záruba and Mencl's 1969 treatise on landslides had just appeared, citing classic examples from Czechoslovakia, which provided useful comparisons with many other parts of the world.

Local transportation was disrupted in hundreds of places in Puerto Rico by the 1970 landslides — and at the same time by floods from the heavy rains that initiated them. Centuries-old roads became blocked or simply dispappeared downhill. Situations that repeatedly lead to such hazards are of major concern to highway authorities, power companies, engineers, and geologists, especially in deeply weathered terrain like the hills of Puerto Rico.

In the new highway system that now extends across parts of the island appropriate measures have been taken to minimize future problems connected with surface sliding. Suitable design has involved recognition that clay-bearing rock, hydrogeology, and climatic factors can all contribute to slope deformation.

References

RADBRUCH-HALL D.R. (1977) : The systematic evaluation of landslide incidence and susceptibility in the United States. Bull. IAEG, 16, 82-86.

ZÁRUBA QU. — MENCL V. (1969) : Landslides and their control. Academia-Elsevier, Prague — Amsterdam, 202 p.

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ESTIMATION OF RISKS DUE TO LANDSLIDES

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One of many types of landslides is that moving very slowly. This slow movement occurs in the first stage of sliding. Strain gages and inclinometers are used to monitor the sliding movement. We have an excellent method developed by Saito, which is based on the theory of rheology. The observed data are plotted on a diagram whose horizontal axis concerns time and the vertical axis indicates the velocity on the logarithmic scale. The obtained line is straight until the end of the slow movement. The break of the straight course shows a rapid increase in displacement velocity, from which the time of failure can be accurately predicted. The use of this method is connnected with a number of problems, as, for example, finding a representative location on the sliding mass for the strain gage. The method cannot be used if there is a very high resistance at he foot of the sliding mass. It is applicable to landslides which show a relatively uniform shearing resistance.

In the following case the method did not prove to be effective: A cut, about 80 m long, was excavated in a hill slope for the construction of a highway. The slope started to move 4 years after the construction had been completed. Strain gages and inclinometers were installed to observe the movement. Its velocity increased day by day, reaching finally about 4 mm per day, but the diagram did not show a broken line, as stated above. The landslide was about 80 m long and the volume of soil in motion was estimated at 100,000 m^3. The highway was very important, and the prediction of the time of destructive movement was urgent.

In Japan, hundreds of people are killed every year as a result of landslides caused by heavy rainfalls, which occur during summer time. It is therefore very important to minimize the disasters of this kind. The first step in estimating the risks due to landslides is to predict dangerous rainfalls. This is done by constructing diagrams as follows: the total rainfall amount before the suspected sliding time is marked on the horizontal axis and the intensity of rainfall during one hour before the expected sliding time on the vertical axis. With the use of these two parameters we can plot a point; if it falls in the domain denoted as dangerous we know that the danger of sliding is very great. This method is based on statistical data obtained from studying the history of landslides.

The second way of risk estimation is based on the soil mechanics principles. Shearing tests, such as in situ block shear tests, are made using shearing apparatuses. These methods, however, are not very successful at the moment. A Swedish weight sounding method was used with success at a particular site.

The third method is to use strain gages to measure the velocity of sliding. Our scientists have tried to find a relationship between velocity of movement and the time of rupture.

Unfortunately, 15 persons were killed during the performance of tests. I have ascertained two important facts when I made investigation of this catastrophe. The first is the relationship between displacement and acceleration. In plotting the acceleration values on the horizontal axis on the logarithmic scale and the displacement on the vertical axis on the arithmetic scale, a straight line was obtained in the diagram. If this relationship could be applied to other slides, the time of rupture could be predicted. The second finding relates to the relationship between the displacement velocity and the extent of movement. A kinetic frictional resistance will appear in this case. Shearing resistance and residual strength are regarded as statical resistance, but kinetic friction is a dynamic one. When the catastrophe took place, four cameras were taking the motion of the sliding masses. The mass moved very quickly and the persons who were watching the experiment could not get away from the route of the sliding mass. Although the total volume of the slide was only some 10 m^3, 15 of them were killed immediately. Frictional resistance was estimated at less than zero, but it increased since then. The kinetic coefficient of friction is very small when there is a thin water film on the ground surface. At the end of the sliding movement, however, it has increased for some reasons. The sliding mass then disintegrated, the kinetic coefficient increased rapidly, which caused the mass movement to stop. It is very important to know the sliding velocity and the reach of the slide extent, because it will thus be possible to escape from the track of the sliding mass.